s47F

From: s47F @qenos.com
Sent: Friday, 24 October 2014 9:29 AM
To: TARCON
Cc: s47F
Subject: Qenos objection to TC1425824
Attachments: HDF193B-CON item cost.xlsx; Qenos invoices HDF193B CON 2014.pdf; TC 1425824 objection Oct 14 signed.pdf; Polyethylene at a Glance 6th Edition.pdf; Book 7 Pipe and Tubing Extrusion_web.pdf

Dear National Manager, Tariff Branch

Please find attached Qenos' objection to Gazette no TC 14/33, TC 1425824 and supporting material.

s47F

s47F
Qenos Pty Ltd
P: s47F | M: s47F
E: s47F qenos.com | W: www.qenos.com

FOI Document #2

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If this form was completed by a business with fewer than 20 employees, please provide an estimate of the time taken to complete this form.

Hours Minutes

SUBMISSION OBJECTING TO THE MAKING OF A TARIFF CONCESSION ORDER (TCO)

THIS FORM MUST BE COMPLETED BY A LOCAL MANUFACTURER WHO WISHES TO OBJECT TO THE GRANTING OF A TCO. THE INFORMATION PROVIDED ON THIS PAGE WILL BE FORWARDED TO THE APPLICANT FOR THE TCO. THE FORM SHOULD BE READ CAREFULLY BEFORE BEING COMPLETED.

DETAILS OF THE TCO APPLICATION TO WHICH THIS SUBMISSION REFERS

GAZETTE NO: TC 14/33 DATE: 23 October 2014

Gazetted description of goods. TC Reference Number: TC 1425824

RESINS, being unpigmented polypropylene hetrophasic copolymer,
propylene based with comonomer ethylene, in pelletised form,
having ALL of the following: (refer TC 1425824)

Stated use: For the manufacture of corrugated and smooth bore pipes for use in drainage and storm water removal

LOCAL MANUFACTURER DETAILS

Name: Qenos			
Business Address: 417-513 Kororoit Creek Road, Altona VIC 3018			
Postal Address *(if the same as business address write "as above")*: Private Mail Bag 3, Altona VIC 3018			
Australian Business Number (A.B.N.): 62 054 196 771		Reference:	
Company Contact: s47F	Phone Number: s47F	Facsimile Number: s47F	E-mail Address: s47F @qenos.com

DETAILS OF THE SUBSTITUTABLE GOODS PRODUCED IN AUSTRALIA

1 Describe the locally produced substitutable goods the subject of the objection.

"Substitutable goods" are defined in the Customs Act 1901 as "goods produced in Australia that are put, or are capable of being put, to a use that corresponds with a use (including a design use) to which the goods the subject of the application or of the TCO can be put".

High density polyethylene (HDPE) pipe resin

2 State the use(s) to which the substitutable goods are put or are capable of being put.

Pipes and fittings

3 **Attach technical, illustrative descriptive material and/or a sample to enable a full and accurate identification and understanding of the substitutable goods.**

4 **Are you aware of any other local manufacturers producing substitutable goods?** ☐ YES ☑ NO

5 **If yes to question 4, please provide details of any goods produced in Australia which are substitutable for the goods for which a TCO is being sought, and the names and addresses of the manufacturers of those goods.**

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6 **PRODUCTION OF GOODS IN AUSTRALIA**

Goods other than unmanufactured raw products will be taken to have been produced in Australia if:

(a) the goods are wholly or partly manufactured in Australia; and

(b) not less than 1/4 of the factory or works costs of the goods is represented by the sum of:

(i) the value of Australian labour; and

(ii) the value of Australian materials; and

(iii) the factory overhead expenses incurred in Australia in respect of the goods.

Goods are to be taken to have been partly manufactured in Australia if at least one substantial process in the manufacture of the goods was carried out in Australia.

Without limiting the meaning of the expression "substantial process in the manufacture of the goods", any of the following operations or any combination of those operations DOES NOT constitute such a process:

(a) operations to preserve goods during transportation or storage;

(b) operations to improve the packing or labelling or marketable quality of goods;

(c) operations to prepare goods for shipment;

(d) simple assembly operations;

(e) operations to mix goods where the resulting product does not have different properties from those of the goods that have been mixed.

A **Are the goods wholly or partly manufactured in Australia?** ☑ YES ☐ NO

B **Does the total value of Australian labour, Australian materials and factory overhead expenses incurred in Australia represent at least 25% of the factory or works costs?** ☑ YES ☐ NO

Specify each of the following costs per unit for the substitutable goods:

- Australian labour
- Australian materials
- Australian factory overhead expenses
- Imported content

TOTAL s47 [redacted]

Specify the date or period to which the costs relate. 12 months to end Sep 2014

Attach a copy of the working papers that were used to prepare the above costing information. Those working papers should be supported by (at least two) extracts from the accounting records of the business.

C **Is at least one substantial process in the manufacture of the goods carried out in Australia?** ☑ YES ☐ NO

If yes, please specify at least one major process involved:

Conversion of ethane gas supplied form Bass Strait into ethylene using a steam cracking process and then polymerised into polyethylene at Qenos's Altona Victoria polymer manufacturing facility

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7 PRODUCTION OF GOODS IN THE ORDINARY COURSE OF BUSINESS
(Answer 7.1 or 7.2)

7.1 SUBSTITUTABLE GOODS OTHER THAN MADE-TO-ORDER CAPITAL EQUIPMENT

Substitutable goods (other than made-to-order capital equipment) are taken to be produced in Australia in the ordinary course of business if:

(a) they have been produced in Australia in the 2 years before the application was lodged; or

(b) they have been produced, and are held in stock, in Australia; or

(c) they are produced in Australia on an intermittent basis and have been so produced in the 5 years before the application was lodged;

and a producer in Australia is prepared to accept an order to supply such goods.

A Have the goods been produced in Australia in the last 2 years? ☑ YES ☐ NO

B Have the goods been produced and are they held in stock in Australia? ☑ YES ☐ NO

C If the goods are intermittently produced in Australia, have they been so produced in the last 5 years? ☑ YES ☐ NO

D Are you prepared to accept an order for the goods? ☑ YES ☐ NO

7.2 SUBSTITUTABLE GOODS BEING MADE-TO-ORDER CAPITAL EQUIPMENT

"Made-to-order capital equipment" means a particular item of capital equipment that is made in Australia on a one-off basis to meet a specific order rather than being the subject of regular or intermittent production and that is not produced in quantities indicative of a production run. Capital equipment means goods which, if imported, would be goods to which Chapters 84, 85, 86, 87, 89 or 90 of Schedule 3 to the Customs Tariff Act 1995 would apply.

Goods that are made-to-order capital equipment are taken to be produced in Australia in the ordinary course of business if:

(a) a producer in Australia:

(i) has made goods requiring the same labour skills, technology and design expertise as the substitutable goods in the 2 years before the application; and

(ii) could produce the goods with existing facilities; and

(b) the producer in Australia is prepared to accept an order to supply the substitutable goods.

E Have goods requiring the same labour skills, technology and design expertise as the goods the subject of the application been made in Australia in the last 2 years? ☐ YES ☐ NO
If yes, describe the goods made during this period:

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F Can the goods be produced with existing facilities? ☐ YES ☐ NO

G Are you prepared to accept an order for the goods? ☐ YES ☐ NO

8 What was the first date on which you were prepared to accept an order? 1 / 1 / 2003

Are the goods still in production? ☑ YES ☐ NO

If the answer is no, when did production cease? / /

If production has ceased and goods are held in stock, please estimate the date by which stock is expected to be sold, based on past sales information and attrition rate of the local goods. / /

9 **Provide any additional information in support of your objection.**

Cost analysis based on the bill of materials (provided) for Qenos grade HDF193B packaged in 20 tonne bulk containers for local delivery.

This product has been in production for over 10 years - the answer to question 8 on the first date on which Qenos was prepared to accept an order is indicative only.

A copy of Qenos' product guide "Polyethylene at a glance" and Qenos' technical guide on pipe and tubing extrusion have been provided in response to question 3.

NOTES

(a) Section 269K and 269M of the *Customs Act 1901* require that a submission opposing the making of a TCO be in writing, be in an "approved form", contain such information as the form requires, and be signed in the manner indicated in the form. **This is the approved form for the purposes of those sections.**

(b) A submission will be date stamped on the day it is first received in Canberra by an officer of Customs. The submission is taken to have been lodged on that day.

(c) For the submission to be taken into account, it must be lodged with Customs:
- no later than 50 days after the gazettal day for an application for a TCO;
- no later than 14 days after the gazettal day for an amended application for a TCO; or,
- where the Chief Executive Officer has invited a submission, within the period specified in the invitation.

(d) **Every question on the form must be answered.**

(e) Where the form provides insufficient space to answer a question, an answer may be provided in an attachment. The attachment should clearly identify the question to which it relates.

(f) Unless otherwise specified, all information provided should be based on the situation as at the date of lodgement of the TCO application.

(g) Customs may require an objector to substantiate, with documentary evidence, information provided in relation to the objection.

(h) Further information on the Tariff Concession System is available in Part XVA of the *Customs Act 1901*, in the foreword to the Schedule of Concessional Instruments, in the administrative guidelines in Volume 13 of the Australian Customs Service Manual, in Australian Customs Notice No. 98/19, on the internet at www.customs.gov.au, by e-mailing information@customs.gov.au or by phoning the Customs Information Centre on 1300 363 263.

I agree, in submitting this form by electronic means (including facsimile) that, for the purposes of Sub-Section 14(3) of the Electronic Transactions Act, this submission will be taken to have been lodged when it is first received by an officer of Customs, or if by e-mail, when it is first accessed by an officer of Customs, as specified in Sub-Section 269F(4) of the Customs Act.

Full Name	Position Held
s47F [redacted]	s47F [redacted]
Signature s47F [redacted]	Date 24 October 2014

NOTE: ***SECTION 234 OF THE CUSTOMS ACT 1901 PROVIDES THAT IT IS AN OFFENCE TO MAKE A STATEMENT TO AN OFFICER THAT IS FALSE OR MISLEADING IN A MATERIAL PARTICULAR.***

WHEN THIS FORM HAS BEEN COMPLETED LODGE IT WITH CUSTOMS BY:

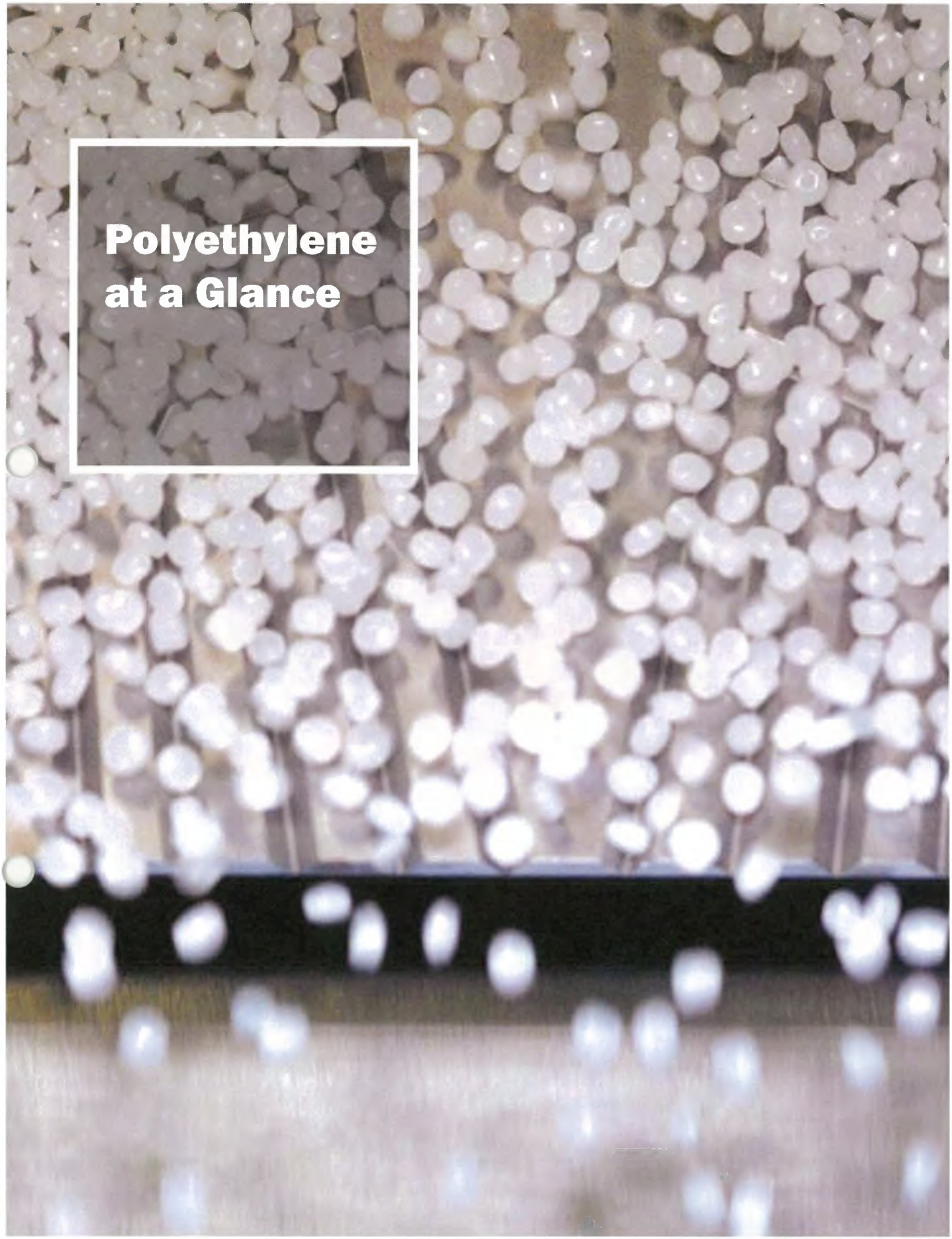
- posting it by prepaid post to the
  National Manager, Tariff Branch
  Australian Customs Service
  Customs House
  5 Constitution Avenue
  CANBERRA ACT 2601

  or
- delivering it to the ACT Regional Office located at
  Customs House, Canberra

  or
- sending it by facsimile to (02) 6275 6376

  or
- e-mailing it to tarcon@customs.gov.au.

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Polyethylene at a Glance

Qenos
A Bluestar Company

Alkadyne™ PE100 Pipe Extrusion Grades

Grade	Melt Index* (g/10 min@ 190°C, 5.00kg)	Density# (g/cm³)	Applications
HDF193B	0.3	0.961[1]	High Density black PE100 type resin certified to AS/NZS 4131, for use in pressure pipes and fittings. Excellent low sag properties and throughput, suitable for the majority of PE100 pipe dimensions.
HDF145B	0.2	0.961[1]	High Density black PE100 type resin certified to AS/NZS 4131, for use in pressure pipes and fittings. Exceptional low sag properties and throughput, suitable for the most challenging pipe dimensions.
HDF193N	0.3	0.952[1]	High Density natural resin for extrusion into a full range of non standard pipe products and as a base for PE100 type striping and jacket compounds.

Notes: [1] ASTM D1505/D2839

Alkadyne™ PE Pipe Extrusion Grades

Grade	Melt Index* (g/10 min @ 190°C, 5.00kg)	Density# (g/cm³)	Applications
MD0898	0.7	0.952[1]	Medium Density black PE80B type resin certified to AS/NZS 4131 for use in pressure pipes and fittings.
MD0592	0.6	0.942[1]	Medium Density natural resin for extrusion into a full range of non standard pipe products and as a base for PE80 type striping and jacket compounds.
GM7655	0.6	0.954[1]	High Density natural high molecular weight resin for extrusion into a full range of non standard pipe products.
MDF169	1.0	0.943[1]	Medium Density natural high molecular weight resin for extrusion into a full range of non standard pipe products.
LL0228	1.7[2]	0.923[1]	Linear Low Density resin for use in pipe extrusion applications.

Notes: [1] ASTM D1505/D2839 [2] D1238@190°C, 2.16kg

Alkadyne™ PE Wire and Cable Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
MD0592	0.12	0.942[1]	Designed for extrusion into a full range of wire and cable products where natural Medium Density resins are required.
MD0898-1	0.12	0.953[1]	Designed as general purpose jacketing compound for buried wires and cables where abrasion and cut through resistance is required.

Notes: [1] ASTM D1505/D2839

Alkatane™ HDPE Tape and Monofilament Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
GF7740F2	0.4	0.950[1]	Extrusion applications including stretched tape, monofilament, tarpaulins, and over-pouches for medicinal products.

Notes: [1] ASTM D1505/D2839

Alkatuff® LLDPE Rotational Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
LL711UV	3	0.938	Applications requiring excellent ESCR, chemical resistance[1], stiffness, toughness and UV protection, such as water and chemical tanks, septic systems and kayaks.
LL705UV	5	0.935	Applications requiring high ESCR, chemical resistance[1], toughness, stiffness and high level UV stabiliser, such as leisure craft, playground equipment and agricultural tanks.
LL755	5	0.935	Applications requiring high ESCR, chemical resistance[1], toughness and stiffness. Incorporation of suitable UV stabilisation is required for outdoor applications.
LL710UV	10	0.930	High speed intricate applications requiring good ESCR, chemical resistance[1], toughness and UV protection, such as consumer goods and playground equipment.

Notes: [1] The level of chemical resistance is a function of product design and environmental conditions. Contact Qenos for further information.

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

Alkathene® LDPE Film Grades				Additives		Applications							
Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Antiblock	Slip[2]	Heavy Duty Bags	Shrink	Produce	Carry Bags	Bread	Cling Wrap	Freezer Film	Overwrap
XDS34	0.30	0.922	Heavy duty sacks, pallet wrap and industrial applications requiring heavy gauge film. Additive free.			✓	✓						
LDF433	0.45	0.925	Heavy duty sacks, pallet wrap and industrial applications requiring medium to heavy gauge film with increased stiffness.	✓		✓	✓						
LDD201	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags and shrink film and for use as a blend component.			✓	✓						
LDD203	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags and shrink film requiring antiblock, and for use as a blend component.	✓		✓	✓						
LDD204	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags and shrink film where a medium level of slip is required.	✓	M	✓	✓						
LDD205	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags, frozen food and produce bags where a high level of slip is required or for use as a blend component.	✓	H	✓	✓	✓				✓	
LDH210	1.0	0.922	Bundle shrink and other medium gauge film applications such as produce bags, carry bags and for blending into other film grades.				✓	✓	✓				
LDH215	1.0	0.922	General purpose medium gauge film for produce bags and carry bags, frozen food where a high level of slip is required or for use as a blend component.	✓	H			✓	✓				
XJF143	2.5	0.921	Additive free, general purpose low gauge film for overwrap and other applications and for use as a blend component.										✓
LDJ226	2.5	0.922	Bundle shrink, low gauge shrink film and general purpose applications where a medium level of slip and antistatic are required.	✓	M[1]		✓		✓				✓
LD0220MS	2.5	0.922	High quality low gauge film for lamination and overwrap applications where a medium level of slip is required.	✓	M								✓
LDJ225	2.5	0.922	High quality, low gauge film primarily intended for bread bags and overwrap but also general purpose applications where a very high level of slip is required.	✓	VH					✓			✓
XLF197	5.5	0.920	High quality, very thin gauge and high clarity film primarily intended for food and packaging wrap and for drycleaning film. Additive free.								✓		

Notes: [1] Based on antistat additive [2] VH = Very High Slip, H = High Slip, M = Medium Slip

Alkatuff® LLDPE Film Grades				Additives			Applications								
Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Antiblock	Slip[1]	Processing Aid	Heavy Duty Bags	Stretch	Agricultural Film	General Purpose	Garbage Bags	Lamination	FFS	Freezer Film	Overwrap
LL438	0.8	0.922	Heavy duty sacks, agricultural films,lamination and form, fill and seal packaging where enhanced toughness and sealing characteristics are desired.			✓	✓		✓	✓		✓	✓	✓	
LL501	1.0	0.925	General purpose industrial, agricultural and heavy duty films and as a blend component to improve film handling in converting and packaging operations.				✓			✓					
LL601	1.0	0.925	General purpose industrial, agricultural and heavy duty films and as a blend component to improve film handling in converting and packaging operations.	✓	H					✓	✓				✓
LL425	2.5	0.918	High quality cast film for applications that require toughness, high clarity and processability.					✓							

Notes: [1] VH = Very High Slip, H = High Slip, M = Medium Slip

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

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Alkamax® mLLDPE Film Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Additives			Applications												
				Antiblock	Slip(1)	Processing aid	Heavy Duty Bags	Stretch	Produce	Carry Bags	Bread	Agricultural Film	General Purpose	Ice Bags	Lamination	FFS	Freezer Film	Overwrap	Liners
ML1810PN	1.0	0.918	Heavy duty bags, industrial and agricultural films, and form, fill and seal applications and ice bags where outstanding toughness, sealing and hot tack properties are desirable or for downgauging of existing film structures.			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ML1810PS	1.0	0.918	Heavy duty bags,industrial and form, fill and seal applications and ice bags where outstanding toughness, sealing, hot tack properties and high slip are desirable or for downgauging of existing film structures.	✓	H	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
ML2610PN	1.0	0.926	Heavy duty bags, lamination, industrial and form, fill and seal applications where outstanding stiffness, toughness, optical and sealing properties are desirable or for downgauging of existing film structures.			✓	✓		✓	✓	✓		✓		✓	✓	✓		✓
ML1710SC	1.0	0.917	Stretch cling films (with addition of appropriate cling additive) and other film applications where outstanding toughness, optical and sealing properties are desirable or for downgauging of existing film structures.			✓		✓				✓							

Notes: (1) VH = Very High Slip, H = High Slip, M = Medium Slip

Alkatane™ HDPE Film Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Applications			
				Carry Bags	General Purpose	Liners	Barrier Film
GM4755F	0.10	0.955(1)	Carry bags and liners where high impact, toughness and stiffness are desirable and as a blend component into LDPE and LLDPE films for heavy duty applications.	✓	✓	✓	
HDF895	0.80	0.960(1)	Moisture barrier and blend component into LDPE and LLDPE films to enhance stiffness. Blend component in core layer for high clarity coextruded films.	✓	✓	✓	✓

Notes: (1) ASTM D1505/D2839

Alkatane™ HDPE Blow Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
HD0840	0.06	0.953(1)	Large part blow mouldings, especially blow moulded self-supported drums and tanks (25 - 220 litres). Exceptional ESCR.
HD1155	0.07	0.953(1)	Large part blow mouldings, including 25 litre to 220 litre tanks and drums. Exceptional ESCR.
GM7655	0.09	0.954(1)	Blow moulded containers including household and industrial chemical (HIC). Suitable for larger part mouldings. Exceptional ESCR.
GF7660	0.30	0.959(1)	Household and industrial chemical (HIC) containers, including detergent and pharmaceutical bottles. Excellent ESCR.
GE4760	0.60	0.964(1)	Blow moulded water, dairy and fruit juice bottles.
HD5148	0.83	0.962(1)	High speed dairy packaging applications and other thin walled bottles such as milk, cream, fruit juice and cordial.

Notes: (1) ASTM D1505/D2839

Qenos imported polymers and additives

Complementing our Australian manufactured Polyethylene grades, Qenos acts as a local distributor for a wide range of imported polymers and additives including rubbers, elastomers, adhesives, plastomers, EVA, BOPP Film, EPS, antioxidants and titanium dioxide. For the full Qenos range, please refer to the Qenos website, Customer Service or your Account Manager.

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

Alkathene® LDPE Extrusion Coating Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
XLC177	4.5	0.923	Applications including milkboard and fabric extrusion coating where very good drawdown, low moisture vapour transmission rates and excellent hot tack are desirable. Additive free.
WNC199	8.0	0.918	Liquids packaging and other sensitive food packaging laminates where excellent heat seal, low extractables, good melt strength and low odour and taint are desirable. Additive free.
LDN248	7.6	0.922	Liquids packaging and other sensitive food packaging laminates where low extractables and low odour and taint are desirable. Additive free.
LD1217	12	0.918	Liquids packaging and other sensitive food packaging laminates where high line speed, low neck-in, low extractables and low odour and taint are desirable. Additive free.

Alkathene® LDPE Injection Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
XDS34	0.3	0.922	Small part injection moulded caps and closures. Additive free.
WJG117	1.7	0.918	Thick section mouldings, caps and closures, industrial containers where a high level of toughness is desirable. Additive free.
XJF143	2.5	0.921	Injection moulded caps and closures, and thick-walled sections. Additive free.
LDN248	7.6	0.922	Injection moulded caps and closures. Additive free.
WRM124	22	0.920	High flow resin for reseal lids, housewares and toys where excellent gloss, low warpage and flow to toughness ratio are desirable. Additive free.
LD6622	70	0.922	High flow resin for lids and other thin wall injection moulding applications. Additive free.

Alkatuff® LLDPE Injection Moulding Grades

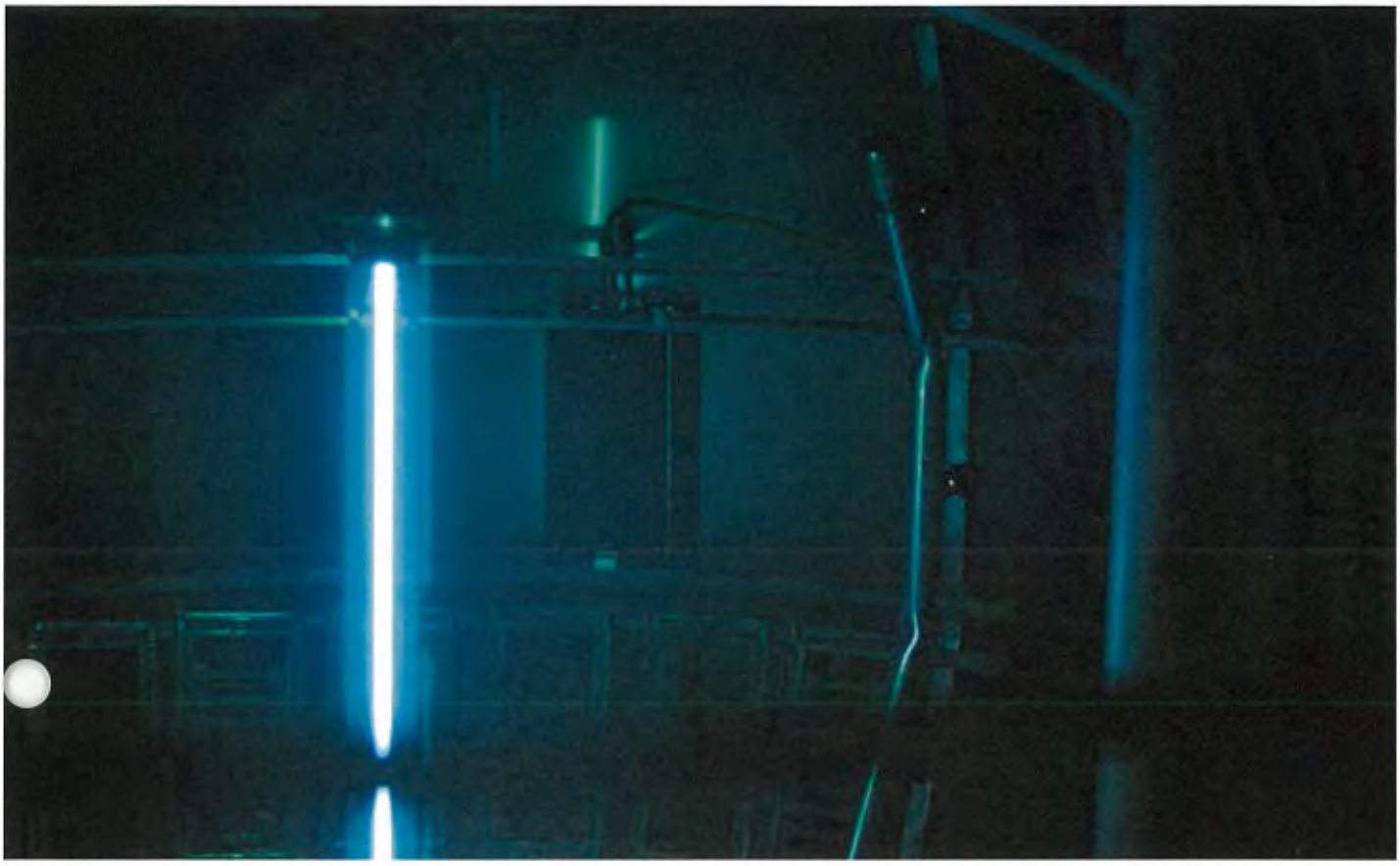
Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
LL820	20	0.925	Injection moulding and compounding applications such as housewares and lids.

Alkatane™ HDPE Injection Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
HD0390	4	0.955	Stackable crates for transport, storage and bottles and industrial mouldings where very good mechanical properties are desirable.
HD0397UV	4	0.955	Mouldings requiring long-term weatherability, including mobile garbage bins, crates, and industrial mouldings where very good mechanical properties are desirable.
HD0490	4.5	0.955	Stackable crates for transport, storage and bottles, and industrial mouldings where very good mechanical properties are desirable.
HD0499UV	4.5	0.955	Mouldings requiring long-term weatherability, including mobile garbage bins, crates, and industrial mouldings where very good mechanical properties are desirable.
HD0790	7	0.956	Industrial pails, crates, closures and sealant cartridges where a good balance between flow and impact resistance is desirable.
HD1090	10	0.956	Industrial pails, crates, closures and sealant cartridges where a good balance between flow and impact resistance is desirable.
HD1099UV	10	0.956	Mouldings requiring long term weatherability including industrial pails, crates, and tote boxes where a good balance between flow and impact resistance is desirable.
HD2090	20	0.956	Housewares, thin-walled containers and closures where excellent mould flow and flexibility is required.
HD3690	36	0.956	Housewares, thin-walled mouldings and closures where excellent mould flow and flexibility is required.

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

FOI Document #5



Qenos Pty. Ltd.
ABN: 62 054 196 771

Cnr Kororoit Creek Road & Maidstone Street,
Altona Victoria 3018, Australia

T: 1800 063 573 F: 1800 638 981
customer.service@qenos.com
qenos.com

Certified System Quality ISO 9001 SAI GLOBAL

AUSTRALIAN MADE

Front Cover: Pellet geometry and pellet quality can have a significant effect on material flow and the efficiency of feeding polyethylene into an extruder. Qenos measures pellet quality using a pellet shape and size distribution analyser, a device that photographs around 10,000 pellets in 4 minutes, digitally analyses the images and generates a report on pellet quality. Where a drift in the pellet quality is detected, adjustments are made proactively to maintain high product integrity.

Rear Cover: The standard for UV performance for PE Water Tanks specified in AS/NZS 4766 PE Tanks for the Storage of Chemicals and Water is 8,000 hours of uninterrupted exposure to an intense and specifically developed UV light source. Qenos exhaustively tests the long term UV performance of its Rotational Moulding Resins under conditions of controlled irradiance, chamber temperature and humidity and repeated rain cycles. Alkatuff® 711UV achieves a class leading UV performance exceeding 20,000 hours against the required standards, ensuring that Alkatuff® 711UV is "Tough in the Sun".

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7 PIPE AND TUBING EXTRUSION

TECHNICAL GUIDE

Alkadyne™

FOI Document #6



Front Cover:
Polyethylene pipe is an engineered product, required to withstand internal pressure and external influences for up to 100 years. Qenos has invested in the largest pipe pressure testing facility in the southern hemisphere, where *Alkadyne* PE100 pipe resin is extruded for testing and then subject to high pressure and elevated temperature for up to three years. This testing is also applied to specially notched pipe samples to ensure damage during installation does not result in premature failure. *Alkadyne* PE100 pipe resin – *Engineered to Outperform*.

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INTRODUCTION

Alkadyne polyethylene grades are used for the extrusion of pipe. The application areas in which *Alkadyne* pipe resin is typically used include:

- Mining for conveyance of corrosive and abrasive slurries and tailings
- Water management projects such as large scale irrigation for agriculture
- Residential water distribution
- Civil work such as sewers
- Residential and industrial gas distribution
- Gas and water management in Coal Seam Gas extraction
- Management of industrial fluids
- Drainage
- Rural applications such as management of water on farms, etc.

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7 PIPE AND TUBING EXTRUSION

INTRODUCTION

Alkadyne polyethylene grades (Table 1) are used for the extrusion of pipe. The application areas in which *Alkadyne* pipe resin is typically used include:

- Mining for conveyance of corrosive and abrasive slurries and tailings
- Water management projects such as large scale irrigation for agriculture
- Residential water distribution
- Civil work such as sewers
- Residential and industrial gas distribution
- Gas and water management in Coal Seam Gas extraction
- Management of industrial fluids
- Drainage
- Rural applications such as management of water on farms, etc.

Pipe materials have high strength and exceptionally high toughness. At present PE 100 is the highest classification for polyethylene resins and compounds from which to make pressure pipe. This means that in addition to retaining the generally acknowledged good properties of PE-HD pipes, such as weldability, flexibility, chemical resistance and abrasion resistance, PE 100 pipes also bring marked improvements in important properties such as creep strength, notch resistance and resistance to rapid crack propagation.

PIPE APPLICATION REQUIREMENTS

The operating pressures for pipe systems could be as high as 2.5 MPa (25 bar) for example in the transportation of water. For gas applications the pressure is usually contained below 1.0 MPa (10 bar). The ability of the pipe to withstand sustained pressure is important and dimensions and pressure ratings for pipe made from polyethylene are specified by relevant standards. A very high resistance to cracking is required, because of the wide range of environments and installation techniques that can be encountered in the field. The pipe must have excellent weathering resistance because of extended outdoor exposure.

Specifications for polyethylene resins to be used in pipes for the transportation of fluids under pressure are outlined in relevant standards.

ALKADYNE GRADE SELECTION FOR PIPE

Table 1: *Alkadyne* Pipe Extrusion Grades

Grade	Melt Index @ 190°C, 5kg (g/10min)	Density (g/cm^3)	Application
HDF193B	0.3	0.961	High Density black PE100 Type resin certified to AS/NZS 4131, for use in pressure pipes and fittings. Excellent low sag properties and throughput, suitable for the majority of PE100 pipe dimensions.
HDF193N	0.3	0.952	High Density natural resin designed for extrusion into a full range of non-standards pipe products and as a base for PE100 Type striping and jacket compounds. HDF193N is not UV stabilised.
HDF145B	0.2	0.961	High Density black PE100 Type resin certified to AS/NZS 4131, for use in pressure pipes and fittings. Exceptional low sag properties and throughput, suitable for the most challenging pipe dimensions.
MD0898	0.7	0.952	Medium Density black PE80B Type resin certified to AS/NZS 4131 for use in pressure pipes and fittings.
MD0592	0.6	0.942	Medium Density natural resin designed for extrusion into a full range of non-standards pipe products and as a base for PE80Type striping and jacket compounds. MD0592 is not UV stabilised.
MDF169	1.0	0.943	Medium Density natural high molecular weight resin designed for extrusion into a full range of non-standards pipe products. MDF169 is not UV stabilised.
LL0228	1.7*	0.923	Linear Low Density resin for use in pipe extrusion applications such as trickle irrigation. LL0228 is not UV stabilised.

* LL0228 @ 190°C, 2.16 kg. Melt Index according to ASTM D1238. Density accodring to ASTM D1505.

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CLASSIFICATION OF POLYETHYLENE PIPE AND PIPE COMPOUNDS

Specifications for polyethylene compounds for use in pressure pipes and pipes for pressure applications in Australia are covered by two Australian Standards:

- AS/NZS 4131 "Polyethylene (PE) compounds for pressure pipes and fittings"
- AS/NZS 4130 "Polyethylene (PE) pipes for pressure applications"

The maximum allowable working pressure (and therefore class) of the pipe at 20°C is determined by:

- The type of compound used to make the pipe, and
- The dimensions of the pipe

Polyethylene compounds for pipe extrusion are designated by the material type (PE) and an appropriate level of Minimum Required Strength (MRS), details of which are given in Table 2.

Table 2: MRS and Hydrostatic Design Stress Requirements for PE 100 and PE 80 Compounds

Designation	Minimum Required Strength (MRS) (MPa)	Hydrostatic Design Stress (MPa)
PE/MRS100	10.0	8.0
PE/MRS80	8.0	6.3

The value of the minimum required strength is based on the long-term hydrostatic stress in the pressure pipe when extrapolated to a 50-year life at 20°C. The hydrostatic design stress is arrived at by applying minimum safety factor of 1.25 to the value of MRS. Reference should be made to the data sheets for *Alkadyne* pipe grades for details of their conformance to these requirements.

For each of the above designations, there are several pressure classes with different wall thicknesses for each nominal pipe diameter.

PIPE EXTRUSION TECHNOLOGY

A pipe extrusion line consists of a number of pieces of equipment. An extruder converts the polyethylene raw material to a continuous tubular melt by extrusion through an annular die. The molten pipe then proceeds through a sizing or calibration device (which fixes its dimensions) to a cooling trough. After being cooled, the pipe passes via a haul-off to handling equipment for cutting into final lengths or coiling. Printing devices may also be inserted into the line to mark the extruded pipes with specific details. A portion of a pipe extrusion line is shown in Figure 1.



Figure 1: Illustration of a Pipe Extrusion Line

Granule Pre-treatment

Polyethylene is a hydrophobic material. However, for polyethylene compounds that contain carbon black that is hygroscopic in nature, problems can arise if the moisture content of black polyethylene compound reaches > 0.03 w/w%. During extrusion, moisture could cause formation of voids in pipe wall and rough pipe surface.



Figure 2: Photograph illustrating a Pipe with Voids and a Rough Pipe Surface due to Excessive Moisture in the Polymer Compound

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7 PIPE AND TUBING EXTRUSION

Such problems can be overcome by drying the polymer granules in a hopper dryer at 70 – 90°C for 1.5 – 2 hours immediately before feeding them into the extruder. The duration of drying and the drying temperature should be such that the moisture content is reduced to < 0.02 w/w%.

Extruder

For processing HDPE and MDPE into pipes, single screw extruders are used. To achieve the high throughput required for pipe production, high-speed extruders with forced-conveying feed systems have been developed and widely used throughout the industry (see Figure 3).

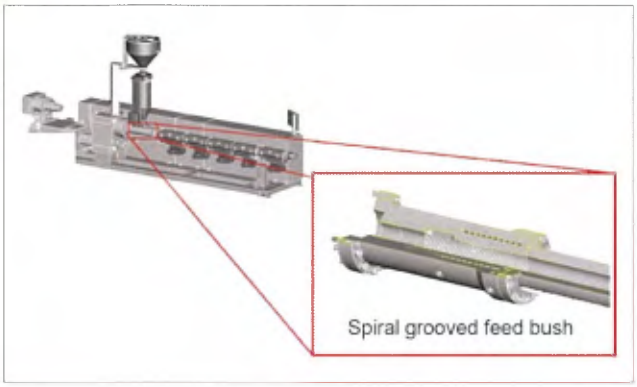


Figure 3: Illustration of a Single Screw Extruder with a Spiral Grooved Feed Bush used for High Polymer Throughput

These extruders have a cooled, grooved feed bushing which is thermally insulated from the extruder barrel. As a result, the conveying efficiency of the pelleted feedstock is greatly enhanced achieving higher extruder throughput. For optimal operation of a grooved bush system, it is required to keep the bush cold to prevent melting of the pellets and fouling of grooves. In order to ensure effectiveness of the grooved zone, these systems are cooled with a high flow of chilled water (e.g. water flows of ~10 L/min and water temperature of approximately 10–20°C).

Recent developments in screw design have seen the creation of barrier screws with enhanced melting capability through the incorporation of a second spiral flight that separates the polymer melt from the unmelted product (see Figure 4).

In addition to the barrier screw, mixing elements are generally used at the melt delivery end of the screw to assist with homogenisation of the polymer melt (see Figure 5).

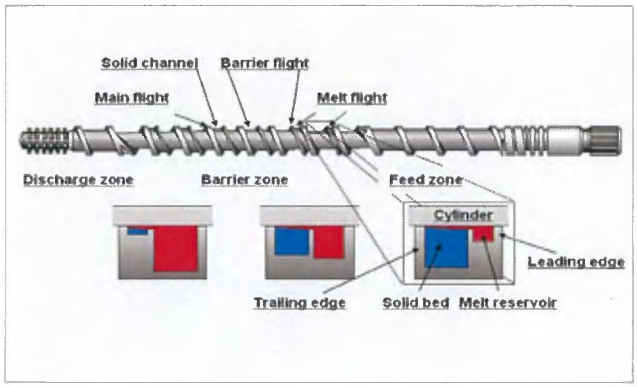


Figure 4: Schematic of a Barrier Flighted Screw incorporating a Pin Mixer



Figure 5: Photos Illustrating some more Commonly Employed Mixing Sections Located at the Melt Delivery End of the Screw

The typical screw length used in modern pipe extruders is generally around 30 L/D (e.g. screw length is described as a ratio of length divided by the screw diameter that is measured at the flight). The newest generation high throughput pipe line extruders have even higher screw lengths of 40 L/D.

For example, a 90 mm well designed grooved feed extruder, would operate at an output of close to 1,000 kg/hr and some advanced extruders may achieve an output of 1,500 kg/hr.

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Table 3 shows expected specific screw output ranges (expressed as kg/hr/rpm) of pipe extruders versus screw diameter for high-speed-extruders with forced-conveying feed sections. Advanced extruders will have outputs close to the maximum of the designated output specification.

Table 3: LDPE and HDPE Specific Screw Output Data Versus Screw Diameter

Screw diameter mm	Specific output [kg/hr/rpm]	
	LDPE	HDPE
45	0.4 – 0.6	0.5 – 0.8
60	0.9 – 1.2	1.2 – 1.7
75	1.8 – 2.4	2.5 – 3.0
90	3.0 – 4.0	4.0 – 5.0
120	6.0 – 8.0	8.0 – 11
150	10 – 13	12 – 16

The economics of a pipe production plant will depend on the following:

- The range of pipe sizes – e.g. diameter sizes
- The length of pipe runs – e.g. producing pipe of a set dimension
- The available length of the cooling unit in the production building

Bearing this in mind, increasing plant production capacity might not be as straight forward as installing larger and higher throughput extruders.

Pipe Dies

Today, manufacturers of pipe extrusion lines supply pipe dies (see Figure 6) which they have developed themselves but which are essentially based on a common design principle.



Figure 6: Photograph of a Pipe Die

High production extruder throughput has resulted in the polymer experiencing low residence times in the extruder. This lack of residence time can lead to concerns about melt homogeneity and whether an even temperature distribution has been achieved throughout the melt. Modern pipe resin grades also have high melt viscosity and elasticity that are required for the strength of the final product, as well as for the ability to make large and thick walled pipes within dimensional tolerances respectively. These polymer features make the extrusion line die absolutely essential for the successful manufacture of pipe, especially with respect to its capacity to even up any melt inhomogeneity and shape it into the pipe without the generation of weld lines or any other memory effects which could potentially compromise the strength or appearance of the final product.

One of the established die designs is a "Spiral Mandrel". The wide acceptance of this die has seen it incorporated into many new pipe production line designs. This die design has an excellent capability to homogenise melt and shape it into pipe without generating any imperfections which could compromise the final quality or integrity of the pipe (see Figures 7 and 8).

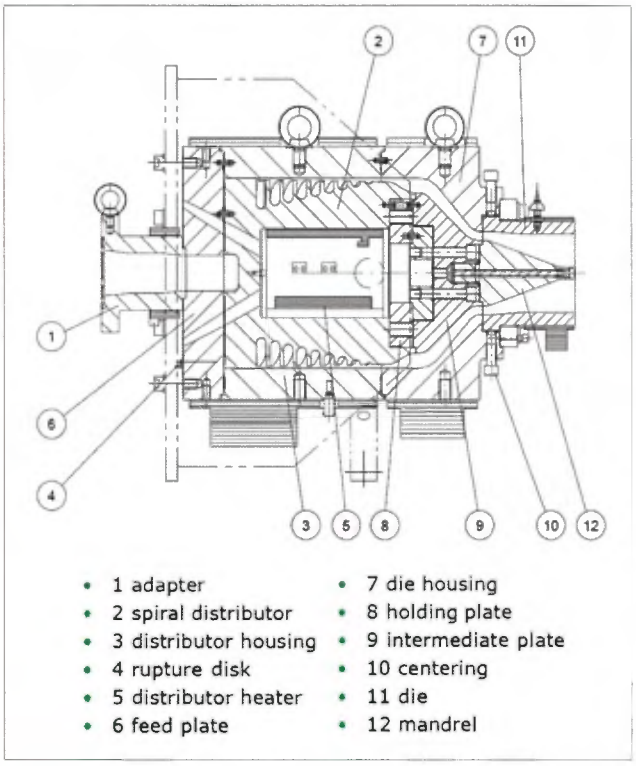


Figure 7: Schematic Diagram Detailing the Components of a Spiral Mandrel Die

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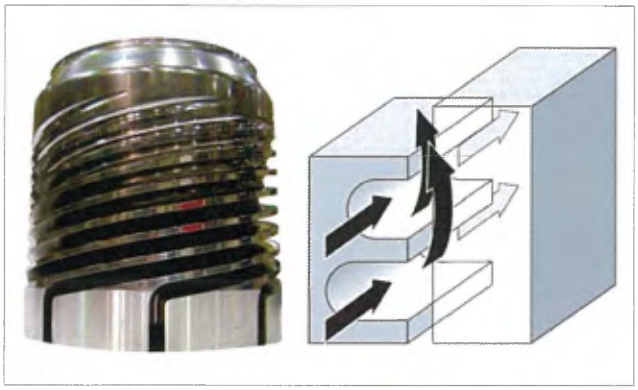


Figure 8: A Spiral Distributor and its Operating Principle for Melt Homogenisation

Another die design which has found wide approval and use in pipe manufacture, for its performance, is the Lattice-Basket type die. This design results in relatively low extrusion melt pressure and consequently relatively low melt temperature, both favourable for high extruder output (see Figure 9).

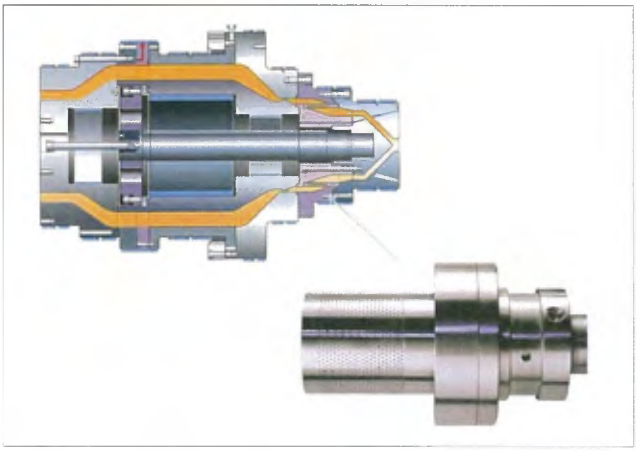


Figure 9: A Lattice-Basket Die and the Basket Part of the Die

Sizing and Cooling

In the state-of-the-art pipe manufacturing lines produced today, vacuum tank sizing is the predominant method used to shape the pipe from the melt. This includes the manufacture of the very largest pipes that have dimensions of 2000 mm. Unlike vacuum sizing, the internal pressure sizing method, where a positive pressure is built up within the pipe through the use of a floating plug, has been rapidly phased out due to safety concerns.

These concerns are associated with potential of building up excessive internal pressure within the pipe and leading to an uncontrolled rupture including release of the floating plug. Vacuum sizing technology enables quick starting up of an extrusion line. In addition, the melt emerging from the die can be drawn down to obtain a range of final pipe diameters so that it is possible to produce at least two standard pipe sizes with a single die/calibrator combination.

The pipe is shaped by a slotted sizing sleeve commonly referred to as a "calibrator". The calibrator is placed at the entrance of the first vacuum tank and it is the first downstream piece of line that the polymer melt sees after having exited the die. Calibrators are usually made from non-ferrous metal for rapid removal of heat (see Figures 10 and 11). A film of water is fed to the inlet of the calibrator to enable rapid cooling (e.g. below the cyrstallisation temperature of the polymer) to solidify the external pipe layer in order to pull the pipe into the calibrator without tearing the molten tube apart. Water also acts as a lubricant to reduce frictional forces on the pipe's surface whilst it is being pulled through the calibrator. The vacuum tank, in which the calibrator is placed, applies a vacuum which pulls the still hot, malleable tube against the wall of the calibrator, thereby setting the outer pipe diameter to ensure conformance to the pipe's dimensional specification. The vacuum is operated at about 0.05 MPa, absolute pressure, which could vary depending on the pipe dimensions. The calibrator is usually 3 – 5% larger than the required final outer pipe diameter to provide for shrinkage which takes place during pipe cooling.

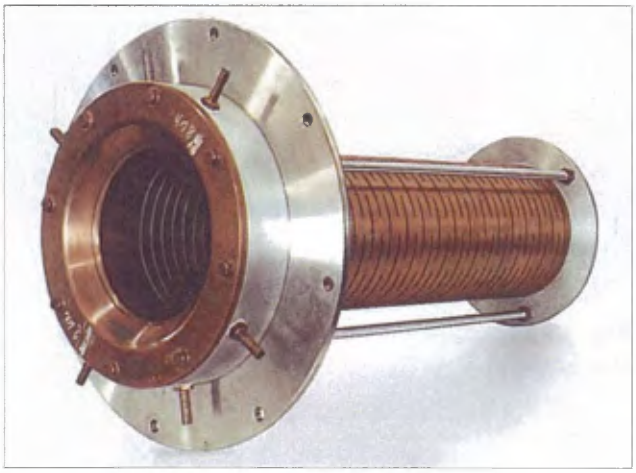


Figure 10: Sizing Sleeve for Vacuum-tank Sizing

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Figure 11: Vacuum Tanks for Sizing Pipes up to 1,400 mm in Diameter

Downstream of the 1st vacuum tank there could be another vacuum tank and certainly more cooling tanks to ensure that the pipe completely solidifies by the time it gets to the saw (see Figure 12). The additional cooling is important to achieving the final pipe dimensions within the desired tolerances.



Figure 12: Photographs of Spray Water Bath

The length of the cooling zone is dependent on the output and the given dimensions of the pipe. The total length (L) of the required cooling zone, can be calculated on the assumption that a molten polymer extrudate, at a temperature of ~220°C, has to be cooled with water to an external pipe temperature of ~20°C, at which point the internal surface temperature of the pipe is a maximum of 85°C.

Using these assumed temperatures, the total cooling-zone length can be calculated as follows:

$$L = L_{spec} \cdot Q \text{ (m)}$$

where

L_{spec} = specific cooling-zone length (m.hr/kg)

Q = output (kg/hr)

Lspec relative to the pipe dimension is outlined in Table 4 below:

Table 4: L_{spec} Relative to the Pipe Dimension

Pipe SDR*	41	33	26	17.6	11	7.4
L_{spec} for HDPE	0.016	0.02	0.024	0.036	0.06	0.08

*SDR = Standard Dimension Ratio; a nominal ratio of the pipe outside diameter to its wall thickness

Downstream Equipment

Downstream equipment covers all other plant units besides the extruder, die, sizing and cooling systems (see Figure 13). Most pipe manufacturing lines will have:

- **Ultrasonic Thickness Meter** – that continuously measures the wall thickness around the circumference of the pipe
- **Caterpillar Haul Off Unit** – with concentrically arranged caterpillars held under pneumatic pressure against the pipe to transmit the haul-off forces. For start-ups, the haul-off unit can be switched to operate in the reverse to enable a pipe to be run back through the cooling and sizing systems to the point where the melt exits from the pipe die. There the pipe can be welded to the extrudate.
- **Marking Unit** – where the pipe is marked with standard specifications
- **Automatically Adjustable Saw** – mounted on a table cuts the pipe into the desired lengths
- **Colling Unit** – where smaller diameter pipes can be wound into coils or onto reels up to the appreciable pipe size of 250 mm pipe diameter

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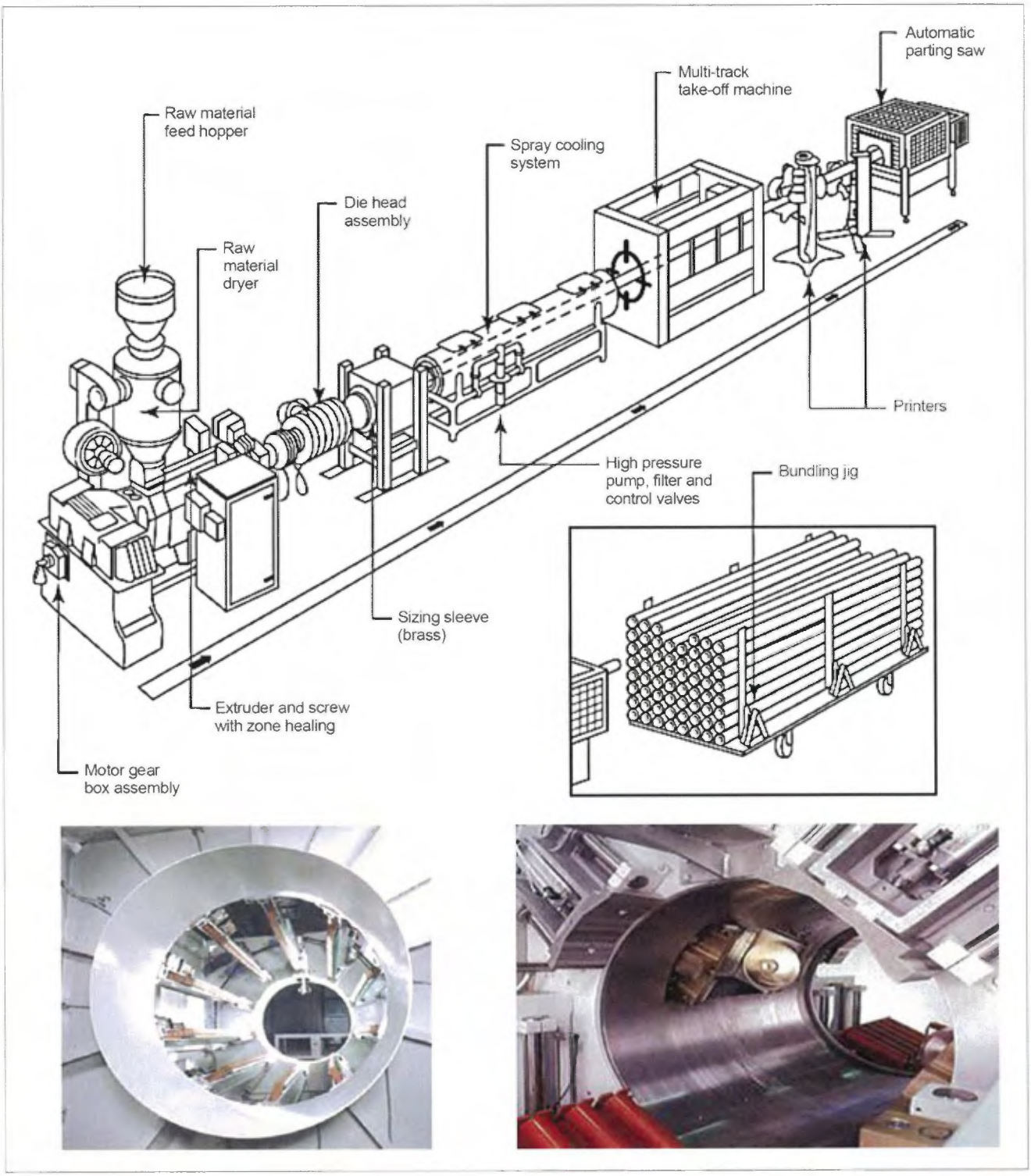


Figure 13: Schematic of a Pipe Extrusion Line showing Haul Off and Automatic Pipe Cutter

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Process Control

In new pipe production lines, process control computers are used to automate production.

To produce pipe in the required dimensions, the relevant operating data is entered, for example:

- Required throughput
- Pipe dimensions
- Screw speed
- Haul-off rate

The set-point values and permissible deviations are suitably fed-back to the controller for process data monitoring.

In pipe manufacture, material costs represent a substantial proportion of the overall costs of production. It is therefore advisable to use computerised process control for optimum production of pipes with the least possible waste of material and the best possible thickness uniformity around the pipe circumference. Figure 14 shows a schematic diagram of a computerized process control system for a pipe production line.

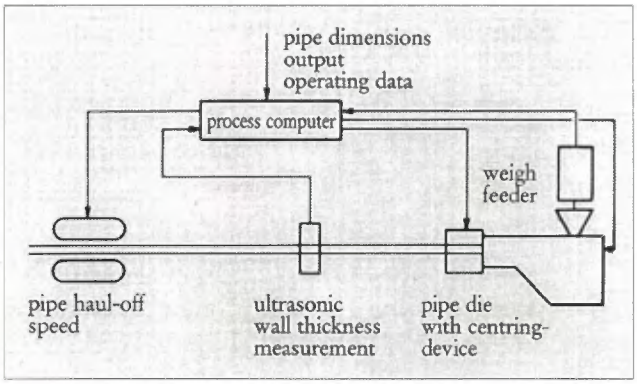


Figure 14: Computerized Process Control System for a Pipe Production Line

The most commonly employed control system operates on the basis of interaction between the following options:

- **Weigh Feeder** – the extruder is equipped with a weigh feeder. Weighed granule portions are fed to the extruder operating at required speed to achieve set off-take of the weighted granulate feed. Any deviation from the set output resulting from the constant weight feed is compensated for by speed adjustment of the extruder screw via the control system.
- **Haul Off Control** – the haul-off is set to a speed calculated from the specified output and the required weight per metre of the pipe. Pipe wall thickness is measured around the circumference with an ultrasonic wall thickness meter.

MECHANICAL PERFORMANCE OF POLYETHYLENE PIPE GRADES

Short-term Behaviour at Low Deformation Rates

A typical stress/strain curve for HDPE pipe (PE 100 type pipe compound) is shown in Figure 15.

The tensile test reveals the characteristic stress/strain curve for cold stretching of an unreinforced, partially crystalline polymer. Initially, tensile stress increases up to the yield point. This is followed by spontaneous necking-down of the test specimen accompanied by an apparent decline in tensile stress, since the stress is related to the initial cross section and not to the necked-down cross section at the yield point. When the necking-down has progressed along the entire length of the test specimen to the clamps, tensile stress increases again as a result of material strengthening due to macromolecular network straining and orienting until the breaking point is reached (ultimate tensile strength, elongation at break).

Because of the special deformation characteristics of polyolefins, it is advisable to use an extensiometer to determine elongation at break. Assessment is only possible when the necking-down has progressed beyond the measuring zone at each end. A polyolefin only retains its useful application properties up to the yield point and so it is better to dispense entirely with measurement of ultimate tensile strength and elongation at break.

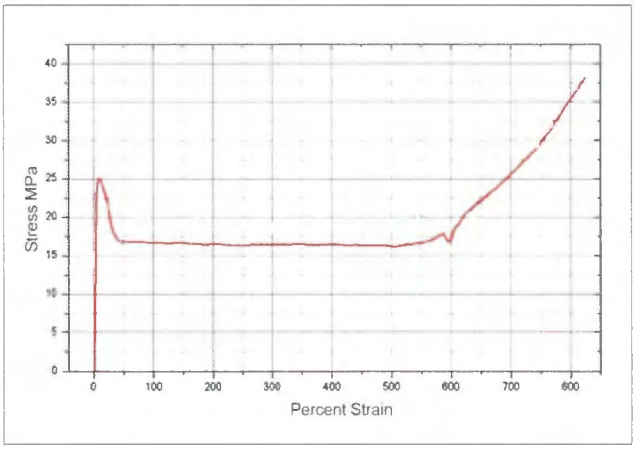


Figure 15: Typical Stress/Strain Curves for HDPE Measured in a Tensile Test on Test Specimen Prepared from Compression Moulded Sheet; Test Temperature 23°C, Testing Rate 50 mm/min

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The effect of temperature on the yield stress, ultimate tensile strength and elongation at break of a typical HDPE pipe grade is shown in Figure 16.

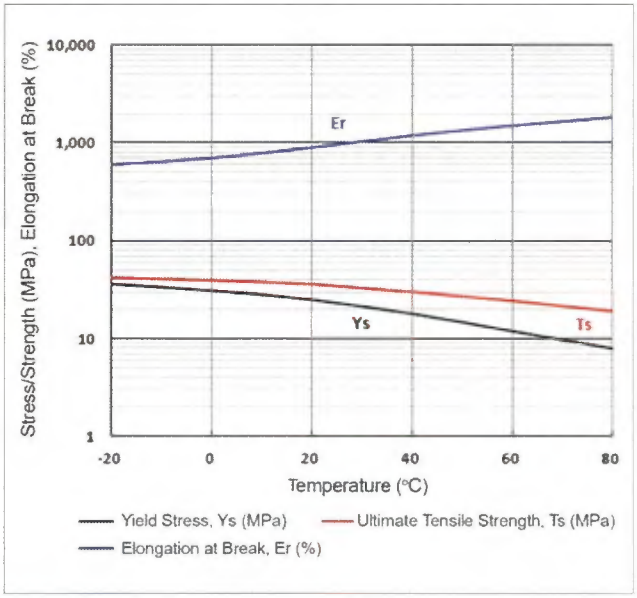


Figure 16: Yield Stress, Ultimate Tensile Strength and Elongation at Break of HDPE as Functions of Temperature

Long-term Behaviour

High density polyethylene is a viscoelastic material. Like all thermoplastics, it exhibits the property known as creep, i.e. over a period of time it undergoes deformation even at room temperature and under relatively low stress. After removal of stress, a moulding more or less regains its original shape, depending on the time under stress and the magnitude of the stress. The recoverable deformation is known as elastic deformation whereas the permanent deformation is called plastic deformation.

It should be remembered that the mechanical properties of a plastic are dependent on the three important parameters of time, temperature and stress.

In design calculations for moulded components, the mechanical property values (which in most cases are determined by long-term tests) must be divided by a safety factor.

Creep Behaviour Under Uniaxial Stress

A distinction is made between creep and relaxation tests.

Creep Test

In the creep test, the increase in deformation with time of a specimen held under a constant stress is measured and from this, the creep modulus is calculated.

Measurement can be carried out in a flexural creep test or a tensile creep test. It should be noted that the creep modulus is dependent on the level of stress as well as on temperature and time. Typical creep curves are shown in Figures 17 and 18.

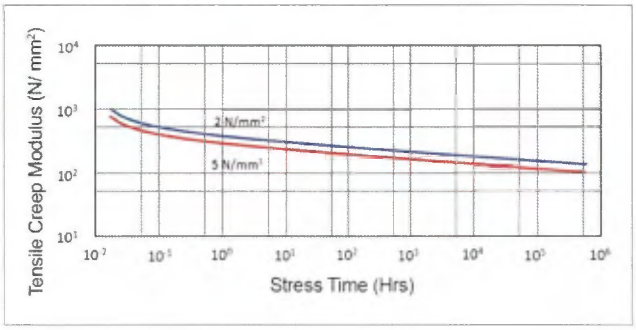


Figure 17: Typical Tensile Creep Modulus Curves of HDPE Determined at 23°C

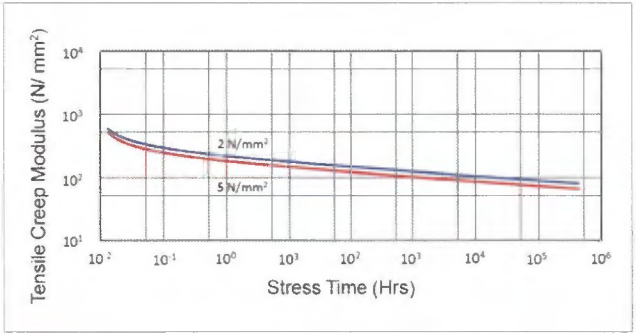


Figure 18: Typical Tensile Creep Modulus Curves of HDPE, Determined at 40°C

Similar tests have been carried out to determine creep moduli under compressive stress. Taking scatter into account, these gave approximately the same results as those for tensile stress.

The creep modulus can be used in design calculations for moulded parts which are to be exposed to constant stress over an extended period of time.

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Relaxation Test

In the relaxation test, the stress decay with time of a specimen held under constant deformation is measured and from this, the relaxation modulus is calculated.

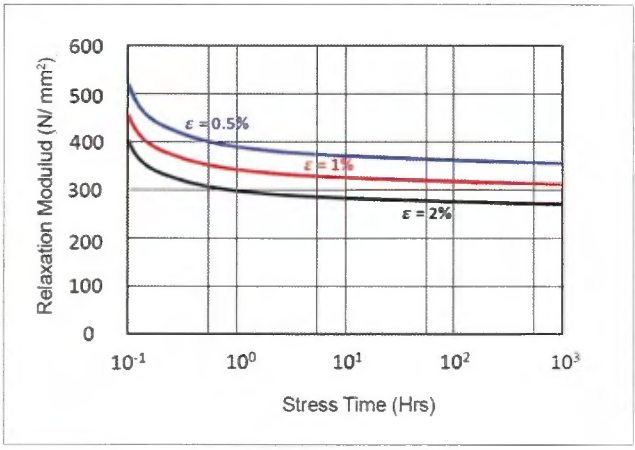


Figure 19: Typical Relaxation Modulus Curves of HDPE, Determined at 23°C

It should be noted that the relaxation modulus is dependent on the level of strain as well as on temperature and time.

The relaxation modulus (see Figure 19) can be used in design calculations for moulded parts that are to be exposed to constant strain or compression over an extended period of time.

Behaviour at High Deformation Rates

Information on the toughness characteristics of polymer materials at high deformation rates is provided by flexural and tensile impact strength tests. The results of impact strength tests (values for impact strength, notched impact strength and tensile impact strength) are considerably influenced by the conditions under which the test specimen is prepared. Injection moulded test specimens because of their rapid cooling rate are less crystalline when solid and therefore more impact resistant than those prepared from compression moulded sheet. The orientation produced by injection moulding also has an effect.

QUALITY TESTING OF POLYETHYLENE PIPE

PE 100: A Package of Good Properties

The designation PE 100 indicates that a PE-HD material has been assigned to performance class MRS 10 where MRS stands for Minimum Required Stress. The minimum creep strength is thus 10 MPa stress in the pipe wall at 20°C and 50 years. However creep strength alone does not determine assignment to material class 100 but rather a whole range of improved properties resulting from the much improved toughness of these materials, the most notable being:

- High resistance to Slow Crack Growth (SCG)
- High resistance to Rapid Crack Propagation (RCP)

Hydrostatic Pressure Tests

Undoubtedly the most important property of plastic pipes is their hydrostatic strength behaviour under internal pressure or "Creep Strength". This is what determines the service life expectancy of the pipe under internal pressure.

The equivalent stress (resulting from the action of the applied pressure within the pipe) corresponds in practice to the hoop stress acting on the pipe internal surface. Knowledge of the permissible stress for the material concerned forms the basis for designing a pipe under a given internal pressure using the calculation formula for pressure vessels.

The pressure to be used in the test is calculated from the equation below, knowing the dimensions of the pipe and the required hoop stress.

$$P = \frac{2ST}{D_{m\,min.} + T}$$

where:
P = maximum working pressure at 20°C (MPa)
S = hoop stress of hydrostatic design stress at 20°C (MPa)
T = minimum wall thickness (mm)
$D_{m\,min.}$ = minimum mean inside diameter (mm)

Creep Test Under Internal Pressure

The stress that leads to rupture in plastic pipes depends on the time under stress and the temperature of the test. Creep behaviour has been studied in long-term tests over many years, in some cases, since 1956 (see Figure 20). ISO 9080 standard "Plastics piping and ducting systems —Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation" sets out rules for the determination of the long-term hydrostatic strength of polyethylene pipes.

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Figure 20: The First Creep Rupture Test Started In 1956 In HOECHST (today known As Lyondell Basell) Laboratory, Frankfurt

The same test rig, and "original" pipes are still in operation today (see Figure 21). On 18th October 2006, two pipe specimens on this "historical" test stand finally confirmed the predicted service of 50 years.

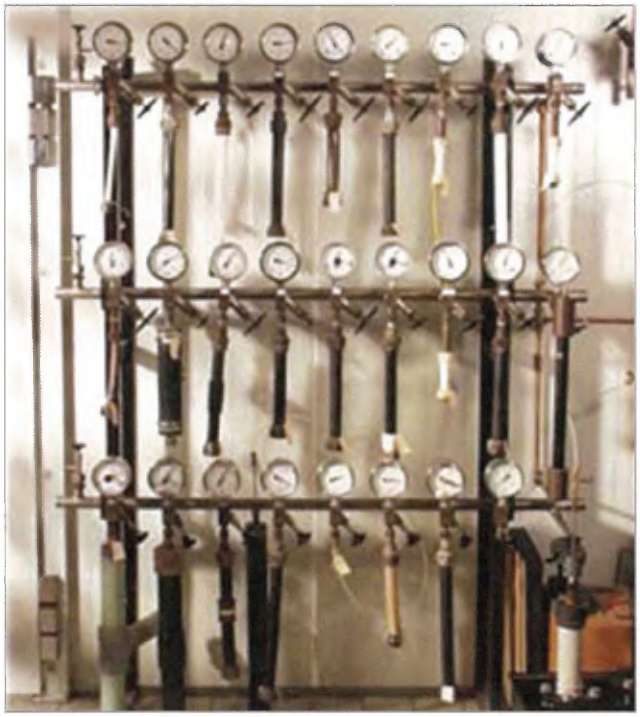


Figure 21: The First Creep Rupture Test Started in 1956 in HOECHST (today known as Lyondell Basell) Laboratory, Frankfurt, is still on test

The hydrostatic tests that are carried out on pipe sections under internal pressure take into account the effect of the multi-axial strain occurring in practice. The pipes are filled with water and suspended in a temperature-controlled environment such as a water bath (see Figure 22).



Figure 22: Extensive Hydrostatic Pipe Testing at Qenos Technical Centre

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Pipe pressure Curve and Service Life Extrapolation

The results of these tests are plotted on a log-log scale. Test stress is plotted against endurance time. After sufficiently long testing times, the typical pipe curve obtained from this plot shows three different regions or stages (see Figure 23).

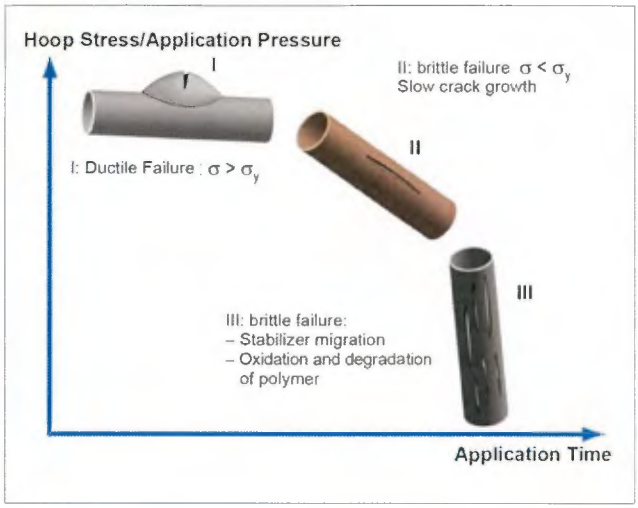


Figure 23: Representation of Pipe Curve According to the 3-stage Model (Illustration by Studsvik Material AB now known as Exova)

Starting with short endurance times, a flat, straight branch can be seen which is followed by a straight, steep branch. With the PE 100 grades currently used, this steep branch does not begin for 10 000 hours, even at elevated temperature (e.g. 80°C). After very long endurance times, a vertical, stress-independent branch of the curve could be expected to follow for testing at 80°C, effectively indicating resin has degraded due to long exposure to high temperature.

Each of the three curve stages is associated with three different failure mechanisms. In the flat stage of the pressure curves at 20°C and 80°C represented on Figure 25, only ductile fractures are observed. Ductile type failure shows a visible deformation on the pipe in the failure region. Figure 24 shows a section of pipe that has failed in a ductile mode.



Figure 24: Pipe Failed in Ductile Mode

Ductile failure indicates ultimate pressure bearing capability of the pipe. The flat branch therefore marks the stress limit for ductile failure.

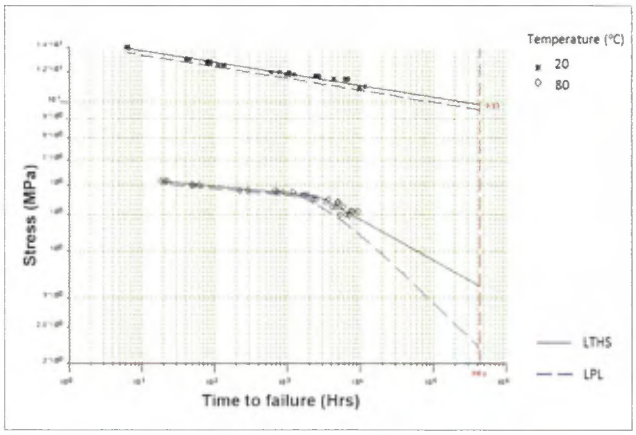


Figure 25: Qualitative Interpretation of Pipe Curve as Generated on PE 80 Pipe Grade. Testing was According to ISO 9080.

For the long-term properties of a pipe material, the position of the steep branch is crucial (e.g. in practice the steeper branch in the pressure test is referred to as a "knee"). It is determined by the resistance of the material to slow crack propagation. This material property, also referred to as brittle fracture resistance, determines the service life of the pipeline. In other words pipelines are designed to operate in a "ductile" failure regime. The inflection point (the transition between the flat and steep branches) can be observed, if at all, only at high temperature and after very long endurance times. This position denotes the transition from "ductile" to "brittle" type behaviour of pipe under pressure.

Pipe that has failed in a brittle mode doesn't show visible ductility in the failure region (see Figure 26).

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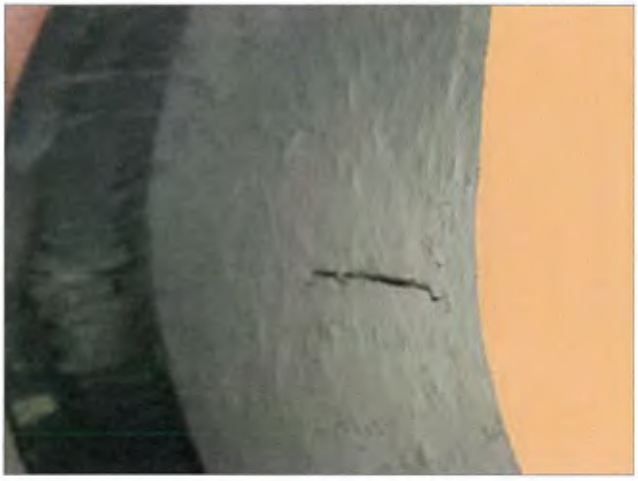


Figure 26: Pipe Failed in Brittle Mode

Modern pipe grades such as PE 100 should not show "brittle" like pipe failures in hydrostatic tests, even at 80°C, within the required one year testing time (see Figure 27).

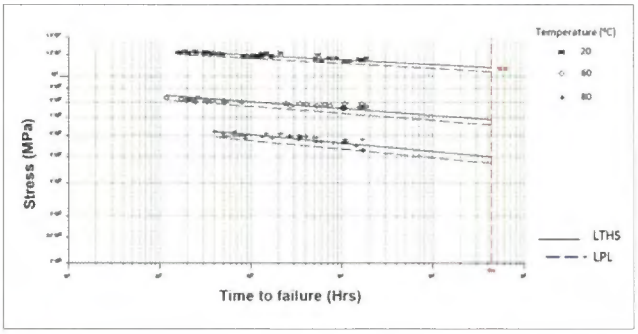


Figure 27: Creep Rupture Curve for Qenos PE 100 Grade *Alkadyne* HDF193B. Testing was According to ISO 9080.

When a PE piping system is to operate at a continuous temperature higher than "designated standard" temperature of 20°C, ISO 9080 analysis could be used to demonstrate capability of the pipe network in terms of extrapolated values for application stress and life time. Actual service life time of the PE pipe network will depend on application conditions and ISO 9080 extrapolation should not be used to infer actual service life time of the PE network.

TEMPERATURE RE-RATING OF PE PIPES

The Maximum Allowable Operating Pressure (MAOP) of a polyethylene (PE) pipe system is influenced by the temperature of the pipe wall. The nominal pressure rating (PN) assigned to an AS/NZS 4130 PE pipe equates to performance at 20°C, i.e. a PN16 pipe is capable of withstanding a MAOP of 160 m head (or 1.6 MPa or 16 bar pressure) when operating continuously at 20°C. However, as the temperature of the pipe wall increases, the MAOP of the pipe is reduced progressively, in other words the pipe system is re-rated with increasing temperature.

The guidance provided in this document is based on typical PE compounds used in Australia and New Zealand to manufacture AS/NZS 4130 PE pipe and listed in PIPA Guideline POP004, *Polyethylene Pipe Compounds*.

Note: These guidelines apply to pipe used for the conveyance of water. Where other incompressible fluids are being considered, the designer must assess the effect of the fluid on the PE pipe system at the operating temperature. For example internal fluids such as aggressive condensates when absorbed may have the effect of reducing the material strength upon which design stress is based.

The rerating factors in this guideline are expressed in terms of metre head of water and are not for use with compressed air or gas applications.

The following information details how to determine the temperature of the pipe wall and, then using Table 5 and 6, determine the de-rated MAOP value for the system. These recommendations are not to be taken as detailed specifications.

Determining the Temperature of the Pipe Wall

The pressure rating of PE pressure pipe systems is based on the temperature of the pipe wall, which may be determined from either:

a. An assumption of a constant pipe wall temperature typical for continuous service at a set temperature, e.g. cold water service; or

b. The determination of an average service temperature where temperature variations are likely to occur in a predictable pattern (refer below), e.g. in cavity walls or roof spaces; or

c. The maximum service temperature less 10°C for installations where large unpredictable temperature variations occur up to a maximum of 80°C, e.g. above-ground installations such as irrigation systems.

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Predictable Temperature Variations

For installations where predictable temperature variations occur, the average material temperature is determined from Item (d) or Item (e) as follows:

d. *Across the wall of the pipe* — the material temperature taken as the mean of the internal and external pipe surface temperatures, where a temperature differential exists between the fluid in the pipe and the external environmental.

   The pressure and temperature condition, where flow is stopped for prolonged periods, should also be checked. In this event, fluid temperature and outside temperature may equalise.

e. *With respect to time* — the average temperature may be considered as the weighted average of temperatures for the proportion of time spent at each temperature under operational pressures; it is calculated with the equation:

$$T_m = T_1L_1 + T_2L_2 + \cdots + T_nL_n$$

where:

T_m = average pipe material temperature for the period of time under consideration, in °C

T_n = average pipe material temperature for a proportion of pipe life, in °C

L_n = proportion of life spent at temperature T_n

Determining the MAOP Value

Once the temperature of the pipe wall has been determined using any one of the methods (a), (b) or (c) above, the following tables can be used to determine the re-rated MAOP for the PE pipe system.

Table 5 nominates the corresponding MAOP for a given temperature for PE 80B material. Table 6 provides the same information for PE 100 material.

Table 5: Maximum Allowable Operating Pressure – PE 80

Temp (°C)	Min Life (yr)	Design Factor	PN 3.2	PN 4	PN 6.3	PN 8	PN 10	PN 12.5	PN 16	PN 20
20	100	1.0	32	40	64	80	102	128	160	200
25		1.0	32	40	64	80	102	128	160	200
30		1.2	27	33	53	67	85	107	133	167
35		1.3	25	31	49	62	78	98	123	154
40		1.3	25	31	49	62	78	99	123	154
45		1.4	23	29	46	57	73	91	114	143
50	36	1.6	20	25	40	50	63	80	100	125
55	24	1.7	19	24	38	47	60	75	94	118
60	12	1.8	18	22	36	44	56	71	89	111
80	1	2.4	13	17	27	33	42	53	67	83

Table 6: Maximum Allowable Operating Pressure – PE 100

Temp (°C)	Min Life (yr)	Design Factor	PN 4	PN 6.3	PN 8	PN 10	PN 12.5	PN 16	PN 20	PN25
			SDR41	SDR26	SDR21	SDR17	SDR13.6	SDR11	SDR9	SDR7.4
20	100	1.0	40	64	80	100	127	160	200	250
25	100	1.1	36	58	73	91	115	145	182	227
30	100	1.1	36	58	73	91	115	145	182	227
35	50	1.2	33	53	67	83	106	133	167	208
40	50	1.2	33	53	67	83	106	133	167	208
45	35	1.3	31	49	62	77	99	123	154	192
50	22	1.4	29	46	57	71	91	114	143	179
55	15	1.4	29	46	57	71	91	114	143	179
60	7	1.5	27	43	53	67	85	107	133	167
80	1	2.0	20	32	40	50	63	80	100	125

Note: the minimum life periods may be considered to be the minimum potential service lives and represent the maximum extrapolated periods permitted by the ISO 9080 extrapolation rules given the available test data.

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NOTCH RESISTANCE (SCG) OF PE PIPES

Behind the phenomenon of creep strength and notch resistance lays the process of slow crack propagation. The brittle fracture observed is initiated by small defects or notches in the pipe. An increase in temperature accelerates this process. The fracture diagram (see Figure 23) shows a small crack running lengthwise along the pipe. As a partially crystalline polymer, polyethylene reacts to the stress concentration at the crack tip (notch root) by forming a crazing zone. This crazing zone develops into a fully propagating crack that leads to a "brittle" type failure. Application stress, which could lead to craze initiation and crack propagation, is of the magnitude that is observed for the hoop stress the pipe experiences in operation due to the presence of an applied operating pressure.

Therefore, it is widely accepted in the field that the most application relevant pipe property is its resistance to slow crack growth, in other words, its susceptibility to "brittle" failure.

Notch Test

The notch test according to ISO DIS 13479 may be regarded as a variant of the pressure creep test in which crack propagation resistance is specially assessed. Unlike the creep test under internal pressure, the failure point in this test is predetermined by notching.

In this test, four notches are cut in the outer surface of the pipe specimen in the longitudinal direction, each at 90° to the pipe circumference and with a defined geometry (Vee angle 60°, notch depth = 20% of wall thickness). See Figures 28 and 29 for details.

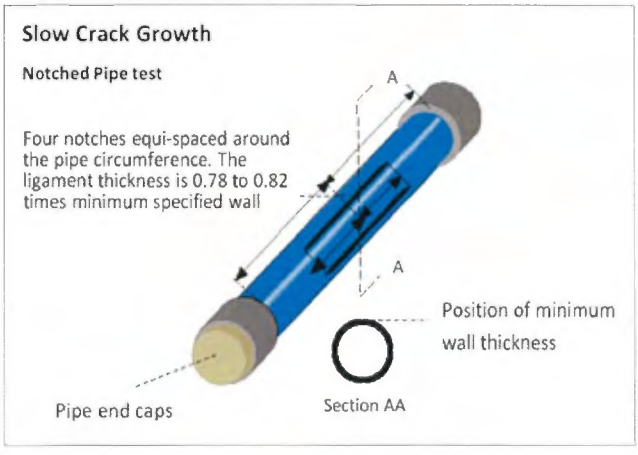


Figure 28: Illustration of Notched Pipe Test

This pipe is then pressure creep-tested under the following conditions:

- PE 100: 80°C; 4.6 MPa Hoop Stress; endurance time > 500 hrs
- The PE 100 materials pass this test without any problem



Figure 29: Pipes Notched and Assembled to be Tested for Slow Crack Growth Property as per ISO 13479. Pipes made from Qenos Pipe Grade *Alkadyne* HDF193B.

RESISTANCE TO RAPID CRACK PROPAGATION (RCP) OF PE PIPES

By rapid crack propagation we mean the following phenomenon: if a gas pipe during operation is damaged by an external force (e.g. by construction machinery) or by a stress-induced crack (e.g. in a defective weld) then, under the action of internal pressure and hence of the potential energy stored in the gas, the crack can spread over an extended length at almost the speed of sound (see Figure 30). In the case of PE 100, the range of applications is widened to include higher operating pressures; therefore pipe designers must be given highly reliable assurances as to the resistance of the pipe material to rapid crack propagation.

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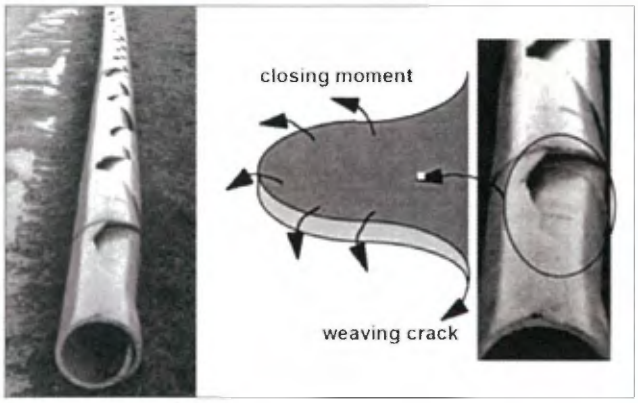


Figure 30: Example of Rapid Crack Propagation Fracture in Pipe Which Shows the Actions of Residual Stresses on the Cracked Pipe During RCP

S4 Test

Commonly employed testing methodology for RCP is based on the ISO 13477 standard. It is known in industry as the S4 test (small-scale, steady-state test). The S4 test is carried out as follows: a weight with a knife attached to the end is dropped onto a pipe of standardised length and under a constant internal gas pressure near one of its ends to produce a rapidly progressing axial crack. The crack initiation process should damage the pipe as little as possible. The term crack propagation is used if the crack length, a, is greater than or equal to 4.7 dn (4.7 times the nominal outside diameter). See Figures 31 and 32 for details.

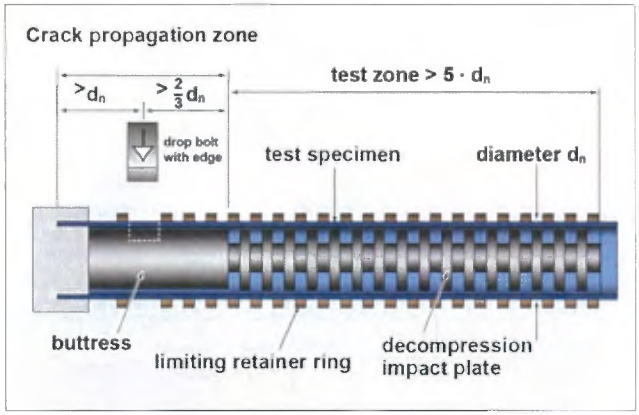


Figure 31: Schematics of a Test Rig for the S4 Test



Figure 32: Actual Test Rig for the S4 Test

A series of tests at 0°C but varying in testing pressure lead to the determination of the critical pressure at which there is a sharp transition from abrupt arrest of the initial crack to continued, steady-state, crack propagation. This method arrives at the "Critical Pressure" at which RCP occurs.

Alternatively, tests can be carried out at the set pressure but varying test temperatures to determine the "Critical Temperature" at which RCP occurs (see Tables 7 and 8).

In designing a pipeline, to carry gas at high pressure or at sub-zero temperatures the RCP property of pipe resin needs to be considered and a safety factor must be taken into account.

For gas pipelines made from Qenos *Alkadyne* PE 100 grades, the high RCP property ensures safe pipe line operation at high operating pressures as well as sub-zero temperatures.

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Table 7: RCP Testing of PE 100 Pipe at a Fixed Pressure and Varying Temperature

Pipe No.	Temperature (°C)	Pressure (MPa)	Crack Length l_c (mm)	l_c/d_n	Results
1	-5	0.5	120	1.1	Crack Arrest
2	-10	0.5	135	1.2	Crack Arrest
3	-15	0.5	165	1.5	Crack Arrest
4	-20	0.5	360	3.3	Crack Arrest
5	-25	0.5	300	2.7	Crack Arrest

The critical temperature T_c of the PE pipes (110 mm diameter) SDR11, Qenos grade *Alkadyne* HDF145B, at a pressure of 0.5 MPa, is lower than or equal at -25°C

Table 8: RCP Testing of PE 100 Pipe at a Fixed Temperature and Varying Pressure

Pipe No.	Pressure (MPa)	Crack Length a (mm)	a/d_n	Results
1	0.0	85	0.8	Initiation Test
2	0.4	110	1.0	Crack Arrest
3	0.6	120	1.1	Crack Arrest
4	0.8	130	1.2	Crack Arrest
5	1.0	125	1.1	Crack Arrest

The critical pressure $P_{c,S4}$ of the PE pipes (110 mm diameter) SDR11, Qenos grade *Alkadyne* HDF145B, at a temperature of 0°C, is higher than or equal to 1.0 MPa

Table 9: Collation of ISO to Australian Standards for Set Items, Equipment, Installation and Testing

International Standard	Subject Matter	Australian Standard
ISO 8085-2	Fittings	AS/NZS4129 Section 6
ISO 4437	Gas Pipe	AS/NZS4130
ISO 4427	Water Pipe	AS/NZS4130
ISO 12176-1	Equipment	Not applicable
ISO/TS 10839	Installation	AS/NZS2033, AS/NZS 4645
ISO 13593	Tensile Test	Not applicable
ISO 1167-1	Hydrostatic Pressure Test	AS/NZS 4130 Clause 10.1
ISO 1167-3	Hydrostatic Pressure Test	AS/NZS 4130 Clause 10.1
ISO 1167-4	Hydrostatic Pressure Test	AS/NZS 4130 Clause 10.1
ASTM F2634	High speed tensile test	Not applicable

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JOINING PE PIPES

Butt fusion jointing of PE pipes and fittings

Note: Information is based on POP 003 prepared by PIPA (Polyolefin Industry Pipe Association) as a guide to the butt fusion of polyethylene pipe using AS/NZS 4130 material as a basis.

Relevant Standards

The butt fusion procedures and parameters are specified in ISO 21307, *Plastics pipes and Fittings – Butt Fusion Jointing Procedures for Polyethylene (PE) Pipes and Fittings Used in Construction of Gas and Water Distributions Systems.*

ISO 21307 specifies three proven butt fusion jointing procedures for pipes and fittings with a wall thickness up to and including 70 mm, taking into consideration:

- The materials and components used
- The fusion jointing procedure and equipment
- The quality assessment of the completed joint

This standard also covers the weld procedure for activities such as surface preparation, clamping, alignment and cooling procedures.

Where ISO 21307 references other International Standards, the equivalent Australian Standard is deemed to apply. Where there is no equivalent Australian Standard then the International Standard applies (see Table 9).

Jointing Procedures

Butt welding involves the heating of two pipe ends to fusion temperature and then subsequently joining the two ends by the application of force. However, a successful butt weld requires the correct combination and sequence of the welding parameters time, temperature and pressure.

Various proven butt fusion methods with minor differences have been in use in different countries for many years. ISO 21307 contains three distinct fusion methods described below for pipe and fittings with a wall thickness up to and including 70 mm.

It is essential that the parameters specified for a given method are followed. Do not mix and match parameters from each method.

- **Single pressure – low fusion jointing pressure**
  This method has been used by most European countries and in Australia. The single pressure parameters specified are very similar to those previously specified by PIPA. Welders familiar with those parameters will adapt easily to the ISO Single pressure – low fusion jointing method.
- **Dual pressure – low fusion jointing pressure**
  This method is used by the water industry in the UK, and in Europe for pipes with a wall thickness greater than 20 mm. These parameters are not commonly used in Australia.
- **Single pressure – high fusion jointing pressure**
  This method has been used extensively in Northern America. The weld interface pressure is approximately three times the low pressure method and, as a consequence, more of the molten material is extruded from the weld zone, thereby enabling a reduced cooling time. Extra attention is required to ensure that:

1. Welding machines have sufficient structural strength and hydraulic capacity to achieve the high pressure parameters in a safe manner. Confirmation should be sought from the machinery manufacturer.
2. The welding operator is sufficiently experienced and proficient with the parameters.

Where the pipe or fitting wall thickness exceeds 70 mm welding parameters should be agreed between the asset owner and the installer. Under these circumstances the pipe and fitting supplier and the equipment supplier should also be consulted.

Schematically all three welding procedures are outlined in Figure 33 and Table 10 which show:

- Procedures are similar in overall approach, i.e. the seven steps of fusion
- Primary differences are in applied pressure and approach to cooling
- When properly performed, all methods result in reliable joints

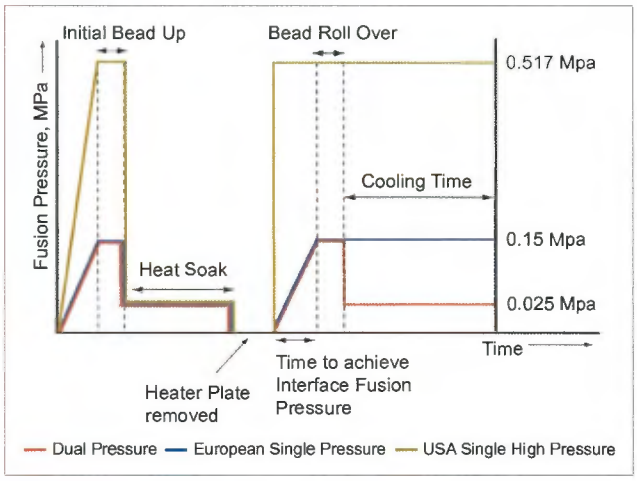


Figure 33: Schematic Diagram of the Various Stages of the Polymer Butt Welding Process

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Table 10: Parameters Corresponding to the Three Butt Welding Processes

Butt Welding Parameter		Unit	Single Low Pressure	Single High Pressure	Dual Low Pressure (If e_n > 20mm)
Heater pipe temperature		°C	200 to 245	200 to 230	225 to 240
P1	Bead up pressure	MPa	0.17 ± 0.02	0.52 ± 0.1	0.15 ± 0.02
T1	Bead up time	Visual	First indication of melt everywhere around pipe. (Approx. 1mm, maximum 6mm)		
P2	Heat soak pressure	MPa	0 to drag pressure	0 to drag pressure	0 to drag pressure
T2	Heat soak time	Seconds	$(11 \pm 1)e_n$	$(11 \pm 1)e_n$	$10e_n + 60$
	Maximum bead size after T2	Mm	$0.5 + 0.1e_n$	$0.15e_n + 1$	$0.5 + 0.1e_n$
T3	Maximum heater plate removal time	Seconds	$0.1e_n + 4$	$0.1e_n + 8$	≤10
T4	Maximum time to achieving welding pressure	Seconds	$0.4e_n + 2$	$0.1e_n + 8$	≤10
P3	Fusion jointing pressure	Seconds	0.17 ± 0.02	0.52 ± 0.1	0.15 ± 0.02
T5	Cooling time	Minutes	$e_n + 3$	$0.43e_n$	
T5a	*Fusion jointing time*	Seconds			10 ± 1
T5b	*Minimum cooling time in machine under reduced pressure*	Minutes			See ISO 21307
P4	*Cooling cycle reduced pressure*	MPa			0.025 ± 0.002
T6	Additional cooling time	Minutes	Additional cooling time out of the machine and before rough handling or installation may be recommended, but in most cases is not necessary		

Electrofusion Jointing of PE Pipes and Fittings

Note: Information is based on POP 001 prepared by PIPA (Polyolefin Industry Pipe Association) as a guide to the electrofusion of polyethylene pipes and fittings complying with Australian/New Zealand Standards AS/NZS 4130 and AS/NZS 4129[1].

These guidelines set out the principal requirements for equipment, jointing procedures, maintenance, servicing and calibration of equipment, records and training for jointing by socket electrofusion (EF) and saddle electrofusion.

The guidelines are also applicable to electrofusion fittings that are available in the size range DN16 to DN800. Development work is being undertaken for larger sized electrofusion fittings.

To consistently make satisfactory joints it is important to follow the jointing procedure with particular emphasis on pipe surface preparation, avoidance of contamination, and machine calibration, as well as temperature control.

Pipes and fittings of different SDR can be joined together by the electrofusion process, e.g. DN250 SDR11 pipe can be successfully electrofused using a DN250 SDR17 fitting. Electrofusion fittings for pressure applications are usually recommended for use with PE pipes SDR17 or lower (i.e. increased wall thickness).

Pipes of different PE materials- PE 63, PE 80 and PE 100 can also be jointed successfully using electrofusion sockets, provided that all components have adequate nominal pressure rating for the operating conditions and the PE materials comply with AS/NZS 4131.

Some manufacturers supply electrofusion fittings for thinner pipes, down to SDR33 whereas others limit the use of some saddle type fittings to SDR11 or thicker. These limitations are usually detailed on the fitting body or on the packaging. If in doubt, check with the supplier or manufacturer, as unsatisfactory joints are likely to occur if the fitting/pipe combination is incorrect.

It is recommended to refer to the supplier or manufacturer of the electrofusion fittings for the installation instructions, as the method may be specific to the fitting geometry.

Accurate record keeping and manual or automatic electrofusion equipment that provides good control of jointing conditions are essential.

1. EF fittings can be used with non-pressure drainage pipes made to AS/NZS 4401 and AS/NZS 5065.

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SDR Pipe to Fitting Fusion Compatibility

The following table provides recommendations of the fusion compatibility of PE pipe to PE electrofusion fittings (see Table 11).

Table 11: SDR 11 Electrofusion Fittings

	Electrofusion Fittings SDR11		Branch Fittings SDR11		Electrofusion Saddles SDR11	
	PE Pipe SDR Rating					
Pipe DN	11	17/17.6	11	17/17.6	11	17/17.6
16	+	–	–	–	–	–
20	+	–	–	–	–	–
25	+	–	–	–	–	–
32	+	–	–	–	–	–
40	+	–	–	–	+	–
50	+	–	–	–	+	–
63	+	–	–	–	+	–
75	+	–	–	–	+	–
90	+	+	+	+	+	+
110	+	+	+	+	+	+
125	+	+	+	+	+	+
140	+	+	+	+	+	+
160	+	+	+	+	+	+
180	+	+	+	+	+	+
200	+	+	+	+	+	+
225	+	+	+	+	+	+
250	+	+	+	+	+	+
280	+	+	+	+	+	+
315	+	+	+	+	+	+
355	+	+	+	+	+	+
400	+	+	+	+	+	+
450	+	+	+	+	+	+
500	+	+	+	+	+	+
560	+	+	+	+	+	+
630	+	+	+	+	+	+

where: + corresponds to suitable and – corresponds to unsuitable

Consultation with the fitting supplier or manufacturer is advised for confirmation of fusion compatibility.

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Electrofusion socket jointing

Electrofusion socket jointing incorporates an electrical resistance element in the socket of the fitting which, when connected to an appropriate power supply, melts and fuses the materials of the pipe and fitting together.

The effectiveness of this technique depends on attention to preparation of the jointing surfaces, in particular the removal of the oxidised surface of the pipe over the socket depth, ensuring the jointing surfaces are clean and free from contamination, and that the assembly and clamping instructions are correctly followed.

The pipe is prepared for jointing by removing a layer, maximum of 0.2 mm for pipes up to DN25, 0.2 mm to 0.3 mm for pipes up to DN75 and 0.2 mm to 0.4 mm for pipes larger than DN75. The minimum allowable outside diameter of the prepared pipe is shown below (see Table 12).

Table 12: DN of Pipe Versus Minimum Outside Diameter of Prepared Pipe

DN of Pipe	Minimum outside diameter (OD) of prepared pipe (mm)	DN of Pipe	Minimum outside diameter (OD) of prepared pipe (mm)
16	15.6	200	199.2
20	19.6	225	224.2
25	24.6	250	249.2
32	31.4	280	279.2
40	39.4	315	314.2
50	49.4	355	354.2
63	62.4	400	399.2
75	74.4	450	449.2
90	89.2	500	499.2
110	109.2	560	559.2
125	124.2	630	629.2
140	139.2	710	709.2
160	159.2	800	799.2
180	179.2		

If entry of the pipe or fitting spigot into an electrofusion coupling is still restricted after the oxidised layer has been removed, the pipe can be scraped down to the permissible minimum outside pipe diameter as in the above table. In this case, the thickness removed may be greater than the thickness stated above.

Pipe should also be checked for out-of-roundness (ovality). Some coiled pipes may be too oval to fit into electrofusion sockets and must be re-rounded with rounding tools or clamps to enable sockets to be fitted.

The equipment and procedures described below relate to fittings with centre stops. If fittings without centre stops are used, the maximum insertion depth should be clearly marked on the pipe ends after the pipe surface has been prepared and cleaned prior to jointing.

Equipment

1. Control Box

The control box input supply should be from a nominal 240V generator suitable to drive inductive loads and phase cut systems, commonly of about 5kVA capacity. Some fitting suppliers may consider smaller capacity generators acceptable for small diameter fittings. The nominal output of the generator should be 240V ± 10%, between no load and full load.

It should be noted that electrofusion control boxes may generate considerable heat. Refer to the supplier of the controller to ensure the box has an integrated cooling system.

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Control boxes should include safety devices to prevent voltages greater than 42V AC for a 40V system being present at the control box output. The safety device should operate in less than 0.5 sec.

2. Peeling Tools

Rotational peeling tools must be capable of removing a continuous and uniform chip thickness from the outer oxidised surface, over the required insertion depth, when preparing the fusion zone.

Hand scrapers are difficult to use, and effective preparation is time consuming, physically demanding and in most cases does not produce uniform scraping. Therefore rotational scrapers or peeling tools are preferred when welding occurs at pipe ends (see Figure 34).

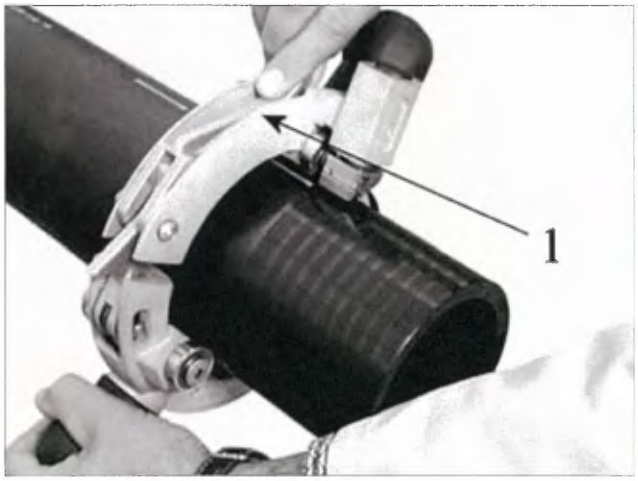


Figure 34: Rotational Peeling Tool Used to Prepare Pipe Ends

3. Re-rounding and Alignment Clamps

Re-rounding and alignment clamps or other approved methods have to be used for restraining, aligning and re-rounding pipes during the fusion cycle (see Figure 35a and b).

The benefits of alignment clamps are that they:

- Allow for re-rounding of pipes, particularly coiled pipes that are oval
- Provide correct assembly and alignment of the pipe with the fitting
- Enable the joint to be stabilised during the welding heating and cooling cycle
- Are stress free joints
- Have uniform melt pressure within the joint



Figure 35a: Re-rounding and Alignment Clamp Assembly used for Wide Bore Pipe



Figure 35b: In-field Laying of Multi-Jointed Pipe

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4. Pipe Cutters

Pipe cutters are mounted instruments that are used for the accurate cutting of pipes to ensure uniform and perpendicular pipe end. Such cutting devices should include the saw and saw guide (see Figures 36a and b).

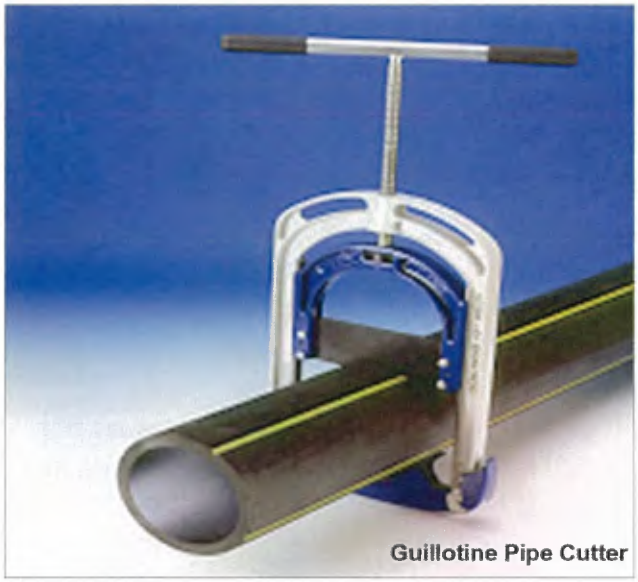


Figure 36a: Examples of a Guillotine

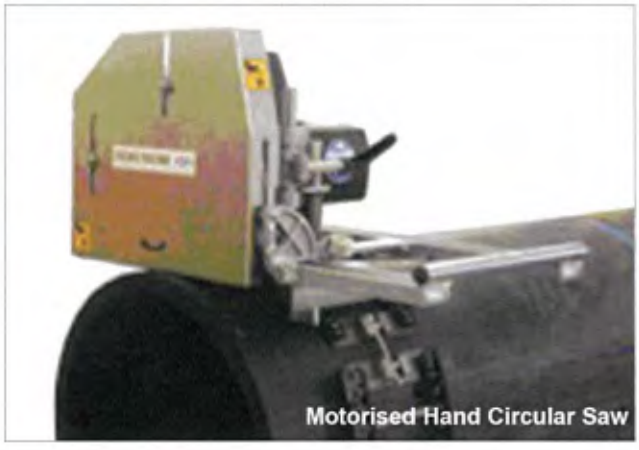


Figure 36b: Motorised Hand Circular Saw Cutter

5. Weather Shelter

Suitable shelter should be used to provide shade and protection for the pipe, fittings and equipment against adverse weather conditions and contamination of the jointing surfaces by dust and/or moisture, which can result in unsatisfactory joints. Fittings should only be removed from their original packaging immediately before using for jointing.

Electrofusion Jointing Method

Preparation of Pipe Ends

i. Ensure hands and tools are free from surface contaminants, such as barrier hand cream, sun screen, detergent and surfactant used in horizontal directional drilling.

ii. Check equipment is complete, clean, undamaged, in working order and protected by shelter.

iii. Ensure there is sufficient space to permit access to the jointing area. In a trench, a minimum clearance of 150 mm is required all round. Larger clearances may be needed for large nominal pipe sizes, depending on the tool used.

iv. Check that the pipe ends to be jointed are cut square to the axis and any burrs and swarf are removed.

v. Clean the fitting bore, followed by the pipe surface with a new approved alcohol wipe to remove traces of dirt, mud and other contamination. When using slip couplings clean the entire area where the fitting will pass over the pipe. The area of the pipe to be fusion jointed may be washed with clean water if necessary and dried with lint free material prior to peeling. Ensure the fusion area is completely dry before proceeding (see Figure 37). Do not use detergent or surfactants to clean pipe surfaces.

   NOTE: *Refer to fitting supplier for recommended alcohol wipes. Personal cleaning wipes may contain lanolin and detergent and are not to be used in electrofusion.*

vi. Check ovality as described above and use re-rounding tools as appropriate.

   With the fittings still in the bag, place alongside the pipe end and put a witness mark on the pipe at half the fitting length plus about 40 mm to enable visual checking of the scraped area after jointing is complete.

   NOTE: *Do not remove the fitting from its packaging at this stage.*

vii. Check that the pipe clamps are of the correct size for the pipes to be jointed. Only use the correct size pipe clamps.

viii. Check the peeling tools are clean of dirt or other contaminants prior to use.

x. Using an appropriate peeling tool, remove the entire surface of the pipe to the depth of the witness mark. Metal files, rasps, emery paper, etc. are not suitable end preparation tools and should not be used.

xi. Mechanical peeling tools are strongly preferred, as they achieve a consistent pipe surface preparation. Hand scraping, particularly for larger diameter pipes, is time consuming and onerous to adequately prepare a complete pipe end.

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xii. It is important in Australia that pipe and fittings are stored in the shade. If left in the sun, pipe and fittings become very hot which may affect weld conditions, particularly with thin pipe. When jointing in high ambient temperature, it is important that the pipe jointing area is shaded by an appropriate shelter. Some fittings do not require adjustment to the heat cycle time for ambient temperatures in the range -10°C to +45°C, whereas others require heat cycle time variation to compensate for ambient temperature within this range.

ENSURE THE PREPARED SURFACES ARE COMPLETELY DRY BEFORE PROCEEDING

DO NOT TOUCH THE PREPARED PIPE SURFACE

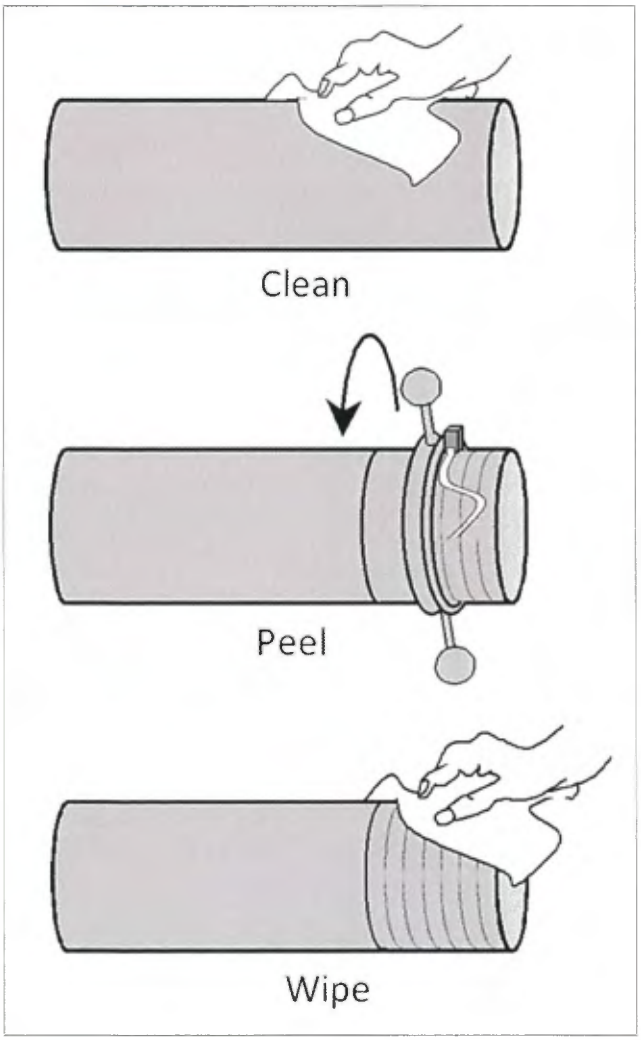


Figure 37: Illustration of Pipe End Preparation Prior to Welding

Jointing Procedure

i. Wipe the prepared pipe surface only with a recommended alcohol wipe to remove any dust residue and other contaminants. For larger diameter pipes use a multiple number of alcohol wipes.

NOTE: *Cleaning of the prepared surface is a critical step and one that has the potential to introduce contaminates if not done correctly – remember this is the surface that is about to be welded and the presence of contaminates can readily result in a poorly welded joint. To avoid contamination, ONLY wipe the peeled fusion zone area.*

Do not under any circumstances use methylated spirits, acetone, methyl ethyl ketone (MEK) or other solvents to clean the fusion area. Rags are not recommended for use with any alcohol solvent to clean the fusion area given the possibility of dirt, detergent or fabric conditioner being transferred into the fusion zone.

Other important factors relating to this procedure:

- Ensure wipes are saturated with alcohol i.e. have not dried out.
- To avoid contamination ONLY wipe the peeled fusion zone area.
- Only use the wipe once.
- Do not touch the prepared pipe surface – sweat, sunscreen, barrier cream, dirt and skin oils are all potential sources of contamination. Disposable latex or nitrile gloves are recommended when handing the wipes for preparation of the surface.
- Ensure alcohol left by the wipe on the cleaned surface has evaporated and the prepared surfaces are completely dry before assembling the joint.
- Refer to the electrofusion fitting supplier for the correct selection of alcohol wipes.

ii. Remove the fitting from its packaging and check that the bore of the fitting is clean. The bore of the fitting may be wiped with an approved isopropyl wipe if necessary.

NOTE: *Ensure the cleaned bore is completely dry before proceeding.*

iii. It is good practice to install the fitting to both pipe ends at the same time. However if this is not possible, open only one end of the fitting package and install the fitting to the pipe end. The package can then be fixed in place to enclose the exposed end of the fitting to keep the fitting bore free from contamination.

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iv. Inscribe an accurate witness mark or insertion depth onto the pipe and then insert the pipe ends into the fitting so that they are in contact with the centre stop and witness mark. It is critical that the pipe be fully inserted, particularly for larger pipes or when there is no centre stop. Ensure an aligned pipe arrangement in order to avoid any stress during the jointing process, especially when using coiled pipes.

v. The pipe end(s) and the fitting must be correctly aligned and free of any bending stress. Use pipe clamps, or other suitable means, to secure the pipe(s) so they cannot move and ensure that the fitting is satisfactorily supported to prevent it sagging during the fusion procedure (see Figure 38).

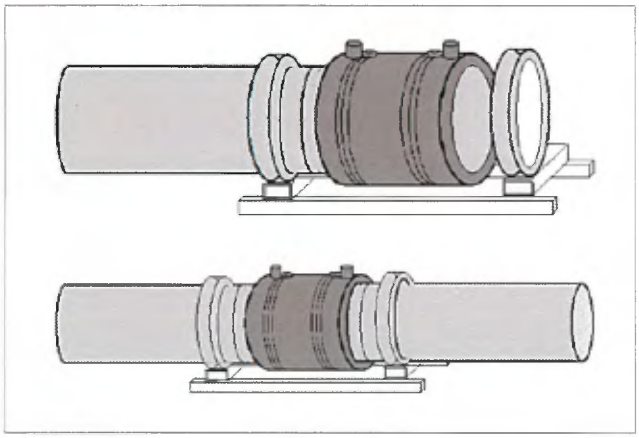


Figure 38: Illustration of Pipe Clamps and Fitting Attached to Pipe Ends Prior to Welding

vi. Check that there is sufficient fuel for the generator to complete the joint. Start the generator and check that it is functioning correctly.

NOTE: *Ensure the generator is switched on and running satisfactorily before connecting the electrofusion control box to the power source.*

vii. Switch on the control box. Check that the reset button, if fitted, is in the correct mode.

viii. Connect the control box output leads to the fitting terminals and check that they have been fully inserted (see Figure 39).

ix. The jointing time is generally indicated either on the fitting or on a data carrier supplied with the fitting. Check that the correct time is shown on the control box display. If required for the control box, enter the fusion jointing time into the control box timer.

NOTE: *Automatic control boxes are available which obviate the need to enter the fusion time.*

x. If the control box is equipped with a barcode reader or barcode scanner, scan the fusion data barcode into the machine to ensure a fully automated and controlled data entry. Barcode reading control boxes automatically adjust for variable temperature conditions. For manual input of the heat fusion time into the control box, refer to the manufacturer's parameters, supplied with the fitting.

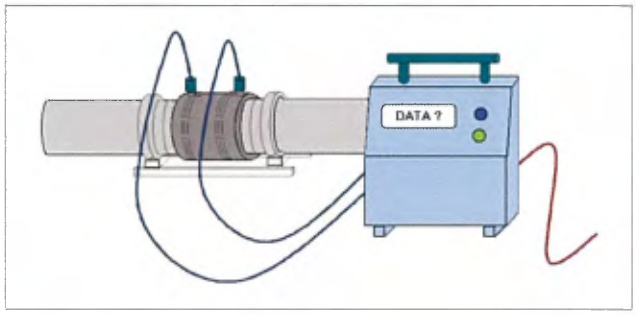


Figure 39: Attachment of Control Box Leads to Pipe Fitting

xi. Press the start button on the control box and check that the heating cycle is proceeding as indicated by the display.

xii. On completion of the heating cycle, both melt indicators within the processed part of the fitting should have risen. If there is no apparent movement of either indicator the joint could be unsatisfactory (see Figure 40) – refer to discussion on electrofusion indicator pins below.

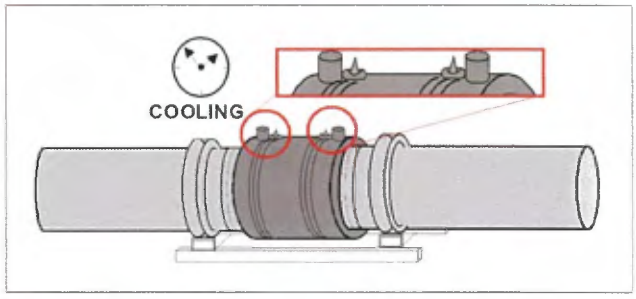


Figure 40: Diagram illustrating Locating of Melt indicators

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xiii. If the fusion cycle terminates before completion of the countdown, check for faults as indicated by the control box warning lights or display. Check for a possible cause of the break, e.g. inadequate fuel in the generator, or power supply failure, etc.

NOTE: *Do not attempt a second fusion cycle until the entire fitting has cooled to less than 45°C. Some manufacturers recommend replacement of the fitting rather than a second fusion cycle. Refer to the fitting manufacturer for details.*

xiv. The completed joint should be left in the clamps for cooling. The time needed will be specified on the fitting, or by its data carrier, or in the display of the automatic control box.

xiv. When the joint has cooled, remove it from the clamps and inspect.

Electrofusion Indicator Pins

The fusion indicator protrusion following the completion of the fusion process indicates that fusion pressure has developed but does not guarantee the quality of the joint. The height of the extended pin is dependent upon the fitting in use, component tolerances and the pipe material.

The pins are used as a pointer to whether a more detailed inspection of the joint is required so in the event that the pin does not rise, the supervisor or operator must investigate the following to determine if the joint is satisfactory.

- Dimensional check and compliance of the pipe spigot OD and ovality.
- The fitting socket internal diameter by measurement or batch traceability.
- In the case where the pipe and socket are concentric, the maximum gap between the two should not exceed 1% of the nominal diameter. If the socket and spigot are eccentric the gap should not exceed 2%.
- That there is no disruption to the input power supply from the fusion box with no control box error messages.
- That the heat fusion parameters are correct.
- The pipe to fitting alignment is correct with no visible plastic extruded out from the fitting.

Maintenance, Servicing and Calibration

All equipment should be well maintained and kept in a clean condition at all times.

The equipment should be serviced and calibrated regularly. The frequency at which this is carried out will be different for individual items of equipment and will also depend on usage, but should be at least once every 12 months. Guidance should be sought from the equipment manufacturer and a scheme of calibration and servicing should be implemented. Particular attention should be given to the control box, the generator and the scraping (or peeling) tools. The sharpness of the cutter head of the tools should be checked at least on a monthly base.

Records

1. Job Supervision

Electronic or written records of appropriate fusion procedure for each joint should be kept as required.

2. Equipment Servicing and Calibration

Electronic or written records of appropriate servicing and calibration should be kept. The minimum information to be recorded is given in Appendix 1.

3. Training

Instructions should be provided by Registered Training Organisations (RTO's) that are accredited by State/Territory Training Authorities under the Australian National Training Authority (ANTA) guidelines and complying with PMB 01–Competency Standards prepared by Manufacturing Learning Australia, Qualification Framework for the plastics, rubber and cable making industry.

The RTO's providing training in all forms of welding plastics pipeline systems must have staff qualified in presenting courses that meet competency standards covered by sections PMBWELD301A through to PMBWELD311A in PMB 01.

The RTO's normally issue an accreditation certificate to successful candidates completing the training course and maintain a register of accredited welders.

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Electrofusion Saddle Jointing

Electrofusion saddle jointing incorporates an electrical resistance element in the base of the saddle which, when connected to an appropriate power supply, melts and fuses the materials of the pipe and fitting together (see Figure 41).



Figure 41: Polymer Fitting that can be Welded onto a Pipe by Electrofusion Saddle Joining

The effectiveness of this technique depends on attention to preparation of the jointing surfaces, in particular the removal of the oxidised surface of the pipe over an area equivalent to the saddle base, and the cleaning of the jointing surfaces and freedom from contamination. Although PE is comparatively inert, the outer surface of the pipe will become oxidised when exposed to the atmosphere. This oxidised outer layer will interfere with the bond between the pipe and fitting and must therefore be removed before joint assembly.

Electrofusion tapping saddles are available to fit all commonly used main sizes from DN40 to DN560 with service connection outlet sizes from DN20 to DN63 and branch saddle spigot off-takes from DN32 to DN125.

NOTE: *Some saddle type fittings are limited to SDR11. Refer to the fitting manufacturer for further details.*

Tapping tee saddles are usually supplied complete with the manufacturer's recommended installation procedure. Generally recommended installation parameters are similar to the procedure described here, which refers to fittings supplied with an underpart with bolts for assembling the two parts on the pipe.

The nominal pipe diameter should be within the tolerances specified in AS/NZS 4130. Pipe ovality in excess of 1.5% of the nominal pipe diameter (DN) will require re-rounding tools to allow satisfactory contact between tapping saddle and pipe. Some full circle tapping saddles may effectively re-round pipe when correctly fitted but a constant and reliable joint quality can always be achieved by using re-rounding tools. If in doubt, refer to the fitting supplier.

Equipment

i. The control box input supply should be from a nominal 240V generator suitable to drive inductive loads and phase cut systems, commonly of about 5kVA capacity. Some fitting suppliers may consider smaller capacity generators acceptable for small diameter fittings. The nominal output of the generator should be 240V +15%, -15% between no load and full load. It should be noted that electrofusion control boxes may generate considerable heat. Refer to the supplier of the controller for details. Control boxes should include safety devices to prevent voltages greater than 42V AC for a 40V system being present at the control box output. The safety device should operate in less than 0.5 sec.

ii. Pipe surface preparation tool (scraper or peeler) has to be capable of removing the oxidised surface of the pipe over the full area of the saddle base. The tool should remove a surface layer of between 0.2 mm and 0.4 mm. Hand scrapers can be difficult to use in trench conditions, and effective preparation by hand may be time consuming and physically demanding. Therefore rotational scrapers or peeling tools are preferred.

iii. Re-rounding clamps or other approved methods of re-rounding pipes should be used, particularly if pipe out of roundness exceeds 1.5%.

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iv. A pipe clamp of suitable dimensions for making the service or branch connection is needed.

v. Pipe cutters should include a saw and saw guide.

vi. Suitable shelter should be used to provide adequate protection for pipe, fittings and equipment against adverse weather conditions and contamination of the jointing surfaces by dust and/or moisture, which can result in unsatisfactory joints. Fittings should only be removed from their original packaging immediately before using for jointing.

Preparation

i. Ensure hands and tools are free from surface contaminants, such as barrier hand cream, sun screen, detergent and surfactant used in horizontal directional drilling.

ii. Expose the pipe onto which the tapping tee or saddle is to be assembled, ensuring there is clear space around the pipe. In a trench a minimum clearance of 150 mm is required all round. Larger clearances may be needed for larger nominal sizes, depending on the tool used.

iii. Wipe the joint area, where the saddle is to be fitted, with alcohol wipes to remove traces of dirt, mud and other contamination. The joint area may be washed with clean water if necessary and dried with lint free material prior to scraping. Ensure the joint surface is completely dry before proceeding. Do not use detergent or surfactants to clean pipe surfaces.

NOTE: *Refer to fitting supplier for recommended alcohol wipes. Personal cleaning wipes may contain lanolin and detergent and are not suitable for use in electrofusion.*

iv. Without removing the fitting from its packaging, place it over the required position on the pipe. Mark the pipe surface outlining the saddle base area plus about 20 mm with a suitable marker pen to allow for visual checking of the scraped area after jointing is complete.

v. Check ovality as described above and use re-rounding tools as appropriate.

vi. Using an appropriate preparation tool remove the entire surface of the pipe over the full area marked. If hand scrapping, ensure long even scrapes starting outside the marked area to ensure craters do not occur in the fusion zone, which can produce an excessive gap leading to a brittle weld. Remove the swarf. Metal files, rasps, emery paper, etc. are not suitable scraping tools and should not be used.

vii. It is important in Australia that pipe and fittings are stored in the shade. If left in the sun the pipe and fittings become very hot which may affect weld conditions, particularly with thin pipe. When jointing in high ambient temperature, it is important that the pipe jointing area is shaded by an appropriate shelter. Some fittings do not require adjustment to the heat cycle time for ambient temperatures in the range -10°C to +45°C, whereas others require heat cycle time variations to compensate for ambient temperature variation within this range.

Jointing Procedure

i. Wipe the prepared surface only with the manufacturer's approved alcohol wipe to remove any dust residue and other contaminants. For larger diameter pipes a multiple number of alcohol wipes shall be used.

NOTE: *Cleaning of the prepared surface is a critical step and one that has the potential to introduce contaminates if not done correctly – remember this is the surface that is about to be welded and the presence of contaminates can readily result in a poorly welded joint (see Figure 42).*

Do not under any circumstances use methylated spirits, acetone, methyl ethyl ketone (MEK) or other solvents. Do not use rags or other cloth soaked in these materials to wipe the prepared fusion surface as they have the potential to contaminate the surface with dirt, grease and fabric conditioner. These are not suitable options for wiping the prepared surface.

Other important factors relating to this procedure:

- Ensure wipes are saturated with alcohol i.e. have not dried out.
- When using the wipe work from the prepared (peeled) surface towards the unprepared area and discard the wipe after it has come in contact with any unprepared areas. Wiping from unprepared areas towards the prepared surface can contaminate the fusion surface and similarly using a wipe which has been used on an unprepared can also introduce contaminants.
- Only use the wipe once.
- Do not wipe over the witness mark.
- Do not touch the prepared pipe surface – sweat, sunscreen, barrier cream, soap, detergent, dirt and skin oils are all potential sources of contamination. Disposable latex or nitrile gloves are recommended when handing the wipes for preparation of the surface.

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- Ensure alcohol left by the wipe on the cleaned surface has evaporated and the prepared surfaces are completely dry before assembling the joint.
- Refer to the electrofusion fitting supplier for the correct selection of alcohol wipes.

ENSURE THE PREPARED SURFACES ARE COMPLETELY DRY BEFORE PROCEEDING

DO NOT TOUCH THE PREPARED PIPE SURFACE

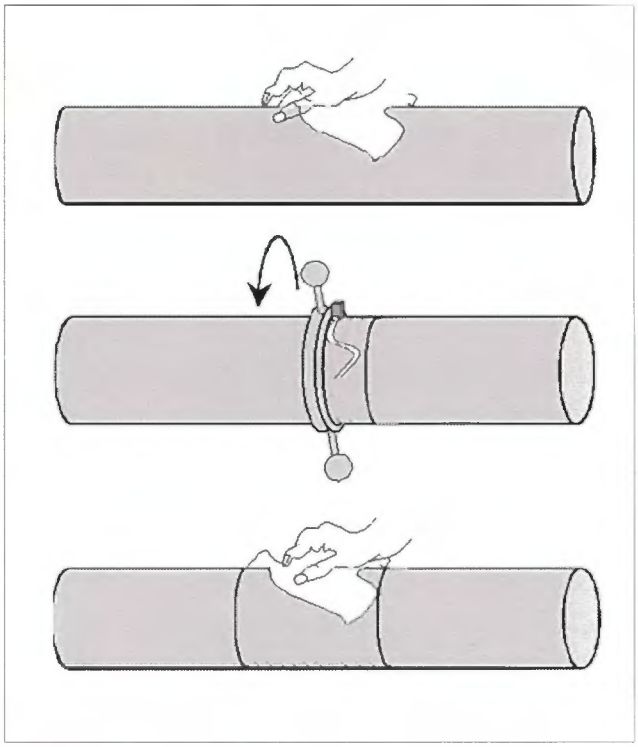


Figure 42: Illustration of Pipe Preparation Required Prior to Welding of Pipe Fitting

Remove the fitting from its packaging and check that the jointing surface of the saddle fitting is clean. The bore of the fitting may be wiped with a recommended alcohol wipe if necessary.

NOTE: *Ensure that the bore is completely dry before proceeding.*

ii. Position the fitting base onto the prepared pipe surface. Bring the lower saddle into position. Then gradually and equally tighten the bolts and nuts until the upper saddle makes firm contact with the prepared surface of the pipe (see Figure 43). Carefully inspect the fitting to ensure a firm contact with the pipe is achieved over the entire upper saddle contact area. Install re-rounding tools if pipe out of roundness exceeds 1.5% or if a firm contact is not achieved over the entire upper saddle contact area.

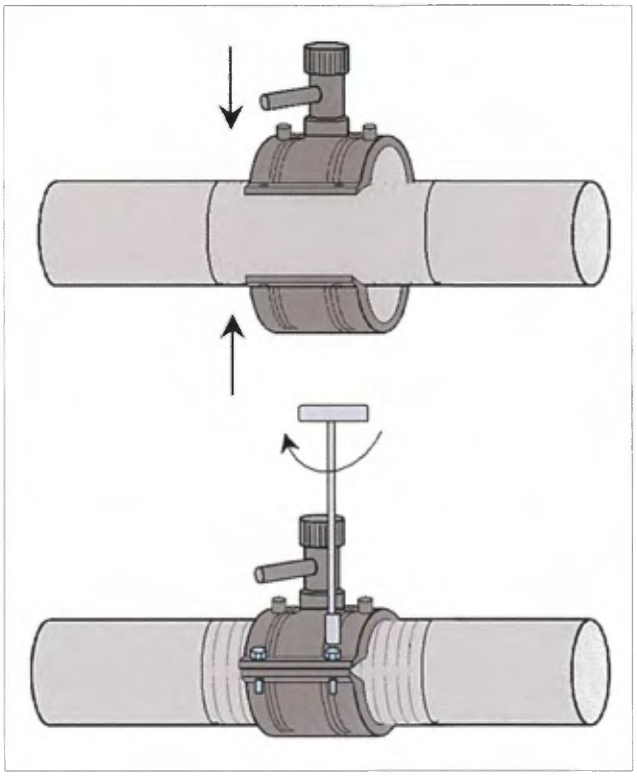


Figure 43: Installation of Saddle Fitting onto Pipe Prior to Welding

iii. Check that there is sufficient fuel for the generator to complete the joint. Start the generator and check that it is functioning correctly.

NOTE: *Ensure the generator is switched on and running satisfactorily before connecting the electrofusion control box to the power source.*

iv. Switch on the control box. Check that the reset button, if fitted, is in the correct mode.

v. Connect the control box output leads to the fitting terminals and check that they have been fully inserted (see Figure 44).

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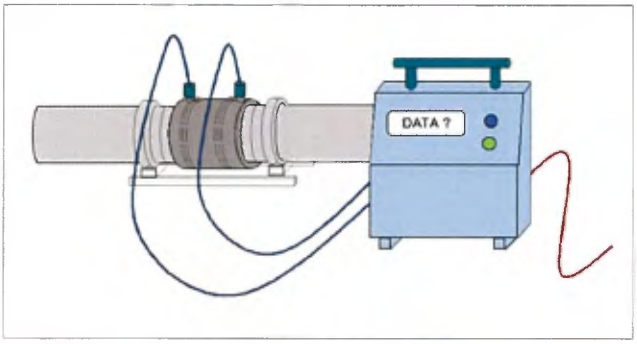


Figure 44: Attachment of Control Box Leads to Pipe Fitting

vi. The jointing time is indicated either on the fitting label or on a data carrier supplied with the fitting. Check that the correct time is shown on the control box display. If required enter the fusion jointing time into the control box timer.

NOTE: *Automatic control boxes are available which obviate the need to enter fusion time.*

vii. If the control box is equipped with a barcode reader or barcode scanner, scan the fusion data barcode into the machine to ensure a fully automated and controlled data entry. Barcode reading control boxes automatically adjust for variable temperature conditions. For manual input of the heat fusion time into the control box, refer to the manufacturer's or supplier's parameters, which should be supplied with the fitting.

viii. Press the start button on the control box and check that the heating cycle is proceeding as indicated by the display.

ix. On completion of the heating cycle, the melt indicator on the fitting should have risen (see Figure 45). If there is no apparent movement the joint could be unsatisfactory – refer to the manufacturer's instructions for further information.

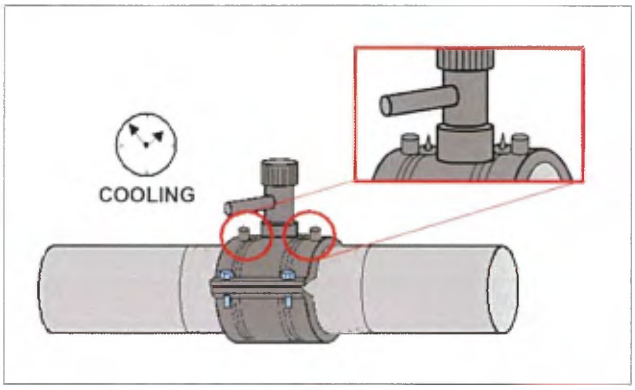


Figure 45: Diagram illustrating Locating of Melt indicators on Fitting

Refer to the fitting supplier or manufacturer for details on branch outlets and specific installation instructions.

x. If the fusion cycle terminates before completion of the countdown, check for faults as indicated by the control box warning lights or display. Check for a possible cause of the break, e.g. inadequate fuel in the generator, or power supply failure, etc.

NOTE: *DO NOT attempt a second fusion cycle until the entire saddle fitting has cooled to less than 45°C. Some manufacturers recommend replacement of the fitting rather than a second fusion cycle. Refer to manufacturer for details.*

xi. The completed joint should be left in the clamps for cooling. The time needed will be specified on the fitting label, or by its data carrier, or in the display of the automatic control box.

xii. The connection of the service pipe to the spigot outlet should be carried out in accordance with the procedure of the appropriate section of these guidelines (see Figure 46).

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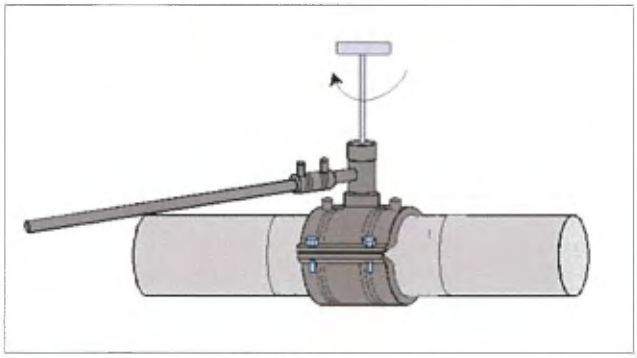


Figure 46: Illustration of Tapping Process used to Connect Spigot Outlet to Main Service Pipe

xiii. DO NOT attempt to tap the main with the integral cutter before the completion of the required cooling cycle as specified by the supplier.

Additional cooling time is recommended before tapping if the pipeline is to be field pressure tested as soon as practical:

- DN40 saddle minimum 10 minutes for field test pressure ≤ 6 bar and minimum 30 minutes for field test pressure > 6 bar ≤ 24 bar
- DN63 - DN560 saddle minimum 20 minutes for field test pressure ≤ 6 bar and minimum 60 minutes for field test pressure > 6 bar ≤ 24 bar

Top load Electrofusion Branch Saddle Jointing

Top load electrofusion branch saddles are typically used for large diameter branch connections ≥ 90 mm. Applications include: new installations, renovation, repair and under pressure live branch connections on existing PE mains for sizes to DN630 mm.

Typical installation instructions are detailed below:

i. Ensure hands and tools are free from surface contaminants, such as barrier hand cream, sun screen, detergent and surfactant used in horizontal directional drilling.

ii. Clean pipe in the fusion area with an approved alcohol wipe as detailed above in the Jointing Procedure, then remove the oxidised layer with a rotary peeler (see Figure 47).



Figure 47: Installation of Detachable Rotary Peeler to Service Pipe

iii. Clean pipe in the fusion zone with an approved alcohol wipe (see Figure 48).



Figure 48: Illustration of Prescribed Cleaning of Pipe Fusion Zone

iv. Mount the fitting to the pipe using a top-load tool and tightening clamp device to ensure a positive contact is made between the pipe and saddle. The joint gap should not exceed 0.5 mm (see Figure 49).

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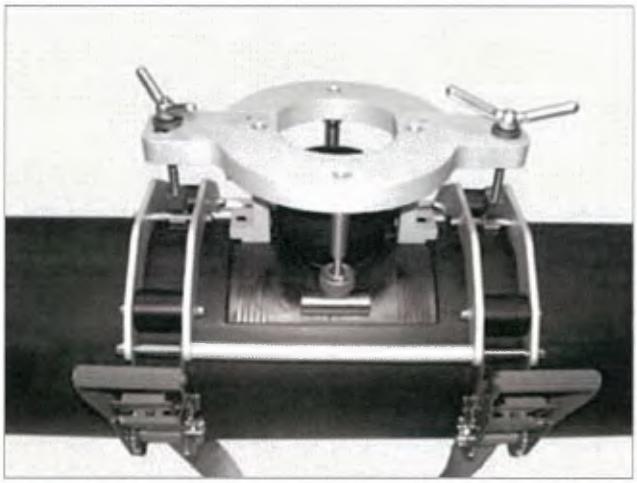


Figure 49: Illustration of Top-load Tool Attached to Both the Saddle and Pipe

v. Connect the terminals and apply the fusion voltage following the method outlined above in Jointing Procedure.

vi. The completed joint should be left in the clamps for cooling. The time needed will be specified on the fitting label, or by its data carrier, or in the display of the automatic control box.

Maintenance, servicing and calibration

All equipment should be well maintained and kept in a clean condition at all times.

The equipment should be serviced and calibrated regularly. The frequency at which this is carried out will be different for individual items of equipment and will also depend on usage, but should be at least once every 12 months. Guidance should be sought from the equipment manufacturer and a scheme of calibration and servicing should be implemented. Particular attention should be given to the control box, the generator and the scraping (or peeling) tools. The sharpness of the cutter head of tools should be checked at least on a monthly base.

Records

1. Job Supervision

Electronic or written records of appropriate fusion procedure for each joint should be kept as required.

2. Equipment Servicing and Calibration

Electronic or written records of appropriate servicing and calibration should be kept. The minimum information to be recorded is given in Appendix 1.

3. Training

Instructions should be provided by Registered Training Organisations (RTO's) that are accredited by State/Territory Training Authorities under the Australian National Training Authority (ANTA) guidelines and complying with PMB 01 - Competency Standards prepared by Manufacturing Learning Australia, Qualification Framework for the plastics, rubber and cable making industry.

The RTO's providing training in all forms of welding plastics pipeline systems must have staff qualified in presenting courses that meet competency standards covered by sections PMBWELD301A through to PMBWELD311A in PMB 01.

The RTO's normally issue an accreditation certificate to successful candidates completing the training course and maintain a register of accredited welders.

Quality Assurance

To achieve consistently good quality fusion joints as outlined by these guidelines, manufacturers and installers should operate a quality system in accordance with the principles of AS/NZS ISO 9001.

Assessment of the achievement would take the form of an audit against the points below. Independent testing of fusion joints may also be required.

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7 PIPE AND TUBING EXTRUSION

Management Responsibility

1. Customer Focus

The organisation responsible for the jointing operation should ensure that customer requirements are determined and are met with the aim of enhancing customer satisfaction.

2. Planning

The organisation responsible for the jointing operation should ensure that all aspects of the jointing operation are given adequate consideration prior to the commencement of work.

3. Responsibility, Authority and Communication

On each site where pipes and fittings are to be jointed in accordance with these guidelines, a person should be nominated to supervise work affecting the jointing quality. The person should:

- Have the responsibility and authority to ensure effective jointing operations
- Ensure that processes needed for jointing operations are established, implemented and maintained
- Be able to communicate the requirements for effective jointing operations

Control of Documents

Document control should ensure that:

- Documents are approved for adequacy prior to use,
- The relevant versions of applicable documents are available at points of use,
- Documents remain legible and readily identifiable,
- The unintended use of obsolete documents is prevented, and to apply suitable identification to them if they are retained for any purpose.

1. Purchasing

The installer should ensure that purchased items including pipe, fittings and fusion jointing equipment conform to specified requirements.

2. Fusion Jointing Control

The installer should ensure that fusion jointing procedures as well as servicing and maintenance of fusion jointing equipment are carried out in accordance with the specified guidelines.

3. Inspection and Testing

a. Inspection of goods received and used on site
The installer should ensure that incoming pipe, fittings and fusion jointing equipment are not used until they have been inspected and confirmed as conforming to specified requirements including appearance and marking. Any non-conforming items should be identified, recorded and segregated.

b. Final inspection and testing
At the commencement of each contract, the frequency and type of inspection by the installer should be agreed with the client and documented.

c. Inspection and test records
The installer should establish and maintain electronic and/or written records of appropriate fusion jointing procedures, servicing and calibration details in accordance with these guidelines.

4. Corrective Action

The installer should establish and maintain procedures to show evidence of:

- Review of non-conformities (including customer complaints) as a result of poor quality joints
- Determining the causes of poor quality joints
- Evaluating the need for action to ensure poor quality joints do not recur
- Determining and implementing action needed
- Recording the results of action taken, and
- Reviewing corrective action taken

5. Preservation of Product

The installer should establish and maintain appropriate procedures for handling and storage of pipe, fittings and fusion jointing equipment on site.

NOTE: *Damaged packaging can permit ingress of dirt and moisture, which can adversely affect joint integrity.*

6. Control of Records

The installer should establish and maintain procedures for collection, indexing, filing and storage of quality records for a minimum period of 6 years from the date of installation.

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7. Competence, Awareness and Training

The installer should:

- Determine the necessary competence for personnel performing fusion jointing
- Provide training or take other actions to satisfy these guidelines
- Evaluate the effectiveness of the actions taken
- Ensure that personnel are aware of the relevance and importance of their activities and how they contribute to the achievement of effective fusion jointing, and
- Maintain appropriate records of education, training, skills and experience

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APPENDIX 1 – RECORD SHEETS

Record sheets should be maintained for all equipment required for all fusion jointing operations. The sheet should be headed:

'SERVICING AND CALIBRATION RECORD SHEET'

Followed by:

'ELECTROFUSION SOCKET EQUIPMENT OR ELECTROFUSION SADDLE EQUIPMENT'

Then the appropriate sub-title from the following list (additional record sheets may be kept if required):

- Electrofusion socket jointing:
  - Generators
  - Electrofusion control box
  - Electrical safety test
- Electrofusion saddle jointing:
  - Generators
  - Electrofusion control box
  - Electrical safety test

The information recorded on the sheet should include, but not be restricted to:

- The date of servicing or maintenance
- The name, address and telephone number of the undertaking or contractor operating the equipment
- The name, address and telephone number of the company conducting the service or maintenance
- The member (or members) of staff responsible for servicing or maintenance
- The serial number of the equipment
- The details of service and/or maintenance carried out. This should include relevant details of test equipment, procedures and/or manuals used, and relevant ambient conditions.
- The signature(s) of the member (or members) of staff responsible for the servicing or maintenance operations conducted

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APPENDIX 2 – PIPE EXTRUSION TROUBLESHOOTING GUIDE

Problem/ Issue	Cause(s)	Potential Solution(s)/ Action(s)
Die (extrudate) lines.	Damage to the exit edges of the tip or die.	Refinish tip or die exit edges to sharp and uniform about the diameters.
	Die drool or build-up on the tip or die faces.	Adjust temperature of the die exit accordingly
Extruder surging	Too fast extruder throughput relative to OEM Extruder specifications	Check OEM guaranteed extruder throughput and run extruder within specifications
	Improper extruder temperature settings	Adjust temperature setting according to OEM recommendations
	Poor resin- extruder design match versus extruder OEM specifications for throughput	Discuss with resin supplier and implement actions to ensure extruder runs within OEM specifications
	Extruder not set as per OEM design specifications	Check with OEM and ensure compliance with design specifications
Gels and other contaminations in pipe	Resin contains foreign particles/ contaminated with gels etc	Check with resin supplier for presence of gels etc.
		Check regrind for contaminants
	Degraded resin coming off the die during extrusion	Follow proper shut-down procedures for extruder to avoid long exposure of resin to excessive temperatures
Localised thick spots in pipe wall	Improper die setting	Adjust the die setting
	Hot and cold spots in die profile temp	Check for uniformity in die heating
	Uneven pipe drag downstream of the extruder	Check for spots in cooling baths which could cause pipe drag
	Haul-off slippage	Check and adjust haul-off
	Uneven melt delivery from die -extruder surging	Check remedies for extruder surging
	Vacuum calibrator and die not levelled well	Adjust the position of the vacuum bath relative to the die
Pipe out of round	Sizing device (calibrator) in adequate or out of shape	Check the calibrator for concentricity.
		Ensure it is 3–5% larger than the final pipe diameter
	Pipe is too warm when it reaches the haul off unit	Ensure sufficient downstream cooling length before pipe gets to the haul off unit
		Decrease throughput
	Wrong vacuum setting in vacuum tanks	Ensure proper vacuum setting in vacuum tanks
Pipe tear	Haul-off too fast	Check and adjust the speed of haul off
	Pipe too hot at the entrance to calibrator	Check for water flows on calibrator and adjust to avoid hot spots
		Ensure adequate calibrator size
	Pipe dragging in cooling tanks	Check and eliminate drag spots
Pipe sag	Melt temperature too high	Adjust extruder temperature setting and throughput to lower melt temperature
	Die gap not adjusted to accommodate sag	Adjust die gap – wider at the top and narrower at the bottom of the die
	Resin's inherent resistance to sag is not adequate for the pipe wall thickness	Use low-sag resin
	No enough cooling capability in line	Ensure adequate water temperature in cooling baths and enough cooling length

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7 PIPE AND TUBING EXTRUSION

Problem/ Issue	Cause(s)	Potential Solution(s)/ Action(s)
Rough surface inside or outside	Moisture in resin	Ensure minimum of 1.5 hrs drying of resin at 70–90°C
	Not adequate water flows setting to the calibrator	Adjust water flows to calibrator
	Melt temperature too low	Increase die/ and or extruder temperatures
Thermal degradation of pipe-failed OIT	Too high melt temperature	Adjust extruder/ and or die temperatures accordingly
	Excessive extruder screw speed	Lower extruder throughput
	Die too small for required throughput	Ensure adequate die size
	Die pin too hot	Check operation of pin cooling otherwise decrease throughput
	Extruder surging	Check remedies for extruder surging
Uneven pipe cut	The saw blade is flexing	Get thicker/ larger blades
	The saw blade is lose	Check and fix
	Saw arm is entering pipe too quickly and with insufficient revolutions	Adjust as required
	The saw arm is lose or bushes worn and is 'floating'	Check and fix
	There is wear/slack in slip rings of the saw planetary components	Check and fix
	Uneven speed of haul-off or cutting carriage	Check uniformity of the speed of haul-off and cutting carriage
	Saw is not capable of cutting the pipe	Check with OEM for saw specifications
Uneven wall thickness	Uneven melt delivery from the die -extruder surging	Check remedies for extruder surging
	Uneven take-off speed	Check haul-off unit
	Improper alignment of die and haul-off units	Check for alignment
	Die and pin not centred evenly	Even die gap
	Excessive sag of a polymer	Check remedies for pipe sag
Voids in pipe	Moisture in resin	Ensure minimum of 1.5 hrs drying of resin at 70–90°C
	Trapped air	Adjust extruder temperature setting and back pressure accordingly

Disclaimer

The proposed solutions in this guide are based on conditions that are typically encountered in the manufacture of products from polyethylene. Other variables or constraints may impact the ability of the user to apply these solutions. Qenos also refers the user to the disclaimer at the beginning of this document.

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2

BIBLIOGRAPHY/FURTHER READING

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PMBWELD301B Butt Weld PE Pipelines Resource Manual, Chisholm Institute, 2010
15. Industry Guidelines, *Butt Fusion Jointing of PE Pipes and Fittings*, PIPA, 2011.
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Issued January 2014.

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Altona Victoria 3018, Australia
T: 1800 063 573 F: 1800 638 981
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FOI Document #7

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s47F

From: s47F @qenos.com
Sent: Thursday, 4 September 2014 9:12 AM
To: TARCON
Subject: Objection Gazette no TC 14/33, TC 1425825
Attachments: TC 1425825 objection Sep 14 signed.pdf; HD3690-CON item cost.xlsx; Polyethylene at a Glance 6th Edition.pdf; Book 5 injection Moulding.pdf

Categories: objections

Dear National Manager, Tariff Branch

Please find attached Qenos' objection to Gazette no TC 14/33, TC 1425825 and supporting material.

s47F

s47F
Qenos Pty Ltd
P: s47F | M: s47F
E: s47F @qenos.com | W: www.qenos.com

FOI Document #8

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If this form was completed by a business with fewer than 20 employees, please provide an estimate of the time taken to complete this form.

TIME SAVER

Hours Minutes

SUBMISSION OBJECTING TO THE MAKING OF A TARIFF CONCESSION ORDER (TCO)

THIS FORM MUST BE COMPLETED BY A LOCAL MANUFACTURER WHO WISHES TO OBJECT TO THE GRANTING OF A TCO. THE INFORMATION PROVIDED ON THIS PAGE WILL BE FORWARDED TO THE APPLICANT FOR THE TCO. THE FORM SHOULD BE READ CAREFULLY BEFORE BEING COMPLETED.

DETAILS OF THE TCO APPLICATION TO WHICH THIS SUBMISSION REFERS

GAZETTE NO: TC 14/33 DATE: 27 August 2014

Gazetted description of goods. TC Reference Number: TC 1425825

RESINS, unpigmented polypropylene heterophasic copolymer, proplyene based with comonomer ethylene, in pelletised form, having ALL of the following: (refer TC 1425825)

Stated use: For the manufacture of this walled containers for food and industrial packaging using high speed injection moulding

LOCAL MANUFACTURER DETAILS

Name: Qenos			
Business Address: 471-513 Kororoit Creek Road, Altona VIC 3018			
Postal Address *(if the same as business address write "as above")*: Private Mail Bag 3, Altona VIC 3018			
Australian Business Number (A.B.N.): 62 054 196 771	Reference:		
Company Contact: s47F	Phone Number: s47F	Facsimile Number: s47F	E-mail Address: s47F @qenos.com

DETAILS OF THE SUBSTITUTABLE GOODS PRODUCED IN AUSTRALIA

1 **Describe the locally produced substitutable goods the subject of the objection.**

"Substitutable goods" are defined in the Customs Act 1901 as "goods produced in Australia that are put, or are capable of being put, to a use that corresponds with a use (including a design use) to which the goods the subject of the application or of the TCO can be put".

High density polyethylene (HDPE) injection moulding resin.

4 SEP 2014

2 **State the use(s) to which the substitutable goods are put or are capable of being put.**

Housewares, thin walled containers and closures.

FOI Document #8

3 **Attach technical, illustrative descriptive material and/or a sample to enable a full and accurate identification and understanding of the substitutable goods.**

4 **Are you aware of any other local manufacturers producing substitutable goods?** ☐ YES ☑ NO

5 **If yes to question 4, please provide details of any goods produced in Australia which are substitutable for the goods for which a TCO is being sought, and the names and addresses of the manufacturers of those goods.**

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6 **PRODUCTION OF GOODS IN AUSTRALIA**

Goods other than unmanufactured raw products will be taken to have been produced in Australia if:

(a) the goods are wholly or partly manufactured in Australia; and

(b) not less than 1/4 of the factory or works costs of the goods is represented by the sum of:

(i) the value of Australian labour; and

(ii) the value of Australian materials; and

(iii) the factory overhead expenses incurred in Australia in respect of the goods.

Goods are to be taken to have been partly manufactured in Australia if at least one substantial process in the manufacture of the goods was carried out in Australia.

Without limiting the meaning of the expression "substantial process in the manufacture of the goods", any of the following operations or any combination of those operations DOES NOT constitute such a process:

(a) operations to preserve goods during transportation or storage;

(b) operations to improve the packing or labelling or marketable quality of goods;

(c) operations to prepare goods for shipment;

(d) simple assembly operations;

(e) operations to mix goods where the resulting product does not have different properties from those of the goods that have been mixed.

A **Are the goods wholly or partly manufactured in Australia?** ☑ YES ☐ NO

B **Does the total value of Australian labour, Australian materials and factory overhead expenses incurred in Australia represent at least 25% of the factory or works costs?** ☑ YES ☐ NO

Specify each of the following costs per unit for the substitutable goods:

- Australian labour
- Australian materials
- Australian factory overhead expenses
- Imported content

TOTAL s47 [redacted]

Specify the date or period to which the costs relate. 12 months ending 31 Aug 2014

Attach a copy of the working papers that were used to prepare the above costing information. Those working papers should be supported by (at least two) extracts from the accounting records of the business.

C **Is at least one substantial process in the manufacture of the goods carried out in Australia?** ☑ YES ☐ NO

If yes, please specify at least one major process involved:

Conversion of Ethane gas supplied from Bass Strait into ethylene using a steam cracking process and then polymerised into polyethylene at Qenos's Altona Victoria polymer manufacturing facility.

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FOI Document #8

7 PRODUCTION OF GOODS IN THE ORDINARY COURSE OF BUSINESS
(Answer 7.1 or 7.2)

7.1 SUBSTITUTABLE GOODS OTHER THAN MADE-TO-ORDER CAPITAL EQUIPMENT

Substitutable goods (other than made-to-order capital equipment) are taken to be produced in Australia in the ordinary course of business if:

(a) they have been produced in Australia in the 2 years before the application was lodged; or

(b) they have been produced, and are held in stock, in Australia; or

(c) they are produced in Australia on an intermittent basis and have been so produced in the 5 years before the application was lodged;

and a producer in Australia is prepared to accept an order to supply such goods.

A	Have the goods been produced in Australia in the last 2 years?	☑ YES ☐ NO
B	Have the goods been produced and are they held in stock in Australia?	☑ YES ☐ NO
C	If the goods are intermittently produced in Australia, have they been so produced in the last 5 years?	☑ YES ☐ NO
D	Are you prepared to accept an order for the goods?	☑ YES ☐ NO

7.2 SUBSTITUTABLE GOODS BEING MADE-TO-ORDER CAPITAL EQUIPMENT

"Made-to-order capital equipment" means a particular item of capital equipment that is made in Australia on a one-off basis to meet a specific order rather than being the subject of regular or intermittent production and that is not produced in quantities indicative of a production run. Capital equipment means goods which, if imported, would be goods to which Chapters 84, 85, 86, 87, 89 or 90 of Schedule 3 to the Customs Tariff Act 1995 would apply.

Goods that are made-to-order capital equipment are taken to be produced in Australia in the ordinary course of business if:

(a) a producer in Australia:

(i) has made goods requiring the same labour skills, technology and design expertise as the substitutable goods in the 2 years before the application; and

(ii) could produce the goods with existing facilities; and

(b) the producer in Australia is prepared to accept an order to supply the substitutable goods.

E	Have goods requiring the same labour skills, technology and design expertise as the goods the subject of the application been made in Australia in the last 2 years? If yes, describe the goods made during this period:	☐ YES ☐ NO
F	Can the goods be produced with existing facilities?	☐ YES ☐ NO
G	Are you prepared to accept an order for the goods?	☐ YES ☐ NO

8	What was the first date on which you were prepared to accept an order?	1 / 1 / 1980
	Are the goods still in production?	☑ YES ☐ NO
	If the answer is no, when did production cease?	/ /
	If production has ceased and goods are held in stock, please estimate the date by which stock is expected to be sold, based on past sales information and attrition rate of the local goods.	/ /

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9 **Provide any additional information in support of your objection.**

Cost analysis based on the bill of materials (provided) for Qenos grade HD3690 packaged in 20 tonne bulk containers for local delivery. Please advise if further cost information is required.

This product has been in production for several decades - the answer to question 8 on the first date on which Qenos was prepared to accept an order is indicative only.

A copy of Qenos' product guide "Polyethylene at a glance" and Qenos' technical guide on injection moulding have been provided in response to question 3.

NOTES

(a) Section 269K and 269M of the *Customs Act 1901* require that a submission opposing the making of a TCO be in writing, be in an "approved form", contain such information as the form requires, and be signed in the manner indicated in the form. **This is the approved form for the purposes of those sections.**

(b) A submission will be date stamped on the day it is first received in Canberra by an officer of Customs. The submission is taken to have been lodged on that day.

(c) For the submission to be taken into account, it must be lodged with Customs:
- no later than 50 days after the gazettal day for an application for a TCO;
- no later than 14 days after the gazettal day for an amended application for a TCO; or,
- where the Chief Executive Officer has invited a submission, within the period specified in the invitation.

(d) **Every question on the form must be answered.**

(e) Where the form provides insufficient space to answer a question, an answer may be provided in an attachment. The attachment should clearly identify the question to which it relates.

(f) Unless otherwise specified, all information provided should be based on the situation as at the date of lodgement of the TCO application.

(g) Customs may require an objector to substantiate, with documentary evidence, information provided in relation to the objection.

(h) Further information on the Tariff Concession System is available in Part XVA of the *Customs Act 1901*, in the foreword to the Schedule of Concessional Instruments, in the administrative guidelines in Volume 13 of the Australian Customs Service Manual, in Australian Customs Notice No. 98/19, on the internet at www.customs.gov.au, by e-mailing information@customs.gov.au or by phoning the Customs Information Centre on 1300 363 263.

I agree, in submitting this form by electronic means (including facsimile) that, for the purposes of Sub-Section 14(3) of the Electronic Transactions Act, this submission will be taken to have been lodged when it is first received by an officer of Customs, or if by e-mail, when it is first accessed by an officer of Customs, as specified in Sub-Section 269F(4) of the Customs Act.

Full Name	Position Held
s47F [redacted]	s47F [redacted]
Signature s47F [redacted]	Date 4 September 2014

NOTE: ***SECTION 234 OF THE CUSTOMS ACT 1901 PROVIDES THAT IT IS AN OFFENCE TO MAKE A STATEMENT TO AN OFFICER THAT IS FALSE OR MISLEADING IN A MATERIAL PARTICULAR.***

WHEN THIS FORM HAS BEEN COMPLETED LODGE IT WITH CUSTOMS BY:

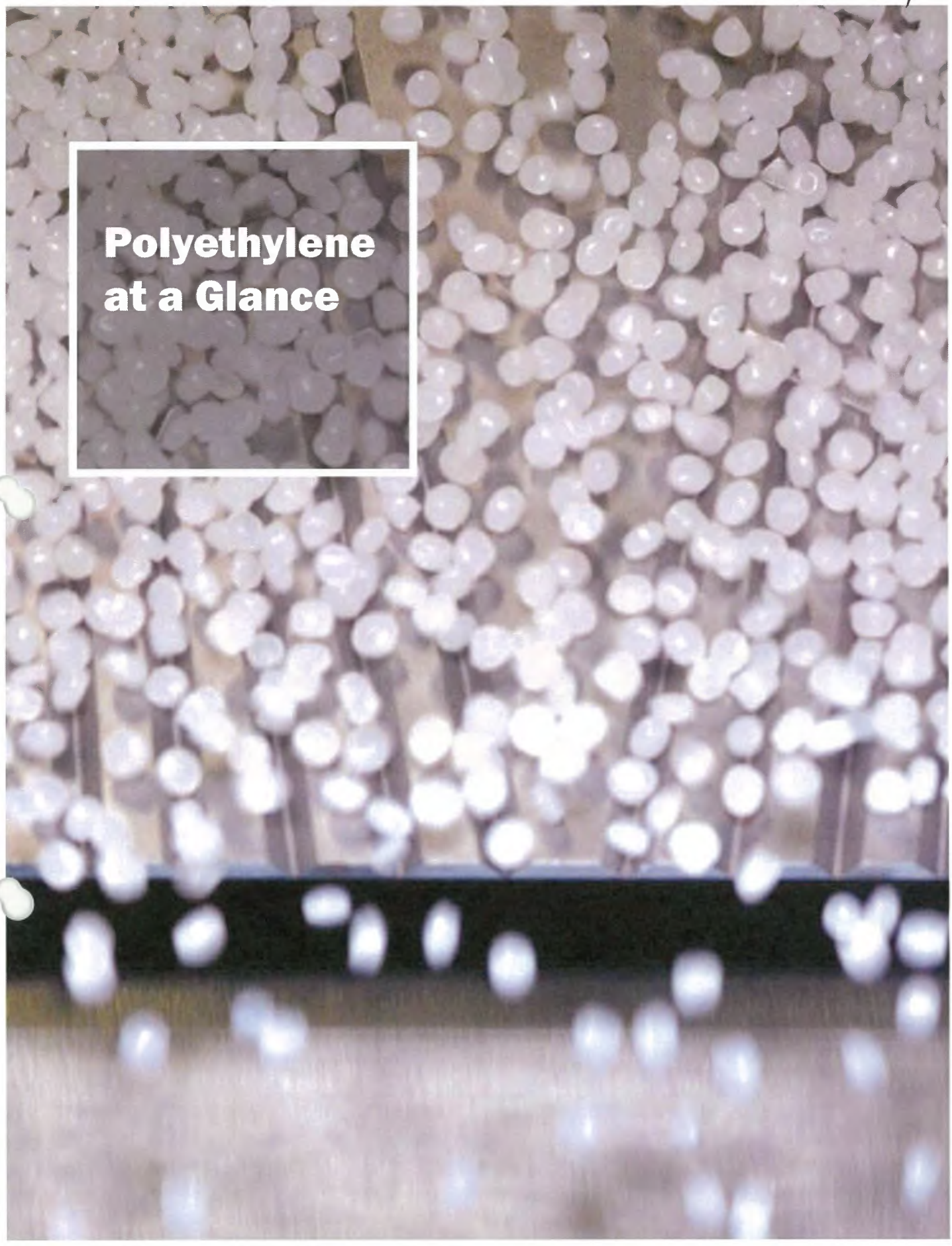
- posting it by prepaid post to the
  National Manager, Tariff Branch
  Australian Customs Service
  Customs House
  5 Constitution Avenue
  CANBERRA ACT 2601

  or
- delivering it to the ACT Regional Office located at
  Customs House, Canberra

  or
- sending it by facsimile to (02) 6275 6376

  or
- e-mailing it to tarcon@customs.gov.au.

FOI Document #11



Polyethylene at a Glance

Qenos
A Bluestar Company

FOI Document #11

Alkadyne™ PE100 Pipe Extrusion Grades

Grade	Melt Index* (g/10 min@ 190°C, 5.00kg)	Density# (g/cm³)	Applications
HDF193B	0.3	0.961(1)	High Density black PE100 type resin certified to AS/NZS 4131, for use in pressure pipes and fittings. Excellent low sag properties and throughput, suitable for the majority of PE100 pipe dimensions.
HDF145B	0.2	0.961(1)	High Density black PE100 type resin certified to AS/NZS 4131, for use in pressure pipes and fittings. Exceptional low sag properties and throughput, suitable for the most challenging pipe dimensions.
HDF193N	0.3	0.952(1)	High Density natural resin for extrusion into a full range of non standard pipe products and as a base for PE100 type striping and jacket compounds.

Notes: (1) ASTM D1505/D2839

Alkadyne™ PE Pipe Extrusion Grades

Grade	Melt Index* (g/10 min @ 190°C, 5.00kg)	Density# (g/cm³)	Applications
MD0898	0.7	0.952(1)	Medium Density black PE80B type resin certified to AS/NZS 4131 for use in pressure pipes and fittings.
MD0592	0.6	0.942(1)	Medium Density natural resin for extrusion into a full range of non standard pipe products and as a base for PE80 type striping and jacket compounds.
GM7655	0.6	0.954(1)	High Density natural high molecular weight resin for extrusion into a full range of non standard pipe products.
MDF169	1.0	0.943(1)	Medium Density natural high molecular weight resin for extrusion into a full range of non standard pipe products.
LL0228	1.7(2)	0.923(1)	Linear Low Density resin for use in pipe extrusion applications.

Notes: (1) ASTM D1505/D2839 (2) D1238@190°C, 2.16kg

Alkadyne™ PE Wire and Cable Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
MD0592	0.12	0.942(1)	Designed for extrusion into a full range of wire and cable products where natural Medium Density resins are required.
MD0898-1	0.12	0.953(1)	Designed as general purpose jacketing compound for buried wires and cables where abrasion and cut through resistance is required.

Notes: (1) ASTM D1505/D2839

Alkatane™ HDPE Tape and Monofilament Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
GF7740F2	0.4	0.950(1)	Extrusion applications including stretched tape, monofilament, tarpaulins, and over-pouches for medicinal products.

Notes: (1) ASTM D1505/D2839

Alkatuff® LLDPE Rotational Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
LL711UV	3	0.938	Applications requiring excellent ESCR, chemical resistance(1), stiffness, toughness and UV protection, such as water and chemical tanks, septic systems and kayaks.
LL705UV	5	0.935	Applications requiring high ESCR, chemical resistance(1), toughness, stiffness and high level UV stabiliser, such as leisure craft, playground equipment and agricultural tanks.
LL755	5	0.935	Applications requiring high ESCR, chemical resistance(1), toughness and stiffness. Incorporation of suitable UV stabilisation is required for outdoor applications.
LL710UV	10	0.930	High speed intricate applications requiring good ESCR, chemical resistance(1), toughness and UV protection, such as consumer goods and playground equipment.

Notes: (1) The level of chemical resistance is a function of product design and environmental conditions. Contact Qenos for further information.

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

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Alkathene® LDPE Film Grades				Additives		Applications							
Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Antiblock	Slip(2)	Heavy Duty Bags	Shrink	Produce	Carry Bags	Bread	Cling Wrap	Freezer Film	Overwrap
XDS34	0.30	0.922	Heavy duty sacks, pallet wrap and industrial applications requiring heavy gauge film. Additive free.			✓	✓						
LDF433	0.45	0.925	Heavy duty sacks, pallet wrap and industrial applications requiring medium to heavy gauge film with increased stiffness.	✓		✓	✓						
LDD201	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags and shrink film and for use as a blend component.			✓	✓						
LDD203	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags and shrink film requiring antiblock, and for use as a blend component.	✓		✓	✓						
LDD204	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags and shrink film where a medium level of slip is required.	✓	M	✓	✓						
LDD205	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags, frozen food and produce bags where a high level of slip is required or for use as a blend component.	✓	H	✓	✓	✓				✓	
LDH210	1.0	0.922	Bundle shrink and other medium gauge film applications such as produce bags, carry bags and for blending into other film grades.				✓	✓	✓				
LDH215	1.0	0.922	General purpose medium gauge film for produce bags and carry bags, frozen food where a high level of slip is required or for use as a blend component.	✓	H			✓	✓				
XJF143	2.5	0.921	Additive free, general purpose low gauge film for overwrap and other applications and for use as a blend component.										✓
LDJ226	2.5	0.922	Bundle shrink, low gauge shrink film and general purpose applications where a medium level of slip and antistatic are required.	✓	M(1)		✓		✓				✓
LD0220MS	2.5	0.922	High quality low gauge film for lamination and overwrap applications where a medium level of slip is required.	✓	M								✓
LDJ225	2.5	0.922	High quality, low gauge film primarily intended for bread bags and overwrap but also general purpose applications where a very high level of slip is required.	✓	VH					✓			✓
XLF197	5.5	0.920	High quality, very thin gauge and high clarity film primarily intended for food and packaging wrap and for drycleaning film. Additive free.								✓		

Notes: (1) Based on antistat additive (2) VH = Very High Slip, H = High Slip, M = Medium Slip

Alkatuff® LLDPE Film Grades				Additives			Applications								
Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Antiblock	Slip(1)	Processing Aid	Heavy Duty Bags	Stretch	Agricultural Film	General Purpose	Garbage Bags	Lamination	FFS	Freezer Film	Overwrap
LL438	0.8	0.922	Heavy duty sacks, agricultural films,lamination and form, fill and seal packaging where enhanced toughness and sealing characteristics are desired.			✓	✓		✓	✓		✓	✓	✓	
LL501	1.0	0.925	General purpose industrial, agricultural and heavy duty films and as a blend component to improve film handling in converting and packaging operations.				✓			✓					
LL601	1.0	0.925	General purpose industrial, agricultural and heavy duty films and as a blend component to improve film handling in converting and packaging operations.	✓	H					✓	✓				✓
LL425	2.5	0.918	High quality cast film for applications that require toughness, high clarity and processability.					✓							

Notes: (1) VH = Very High Slip, H = High Slip, M = Medium Slip

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

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Alkamax® mLLDPE Film Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Additives: Antiblock	Additives: Slip(1)	Additives: Processing aid	Applications: Heavy Duty Bags	Applications: Stretch	Applications: Produce	Applications: Carry Bags	Applications: Bread	Applications: Agricultural Film	Applications: General Purpose	Applications: Ice Bags	Applications: Lamination	Applications: FFS	Applications: Freezer Film	Applications: Overwrap	Applications: Liners
ML1810PN	1.0	0.918	Heavy duty bags, industrial and agricultural films, and form, fill and seal applications and ice bags where outstanding toughness, sealing and hot tack properties are desirable or for downgauging of existing film structures.			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ML1810PS	1.0	0.918	Heavy duty bags,industrial and form, fill and seal applications and ice bags where outstanding toughness, sealing, hot tack properties and high slip are desirable or for downgauging of existing film structures.	✓	H	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
ML2610PN	1.0	0.926	Heavy duty bags, lamination, industrial and form, fill and seal applications where outstanding stiffness, toughness, optical and sealing properties are desirable or for downgauging of existing film structures.			✓	✓		✓	✓	✓		✓		✓	✓	✓		✓
ML1710SC	1.0	0.917	Stretch cling films (with addition of appropriate cling additive) and other film applications where outstanding toughness, optical and sealing properties are desirable or for downgauging of existing film structures.			✓		✓				✓							

Notes: (1) VH = Very High Slip, H = High Slip, M = Medium Slip

Alkatane™ HDPE Film Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Applications: Carry Bags	Applications: General Purpose	Applications: Liners	Applications: Barrier Film
GM4755F	0.10	0.955(1)	Carry bags and liners where high impact, toughness and stiffness are desirable and as a blend component into LDPE and LLDPE films for heavy duty applications.	✓	✓	✓	
HDF895	0.80	0.960(1)	Moisture barrier and blend component into LDPE and LLDPE films to enhance stiffness. Blend component in core layer for high clarity coextruded films.	✓	✓	✓	✓

Notes: (1) ASTM D1505/D2839

Alkatane™ HDPE Blow Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
HD0840	0.06	0.953(1)	Large part blow mouldings, especially blow moulded self-supported drums and tanks (25 - 220 litres). Exceptional ESCR.
HD1155	0.07	0.953(1)	Large part blow mouldings, including 25 litre to 220 litre tanks and drums. Exceptional ESCR.
GM7655	0.09	0.954(1)	Blow moulded containers including household and industrial chemical (HIC). Suitable for larger part mouldings. Exceptional ESCR.
GF7660	0.30	0.959(1)	Household and industrial chemical (HIC) containers, including detergent and pharmaceutical bottles. Excellent ESCR.
GE4760	0.60	0.964(1)	Blow moulded water, dairy and fruit juice bottles.
HD5148	0.83	0.962(1)	High speed dairy packaging applications and other thin walled bottles such as milk, cream, fruit juice and cordial.

Notes: (1) ASTM D1505/D2839

Qenos imported polymers and additives

Complementing our Australian manufactured Polyethylene grades, Qenos acts as a local distributor for a wide range of imported polymers and additives including rubbers, elastomers, adhesives, plastomers, EVA, BOPP Film, EPS, antioxidants and titanium dioxide. For the full Qenos range, please refer to the Qenos website, Customer Service or your Account Manager.

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

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Alkathene® LDPE Extrusion Coating Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
XLC177	4.5	0.923	Applications including milkboard and fabric extrusion coating where very good drawdown, low moisture vapour transmission rates and excellent hot tack are desirable. Additive free.
WNC199	8.0	0.918	Liquids packaging and other sensitive food packaging laminates where excellent heat seal, low extractables, good melt strength and low odour and taint are desirable. Additive free.
LDN248	7.6	0.922	Liquids packaging and other sensitive food packaging laminates where low extractables and low odour and taint are desirable. Additive free.
LD1217	12	0.918	Liquids packaging and other sensitive food packaging laminates where high line speed, low neck-in, low extractables and low odour and taint are desirable. Additive free.

Alkathene® LDPE Injection Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
XDS34	0.3	0.922	Small part injection moulded caps and closures. Additive free.
WJG117	1.7	0.918	Thick section mouldings, caps and closures, industrial containers where a high level of toughness is desirable. Additive free.
XJF143	2.5	0.921	Injection moulded caps and closures, and thick-walled sections. Additive free.
LDN248	7.6	0.922	Injection moulded caps and closures. Additive free.
WRM124	22	0.920	High flow resin for reseal lids, housewares and toys where excellent gloss, low warpage and flow to toughness ratio are desirable. Additive free.
LD6622	70	0.922	High flow resin for lids and other thin wall injection moulding applications. Additive free.

Alkatuff® LLDPE Injection Moulding Grades

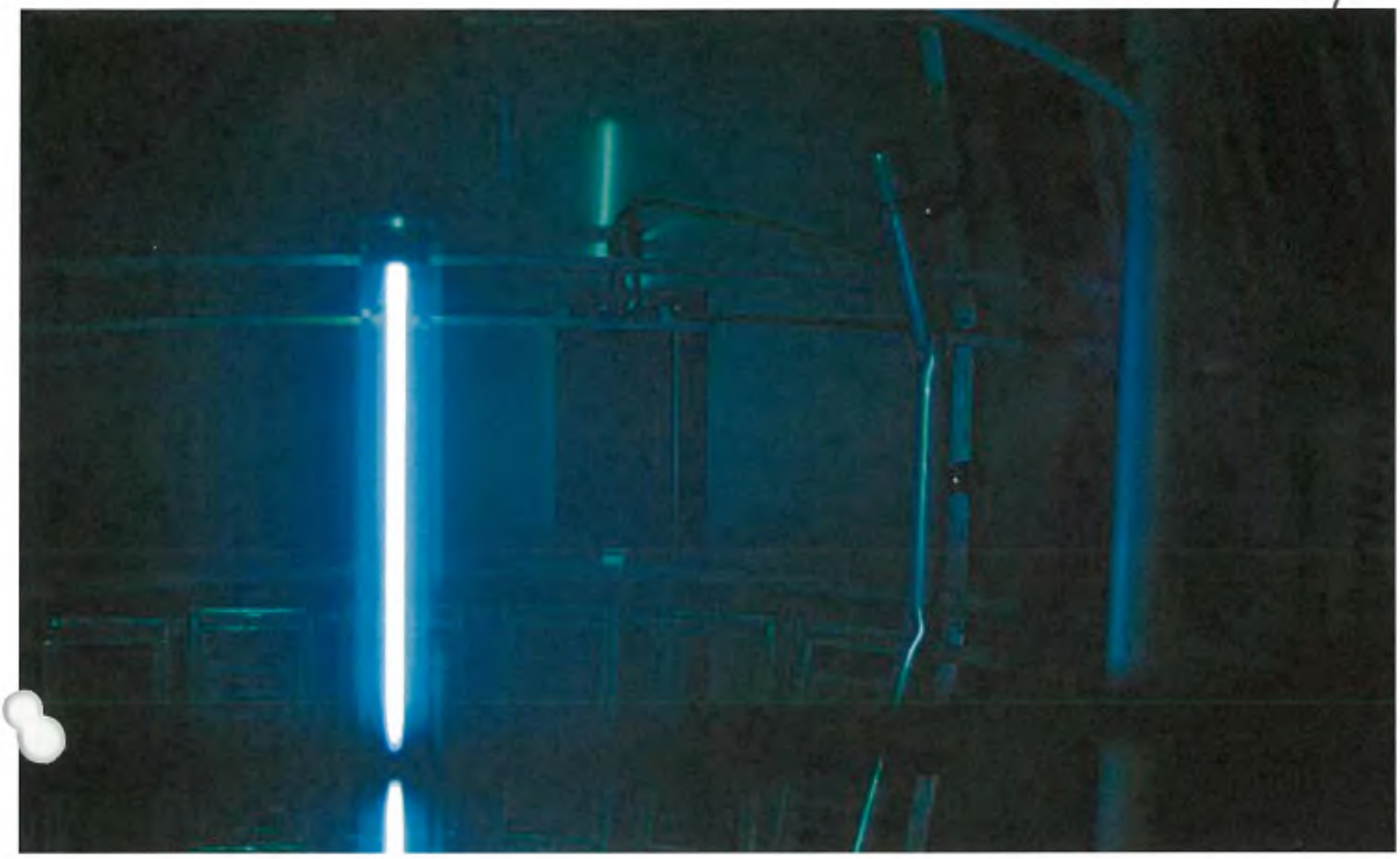
Grade	Melt Index* (g/10 min @ 190°C 2.16kg)	Density# (g/cm³)	Applications
LL820	20	0.925	Injection moulding and compounding applications such as housewares and lids.

Alkatane™ HDPE Injection Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
HD0390	4	0.955	Stackable crates for transport, storage and bottles and industrial mouldings where very good mechanical properties are desirable.
HD0397UV	4	0.955	Mouldings requiring long-term weatherability, including mobile garbage bins, crates, and industrial mouldings where very good mechanical properties are desirable.
HD0490	4.5	0.955	Stackable crates for transport, storage and bottles, and industrial mouldings where very good mechanical properties are desirable.
HD0499UV	4.5	0.955	Mouldings requiring long-term weatherability, including mobile garbage bins, crates, and industrial mouldings where very good mechanical properties are desirable.
HD0790	7	0.956	Industrial pails, crates, closures and sealant cartridges where a good balance between flow and impact resistance is desirable.
HD1090	10	0.956	Industrial pails, crates, closures and sealant cartridges where a good balance between flow and impact resistance is desirable.
HD1099UV	10	0.956	Mouldings requiring long term weatherability including industrial pails, crates, and tote boxes where a good balance between flow and impact resistance is desirable.
HD2090	20	0.956	Housewares, thin-walled containers and closures where excellent mould flow and flexibility is required.
HD3690	36	0.956	Housewares, thin-walled mouldings and closures where excellent mould flow and flexibility is required.

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

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Certified System Quality ISO 9001 SAI GLOBAL

AUSTRALIAN MADE

Front Cover: Pellet geometry and pellet quality can have a significant effect on material flow and the efficiency of feeding polyethylene into an extruder. Qenos measures pellet quality using a pellet shape and size distribution analyser, a device that photographs around 10,000 pellets in 4 minutes, digitally analyses the images and generates a report on pellet quality. Where a drift in the pellet quality is detected, adjustments are made proactively to maintain high product integrity.

Rear Cover: The standard for UV performance for PE Water Tanks specified in AS/NZS 4766 PE Tanks for the Storage of Chemicals and Water is 8,000 hours of uninterrupted exposure to an intense and specifically developed UV light source. Qenos exhaustively tests the long term UV performance of its Rotational Moulding Resins under conditions of controlled irradiance, chamber temperature and humidity and repeated rain cycles. Alkatuff® 711UV achieves a class leading UV performance exceeding 20,000 hours against the required standards, ensuring that Alkatuff® 711UV is "Tough in the Sun".

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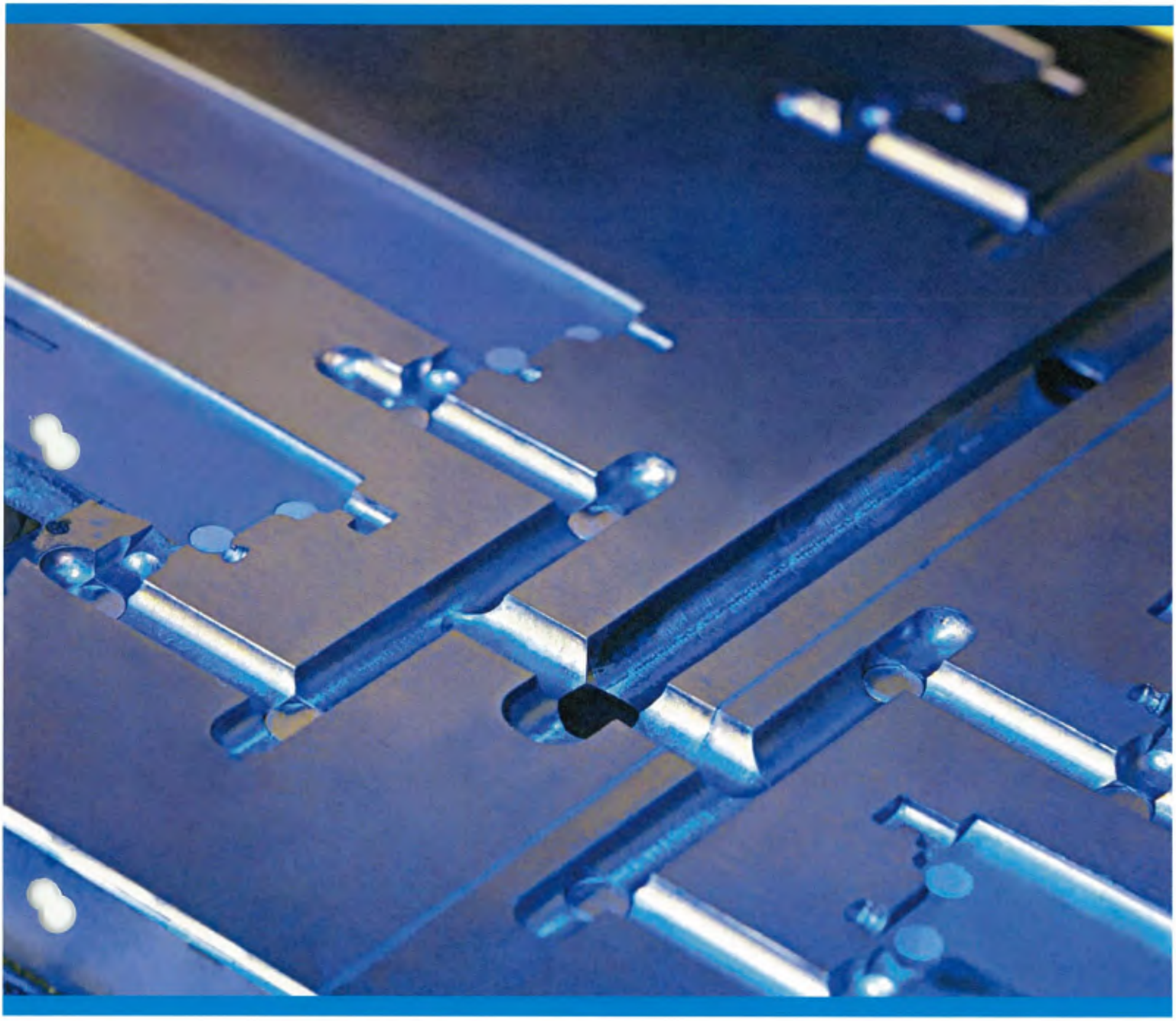
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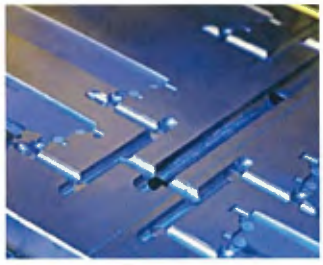
5 INJECTION MOULDING

TECHNICAL GUIDE

Alkathene® Alkatuff® Alkatane™

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Front Cover:
Qenos produces injection moulded products for applications including caps, pails, crates, sealant cartridges, mobile garbage bins, produce bins, housewares and lids. A full range of *Alkatane* HDPE, *Alkathene* LDPE and *Alkatuff* LLDPE grades are available across the Melt Index and density spectrum. In addition, Qenos distributes a number of speciality polymers suitable for injection moulding.

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INJECTION MOULDING

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5 INJECTION MOULDING

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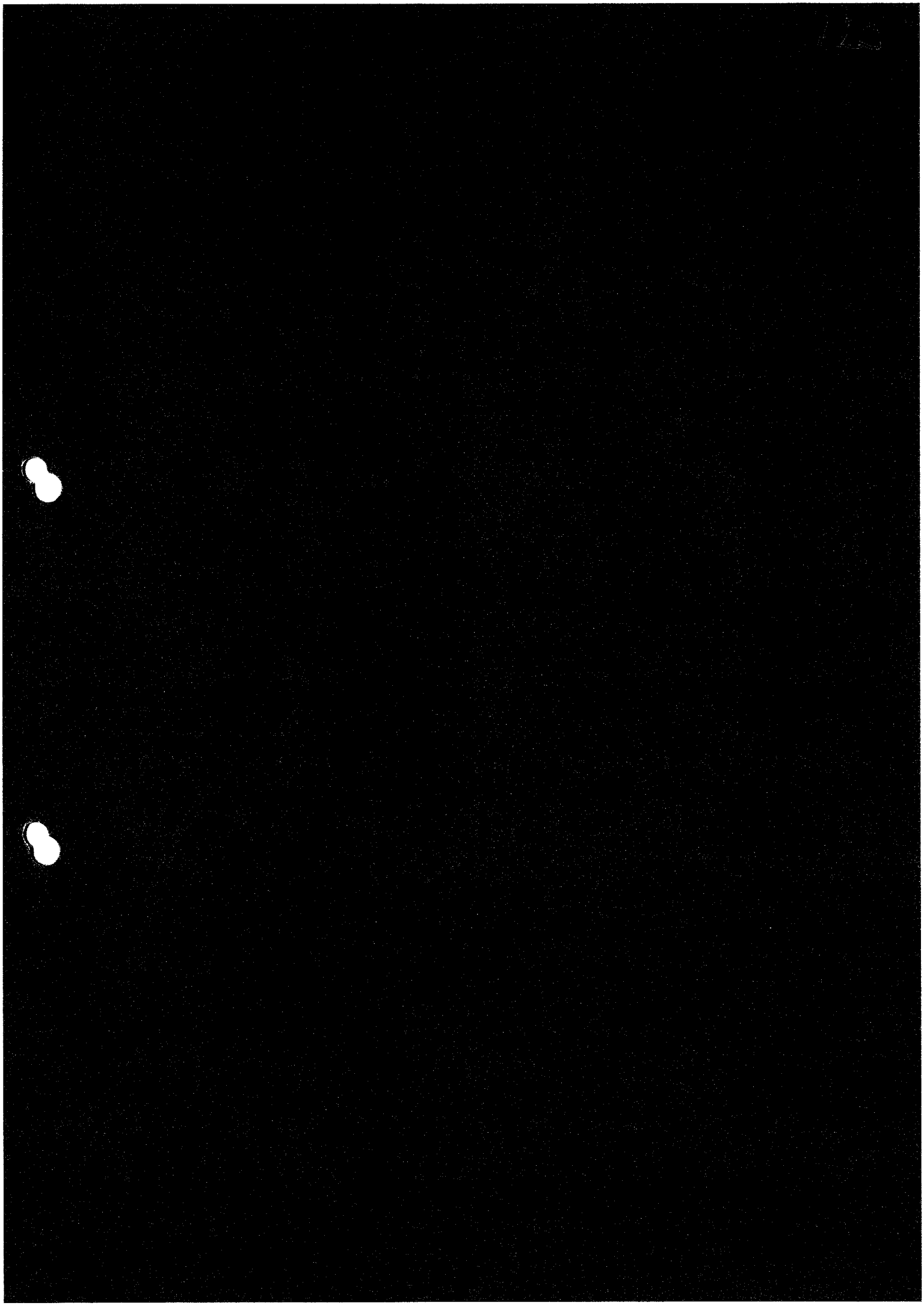
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INJECTION MOULDING 5

INTRODUCTION

The purpose of this document is to provide an introduction to the processing of polyethylene by injection moulding. The effects of Melt Flow Index (MFI) and density on moulding characteristics and on the properties of the finished moulding are discussed, in the light of which, recommendations are made as to the desirable values of these two factors for stressed and unstressed applications.

Mould design is considered with special reference to questions of shrinkage and distortion and examples are given to illustrate these points. The moulding process itself is discussed in some detail, guidance being given on all the operations which have to be carried out. Moulding faults, causes and remedies are also summarised.

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INTRODUCTION

Injection moulding is one of the most widely used processes for converting thermoplastic raw materials into finished products. Fundamentally, a solid polymer is plasticated into a molten mass via thermal and frictional heating and once a suitable volume of melt has been produced, the polymer is injected into the mould to form the finished part (see Figures 1 and 2).

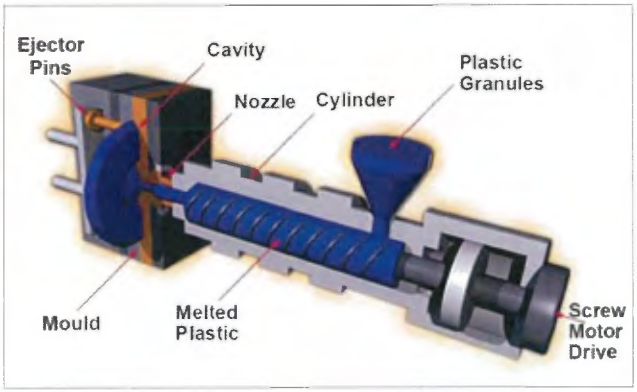


Figure 1: Schematic Representation of an Injection Moulding Machine



Figure 2: Finished Moulded Part including Sprue Injection Point

Injection Moulding is fundamentally simple, easy to operate and is capable of producing a very wide variety of industrial and domestic articles. Of all thermoplastics, polyethylene is one of the easiest to injection mould. The resin flows easily into difficult cavities, its viscosity changes smoothly as the melt temperature increases and it can be processed over a wide temperature range without decomposition.

However, this very ease of processing often leads to the use of moulding conditions which are not the most suitable for producing the finished part. Also, because almost all of the many different types of polyethylene can be moulded on standard equipment, the polyethylene type that is most suitable for a particular application is not always chosen.

EFFECT OF TYPE OF POLYETHYLENE ON PROCESSING AND PROPERTIES OF MOULDINGS

To obtain polyethylene mouldings which will withstand long and arduous service two important questions must be answered:

a. Which type of polyethylene should be used?

b. What are the correct moulding conditions?

To do this it is necessary to know how the different types of polyethylene used for injection moulding differ from each other: first, in the way in which they are processed and second, in the physical properties of the moulded article.

Classification of Polyethylenes

The most important variables which characterise a polyethylene are its Melt Flow Index (MFI) and density.

Melt Flow Index (MFI)

MFI is a measure of melt viscosity at low shear rates and is defined as the weight in grams of polyethylene extruded in 10 minutes from a special plastometer under a given load at 190°C. Thus, a low MFI corresponds to a high melt viscosity. Figure 3 shows how the MFI is related to the number average molecular weight of the polymer.

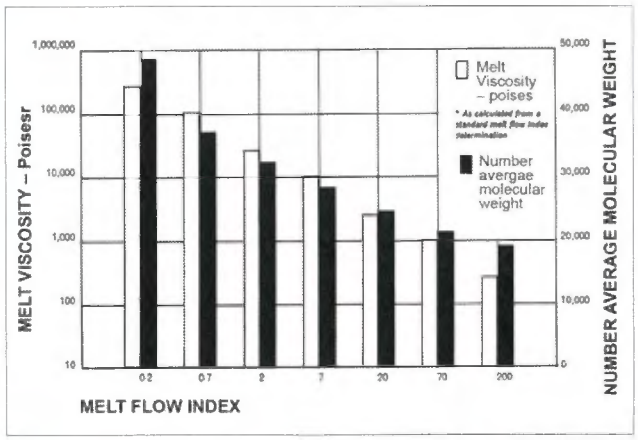


Figure 3: Relation between MFI (g/10 min) and Number Average Molecular Weight

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DENSITY

Density is related to the crystallinity of the polyethylene and is measured in g/cm^3.

Because polyethylene molecules are long and contain branches, complete crystallisation cannot take place when polyethylene is cooled from the molten state, and amorphous regions occur between the crystallites. The smaller the number of branches, the more crystalline the polyethylene will be and the higher its density.

Although MFI and density are the most important variables which characterise a polyethylene, it must be emphasised that all polyethylenes with the same MFI and density are not necessarily identical. Each polyethylene producer has specific manufacturing processes and by varying reactor conditions it is possible, while maintaining a constant MFI and density, to alter various features of the polymer such as the molecular weight distribution and the degree of long and short chain branching that cause changes in the processing behaviour and the physical properties of the polymer.

Effect of MFI and Density on Moulding Characteristics

The injection moulding process is shown diagrammatically in Figures 4 and 5. For any given machine and mould, the MFI and density of the polyethylene will considerably affect the injection dwell and cooling times in the cycle. The injection time is not significantly affected and the mould opening, extraction, and mould closing times are not affected by the MFI or density of the polymer.

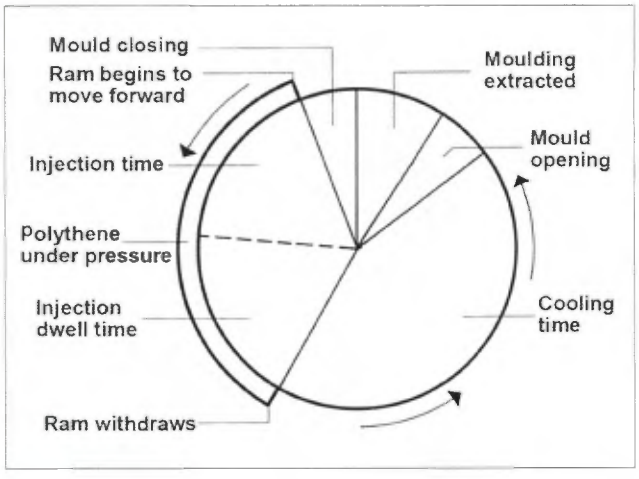


Figure 4: Injection Moulding Cycle

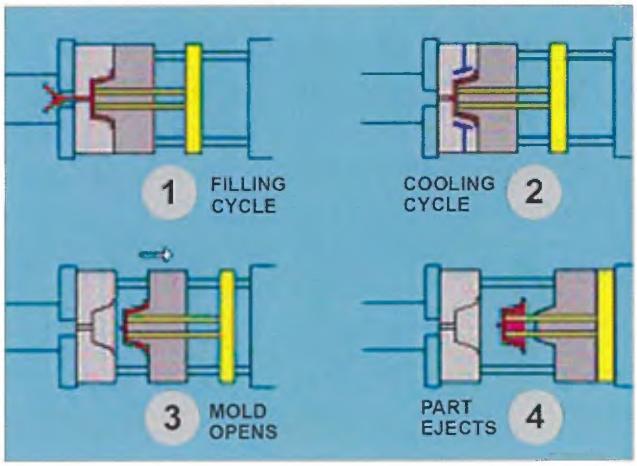


Figure 5: Pictorial Representation of the Injection Moulding Cycle

As far as the polyethylene is concerned the output of any injection moulding machine depends predominantly on two factors:

- The time taken for the polyethylene to reach moulding temperature
- The time taken for the polymer to be cooled sufficiently in order for the moulding to be removed.

A convenient method of assessing the effect of different types of polyethylene on output rate is to plot the number of mouldings which can be made in one hour against the cylinder temperature used. Although the design of the mould and the type of machine affect output greatly, for any given mould on a particular machine an output curve can be obtained by finding for each cylinder temperature the fastest possible cycle which gives mouldings acceptable in all respects except for that of surface gloss, i.e. the minimum injection dwell time, pressure, and cooling time have been used. A typical curve for a plunger machine is shown in Figure 6. It will be noticed that, at first, as the temperature increases the output also increases. The reason for this is that at low temperatures a long cycle is necessary to melt the granules thoroughly, but as the temperature increases, the melting time becomes shorter and therefore the cycle is also shortened. A point is soon reached, however, when the time taken to melt the granules is no longer the limiting factor. The greater parameter of importance is then the time taken for the mouldings to cool to a temperature at which they can be extracted easily from the mould. Beyond this point, as the melt temperature increases the cycle time has to be extended and the output consequently falls.

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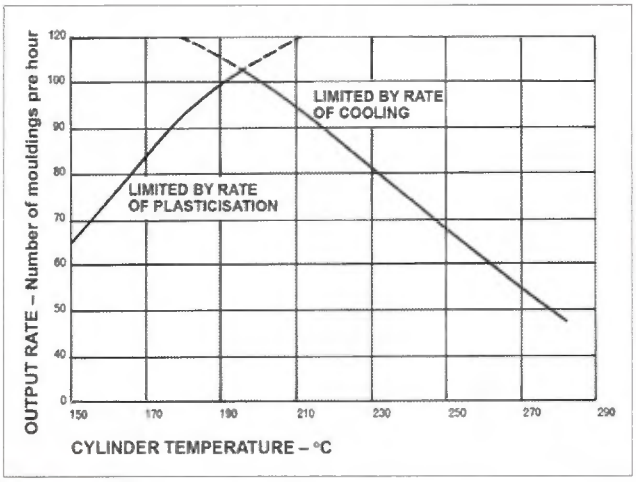


Figure 6: Variation in Output Rate of Mouldings with Cylinder Temperature

Figure 7 shows the effect of density on output rate for polyethylenes of the same MFI. It indicates that the higher the density, the higher the output rate on the cooling side of the curve at any given cylinder temperature. The reason for this is that mouldings of higher density can be extracted from the mould at higher temperatures because they are more rigid at these temperatures than are mouldings of lower density. The higher density materials, however, require higher cylinder temperatures to produce adequate melting of the granules, particularly if the amount of material being handled is near the plasticising capacity of the machine, and the use of such temperatures may slow down the output rate.

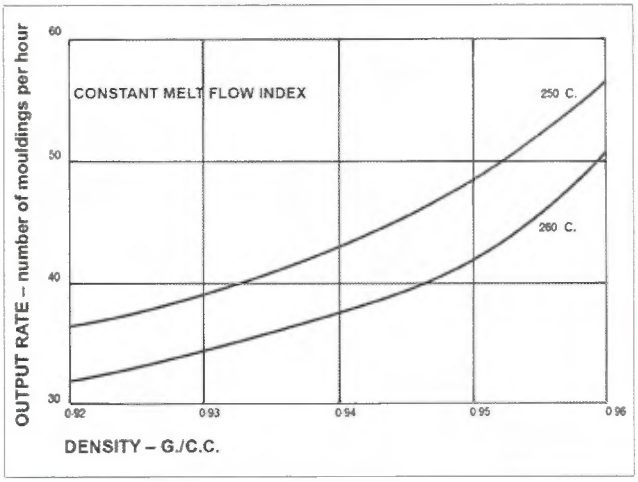


Figure 7: Effect of Density on Output Rate for Polymers of the Same MFI

To use injection moulding machines most efficiently, the cylinder temperature should be chosen so that the output is at its peak. There are, however, two factors which frequently prevent this being done, namely, the necessity to fill the mould, and the desire to obtain mouldings with a good surface finish. These factors are discussed below.

MOULD FILLING

In practice, there are some moulds for which it is not possible to draw an output curve over the whole range of cylinder temperatures because the mould cannot be filled at the lower temperatures. Therefore, the moulding temperature which has to be used is the lowest temperature at which the mould can be filled, and this may restrict the output. In order to attain as close to the maximum theoretical output, good mould filling properties are obviously desirable in a polyethylene.

The spiral flow test was devised to assess the mould filling properties of materials. It involves the measurement of the length of spiral obtained when moulding under standard conditions using the special mould shown in Figure 8. In order to compare different types of polyethylene the cylinder temperature, mould temperature, cycle time, injection speed and pressure are all held constant, and under these conditions the length of spiral obtained gives a good comparative evaluation of the mould filling properties of the polyethylenes being used.

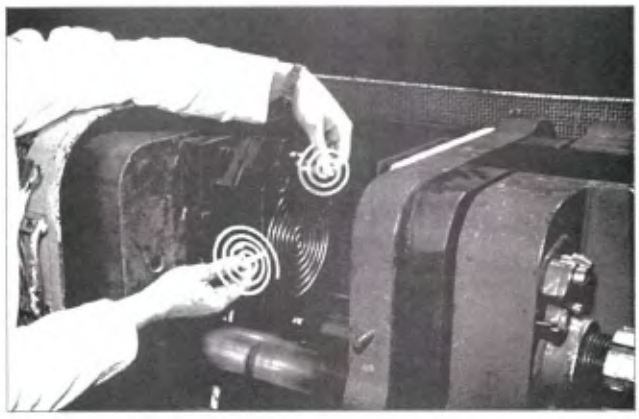


Figure 8: Spiral Flow Mould

Figure 9 shows that the main factor which influences ease of mould filling is MFI. Although density undoubtedly has an effect on the spiral flow length, for polymers with constant MFI this effect is relatively small.

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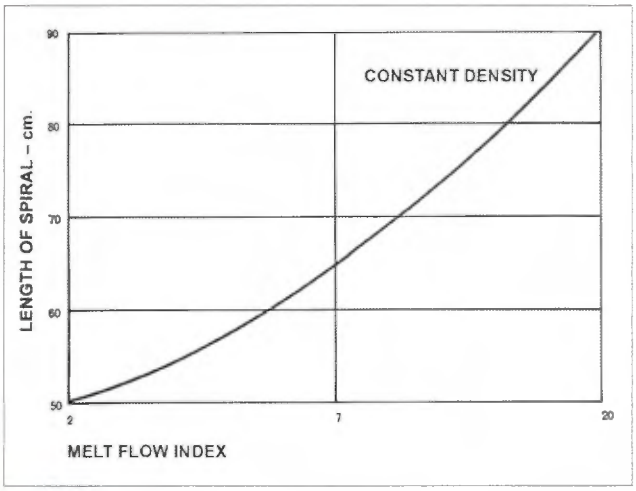


Figure 9: Effect of MFI on the Mould Filling Properties of Polyethylenes of Constant Density

A feature of the spiral flow test is that it can be applied to all injection moulding materials. Figure 10 shows a chart on which the spiral flow length has been plotted against a series of cylinder temperatures for a range of polymers. For most materials the temperatures used range from the lowest at which a readable flow length can be obtained to the highest that can be used without degrading the material. However for polyethylenes of high MFI, with the particular equipment used, the upper temperature was set by the first observance of "flashing" (thin films of excess polymer) on the moulded part.

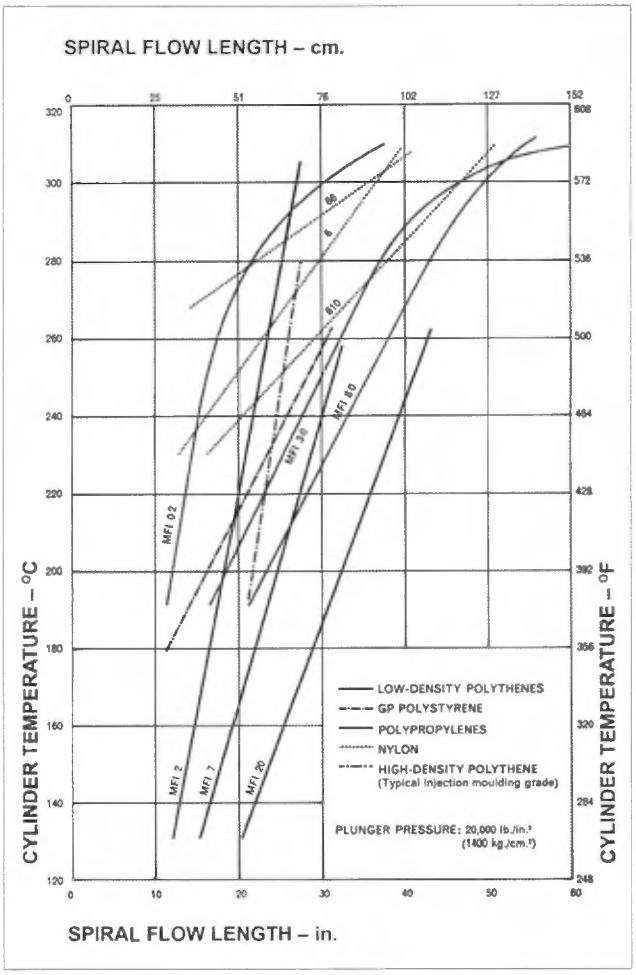


Figure 10: Spiral Flow Curves for some Typical Thermoplastics

Surface Finish

The second factor which may prevent moulding being carried out at the peak of the output curve is the requirement to obtain a good surface finish on the moulded article. It can be seen from Figure 11 that the gloss of a polyethylene moulding improves with increasing cylinder temperature and that mouldings produced at the lower temperatures have 'chevron' marks or rings on the surface (see Figure 12). When mouldings with an even, glossy surface are required it may be necessary to mould at a cylinder temperature which is higher than that which corresponds to the fastest output rate.

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5 INJECTION MOULDING

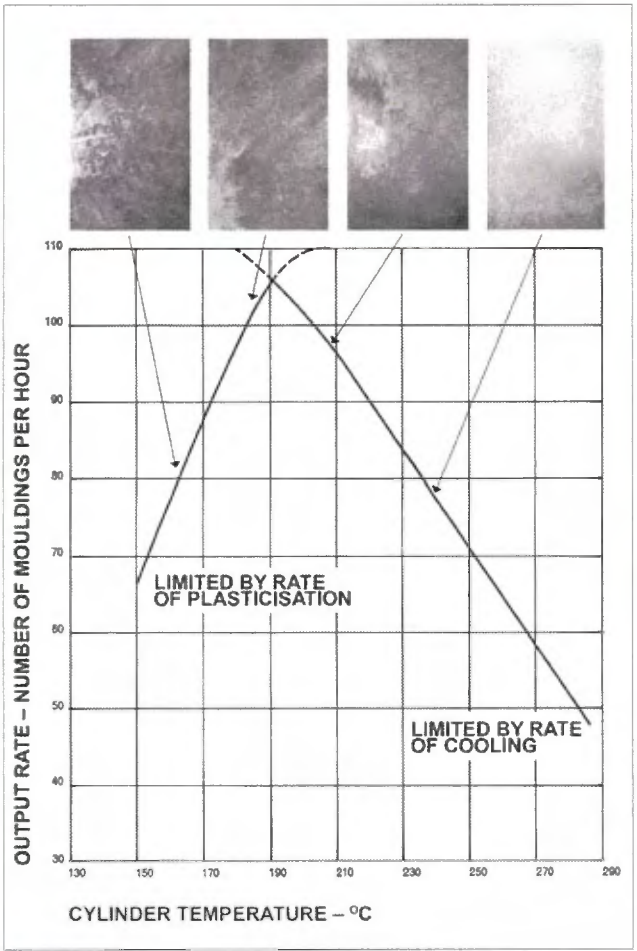


Figure 11: Variations of Surface Gloss of Mouldings with Cylinder Temperature

Gloss is assessed both visually and by measuring the light reflected from the surface of mouldings made under standard conditions. By the latter method, gloss/temperature curves can be plotted as shown in Figure 13. This not only shows the effect of cylinder temperature on gloss, but also the very marked effect of MFI. With a higher MFI, high-gloss mouldings can be produced at a lower cylinder temperature which allows for a faster output (see Figure 13).



Figure 12: Photo Illustrating 'Chevron' Rings on an Injection Moulded Surface

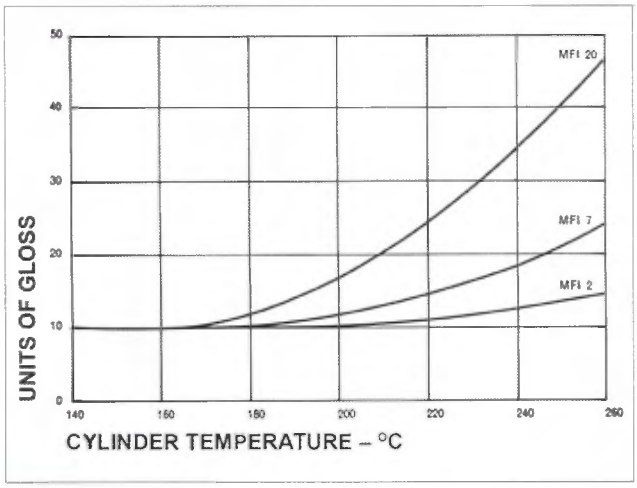


Figure 13: Effect of MFI and Temperature on Gloss

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Summary

It can be concluded that a high MFI is the characteristic mainly responsible for ease of moulding and high output rates. The higher the MFI, the lower the cylinder temperature which can be used to obtain adequate mould filling and acceptable surface finish, and consequently, in most cases, the higher the output will be. For resins with a constant MFI, the degree to which an increase in density leads to higher or lower outputs will depend mainly on the size of the moulding in relation to the size of the machine. For adequate melting of the granules, higher density polyethylenes require higher cylinder temperatures than do the lower density polyethylenes, and melting is more likely to be a limiting factor.

Thus, as far as processing is concerned, the type of polyethylene chosen should have as high an MFI as possible. However, the choice of both MFI and density must also take into account the physical properties required in the finished moulding, and this subject is discussed in the next section.

EFFECT OF MFI AND DENSITY ON THE PROPERTIES OF POLYETHYLENE MOULDINGS

The physical properties of polyethylene which are of particular importance in injection moulded articles are:

- Stiffness
- Impact properties
- Resistance to environmental stress cracking
- Resistance to mechanical stress cracking

Stiffness

The main factor determining the stiffness of a moulding is the density of the polyethylene. Figure 14 shows how the stiffness (as measured by the 100 sec tensile modulus) increases rapidly with increasing density. In the lower density range a change in density of as little as 0.007 g/cm^3 will double the stiffness. Figure 14 also shows the effect of temperature on stiffness.

MFI has virtually no effect on stiffness.

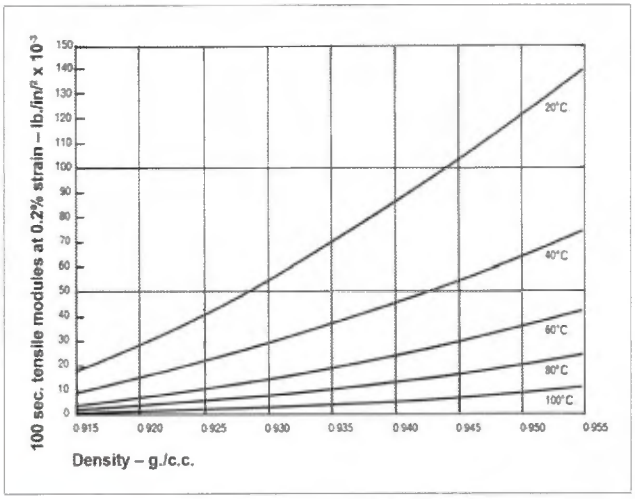


Figure 14: Variation of Stiffness and Density with Temperature

Impact Properties

One of the outstanding properties of low density polyethylene is its toughness; when subjected to impact it will stretch and cold-draw before it breaks, rather than fail in a glass-like manner. On the other hand, medium and high density polyethylenes can fail in a way that is unknown in low density polyethylenes. This type of failure is known as brittle failure. It is quite different from the tough failure of low density materials and is particularly noticeable in mouldings which have sharp notches or scratches on the surface. The usual impact tests for plastic materials are difficult to apply to both brittle and tough types of polyethylene and therefore a special test had to be devised. For this an impact machine is used (see Figure 15) in which small specimens (1 x 1 x 0.16 cm) are notched to a depth of 0.020 cm and subjected to a blow from a pendulum. The energy lost by the pendulum in striking the specimens is termed the impact energy, although much of this energy is expended in bending the specimen as the pendulum swings past it. Polyethylene specimens are rarely broken by the first blow, and therefore after a short rest period they are given a second blow. The energy absorbed by this second blow, expressed as a percentage of the energy absorbed by the first blow, is termed the fracture resistance. This quantity is found to be a useful measure of the amount of damage caused by the first blow.

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5 INJECTION MOULDING

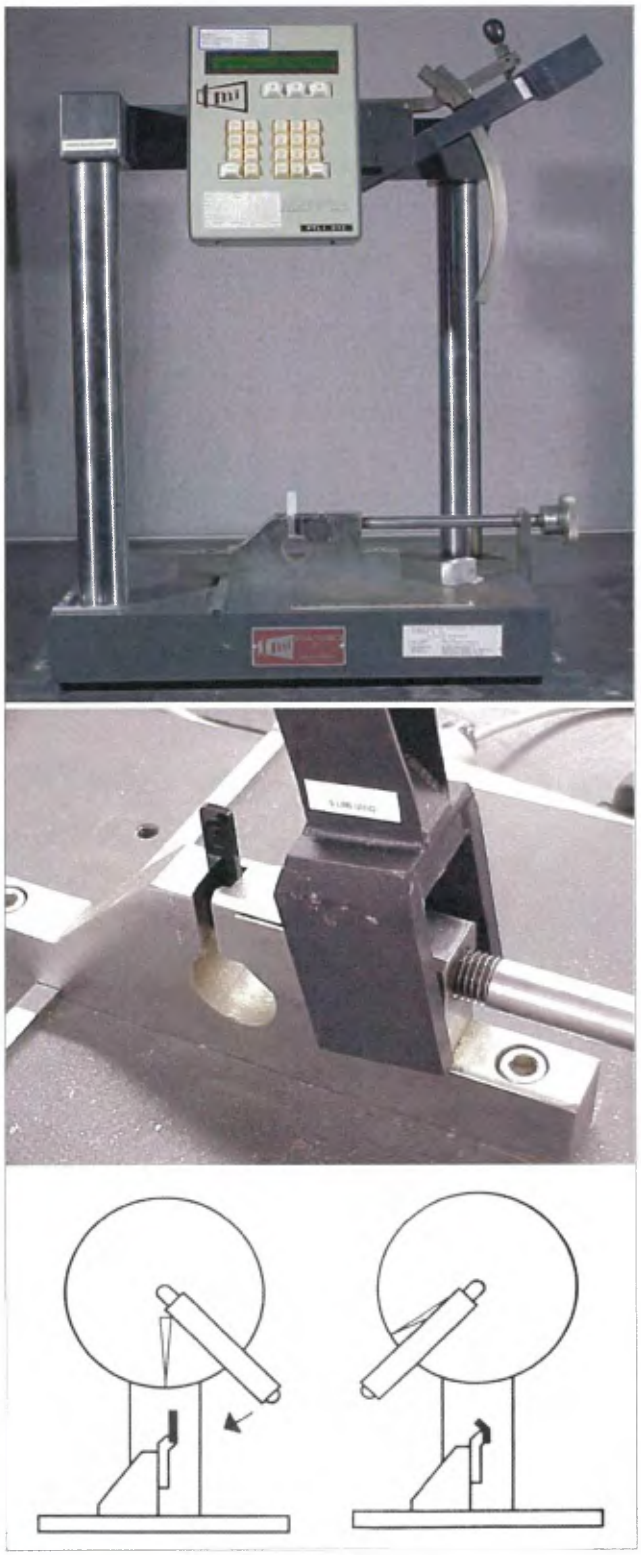


Figure 15: Impact Machine Showing Sample Holder and Process of Use

Impact energy and fracture resistance depend on both MFI and density, as may be seen from Figure 16. For some polyethylenes the impact energy may increase at first with increasing density and then decrease. This initial increase in impact energy is due to the contribution from the energy used in bending a specimen of increased stiffness. Ultimately, however, the increase in density trends towards brittleness, which becomes the dominant factor and results in the measured impact energy falling to very low levels. It can be seen quite clearly that in order to avoid brittleness the higher density polyethylenes must have a low MFI. Consequently, if toughness is required in the higher density polyethylenes, poorer processability, poorer mould filling and, in general, higher processing temperatures will be required. It can also be seen that with polyethylenes of lower density, a much wider choice of MFI is possible without sacrificing toughness.

The dependence of brittle failure on density is also complicated by the fact that the density of any polyethylene is affected by its rate of cooling from the molten state. This effect is illustrated opposite in Table 1.

Values for densities quoted in the literature usually refer to specimens prepared in a standard way involving slow cooling. In injection moulding, however, the polyethylene is cooled rapidly and the molecular chains have no time in which to pack into their equilibrium positions and consequently the density is reduced to below the equilibrium value. Subsequently, over time, the density increases towards its equilibrium value, a process which is very slow but which is accelerated at elevated temperatures. Provided that a polyethylene is chosen with a density and MFI such that the polyethylene, when cooled at the slowest rate found in injection moulding, lies in the 'tough' region in Figure 16, no detrimental change to the mouldings impact strength will arise. But if a polyethylene in the 'brittle' region is chosen (for example, a material with a MFI of 20 g/10 min and a density greater than 0.927 g/cm^3) mouldings produced under conditions of rapid cooling will appear to be tough initially, because of the decrease in density, but may become brittle as the density increases over time.

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Table 1: Effect of Cooling Rate on the Density of Polyethylene (MFI 20)

Cooling Rate	Density g/cm³		
Annealed at 140°C and cooled at 5°C per hour	0.918	0.923	0.927
Annealed at 140°C and cooled at 30°C per hour	0.916	0.921	0.925
Fast cooled in injection moulding	0.913	0.919	0.922

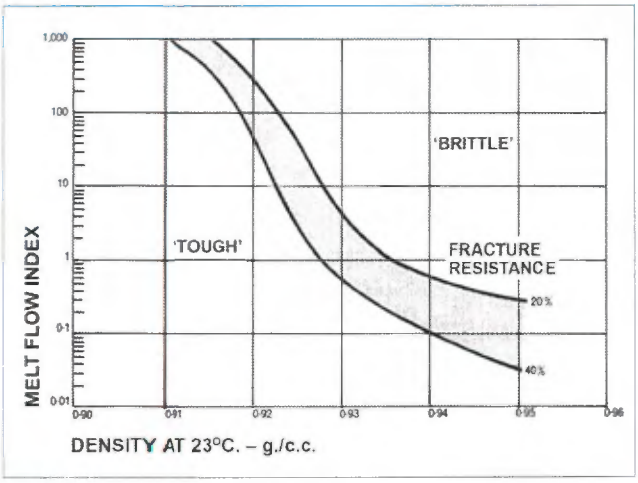


Figure 16: Variations in the "Tough Brittle" Transition (as defined by fracture resistance contours at 40% and 20%) with MFI and Density

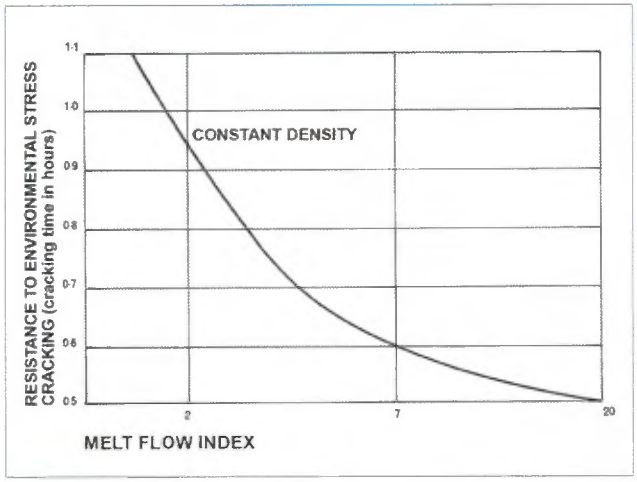


Figure 17: Resistance of Polyethylenes of Different MFI to Environment Stress Cracking

Environmental Stress Cracking

Environmental stress cracking is the name given to a phenomenon by which polyethylene under high stresses may crack in contact with certain active environments such as detergents, fats and silicone fluids.

The resistance of polyethylene to environmental stress cracking decreases rapidly as the MFI is increased. Figure 17 indicates how test specimens of polyethylenes of different MFI and of constant density behave when subjected to a severe stress in the presence of an active environment. Comparison of polyethylenes of constant MFI but of different densities is more complicated because in such tests the specimens are tested under constant strain and therefore the higher density polyethylenes will be under greater stress because they are stiffer. Nevertheless, the comparison is a valid one because in many applications, for example, screwing down a bottle closure or forcing a washing-up bowl into a sink, it is the deformation which is constant rather than the stress.

In practice it is important that high MFI polymers, even of low density, should not be used for applications in which they will be severely stressed when in contact with active environments. For such applications a polyethylene of low MFI is essential and the higher the density of the polyethylene the lower the MFI must be.

A typical application for which a polyethylene of low MFI is preferred in order to reduce the hazards of environmental stress cracking is that of closures used in contact with liquid detergents, soap solutions and certain cosmetics.

It is important however not to exaggerate the seriousness of environmental stress cracking. It has been found that the majority of mouldings made from polyethylene are not subjected to severe enough stressing in service to cause failure, even though they may be in contact with active environments. For example, most polyethylene housewares are in daily contact with both detergents and fats, and yet the externally applied stresses to which they are subjected to are not sufficient to cause failure through environmental stress cracking.

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Careful consideration needs to be made of the choice of polymer that will meet the demands of the finished product and the environment(s) that it will be exposed to (e.g. oils, fats, alkalis, acids and temperature, etc.). To make the best resin selection, customers are advised to discuss their specific end product requirements with their Qenos Technical Service Representative.

Mechanical Stress Cracking

Under certain conditions the moulding process itself can create high levels of internal stress in polyethylene. This is due to the semi-crystalline nature of the polymer which enters the mould in a molten state and undergoes crystallisation as the resin solidifies. The different polyethylenes undergo different degrees of crystallisation which is dependent on their molecular structure.

In general, the polyethylenes can be ranked in terms of their crystalisability/shrinkage in the following order:

$$\text{HDPE} \geq \text{LLDPE} \geq \text{LDPE}$$

The internal stress that is also commonly referred to as 'frozen in strain' or 'residual strain' may cause similar effects to those seen where polyethylene is exposed to external stresses in service.

The occurrence of 'frozen in strain' is due to both the crystalline nature of the resins used and also as a result of the moulding conditions and the design of the finished part (see Conditions for Moulding Polyethylene section on pg. 18).

Once a polyethylene has been selected (HDPE, LLDPE, LDPE) for fabrication of the finished part, internal stresses can be negated/minimised through careful mould design and by controlling the processing conditions on the injection moulding machine.

Many mouldings, however, are also subjected in service to externally applied mechanical stresses which can cause cracking. Examples of such mouldings are those containing metal inserts (e.g. knobs) and those used for interference applications (e.g. snap-on closures, ferrules or feet for tubular furniture). For such finished parts careful selection of the polymer is important. Within the polyethylenes a balance is required between the MFI (e.g. for ease of processing) and the density (e.g. which affects the level of shrinkage) in order to minimise the level of internal stress.

Generally, higher density polyethylenes would require a lower MFI and vice versa. For example, a polyethylene of MFI 20 g/10 min should generally not exceed a density of 0.918 g/cm^3. Although such "rules of thumb" are only general recommendations, other considerations of mould design and the generation of weld lines in the finished part are factors that need to be reviewed when assessing the strength of the moulding.

For articles not expected to be stressed in service, cracking caused by 'frozen-in strain' is the hazard to be avoided. A polyethylene of higher MFI is preferable because it is easier to mould such a polyethylene to give a low level of 'frozen-in strain'.

Summary

In general, polyethylenes of high MFI and low density are most commonly used for injection moulding because they give the highest outputs, have the best mould filling properties, and give the glossiest mouldings. For applications in which mouldings are likely to be stressed in service, polyethylenes of low MFI must be used. If increased stiffness is required, polyethylenes of higher density are necessary, but these must have a lower MFI to prevent them from becoming brittle and to improve resistance to environmental and mechanical stress cracking. For non-stressed applications 'frozen-in strain' is the hazard to be avoided and a polyethylene of higher MFI is preferred. Provided that these few simple principles are followed, articles giving a long and satisfactory service life can be moulded from polyethylene without difficulty.

SOME ASPECTS OF DESIGNING MOULDS FOR POLYETHYLENE

A detailed examination of mould design is outside the scope of this booklet. There are however, three problems affecting mould design which, although not peculiar to low density polyethylene, occur frequently with this material and which can conveniently be discussed here. These are:

- Shrinkage
- Distortion
- Weld lines

Shrinkage of Polyethylene Mouldings

The influence of moulding conditions and the shape of mouldings is so great that it is almost impossible to predict the exact shrinkage of polyethylene mouldings. It is recommended therefore that trials under controlled moulding conditions should be carried out before the mould is hardened and polished. The mould may then be adjusted accordingly. To allow for any after-shrinkage the dimensions of mouldings should not be checked until at least 24 hours after removing the mouldings from the mould.

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Measurements must be checked in all important dimensions because mould shrinkage varies with the direction of flow, and checking only one dimension and applying proportional corrections to the others may lead to major inaccuracies.

The following major variables affect mould shrinkage.

- **Melt temperature:** the higher the melt temperature, the greater the shrinkage will be
- **Mould temperature:** the higher the mould temperature, the greater the shrinkage will be
- **Injection dwell time and injection pressure:** shrinkage will be smaller for longer injection dwell times and higher pressures
- **Thickness of section:** the thicker the moulded section, the slower the cooling and the greater the contraction of the moulding will be
- **Orientation:** shrinkage will be greater in the direction of flow than at right angles to it
- **Density:** shrinkage is greater with polyethylenes of higher density e.g. a polyethylene of density 0.930 g/cm^3 will shrink more than a polyethylene of density 0.918 g/cm^3
- **Gating:** shrinkage is usually greater when pin gates are used than when sprue gates are used

Because the above variables have such a marked effect on shrinkage, it is clear that in order to maintain accurate dimensions, close control of moulding conditions is essential. Cooling channels must provide adequate and even control of mould temperature over the whole mould. Cycle time control is of equal importance, especially for precision work. Injection pressures should be controlled and the values checked regularly on a gauge.

A point which must always be kept in mind when specifications call for close moulding tolerances is that the coefficient of thermal expansion of polyethylene is high and that a change of 5°C in room temperature will alter the length of a moulding by as much as 0.001 cm/cm.

Some examples of shrinkage are illustrated in Figure 18. Because it is usually on small mouldings that close dimensional control is required, Figure 18 shows where sink marks and warping are likely to occur in such finished items.

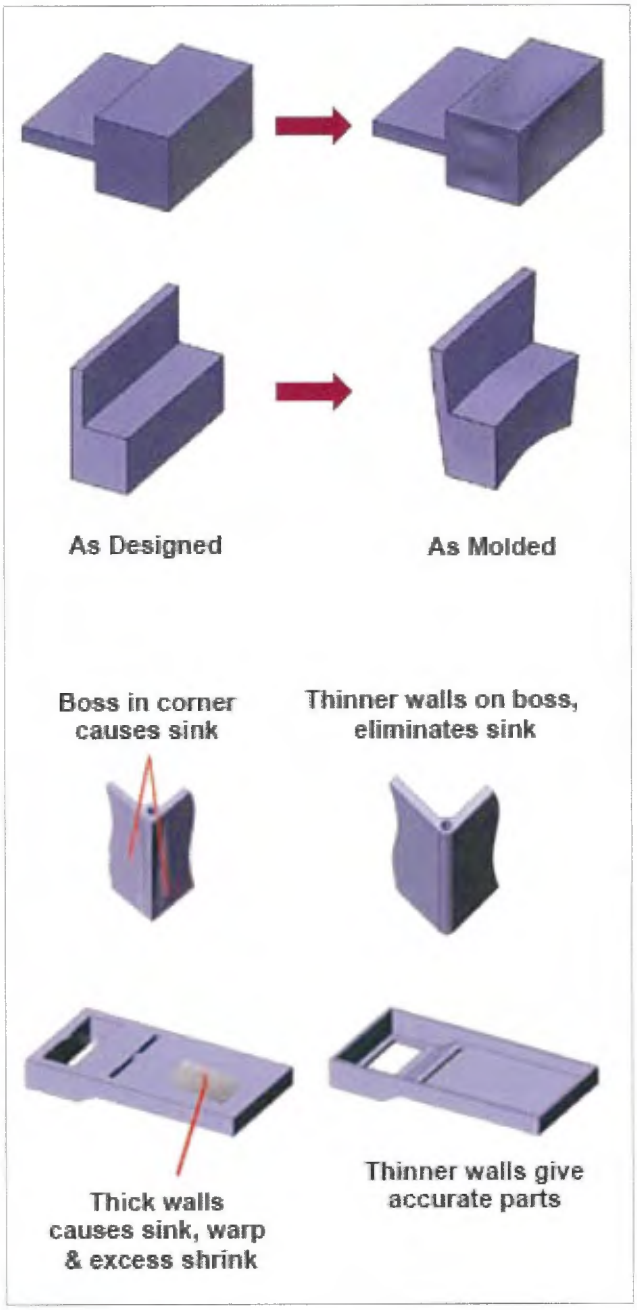


Figure 18: The Effects of Processing Conditions on Shrinkage and Warping

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Distortion of Polyethylene Mouldings

Distortion or warping of polyethylene mouldings can be a problem on flat articles which do not have a solid rim or walls to keep the base firmly held in position. The explanation of this warping is mainly due to polymer orientation and differential crystallisation across the moulding (see Figure 19).

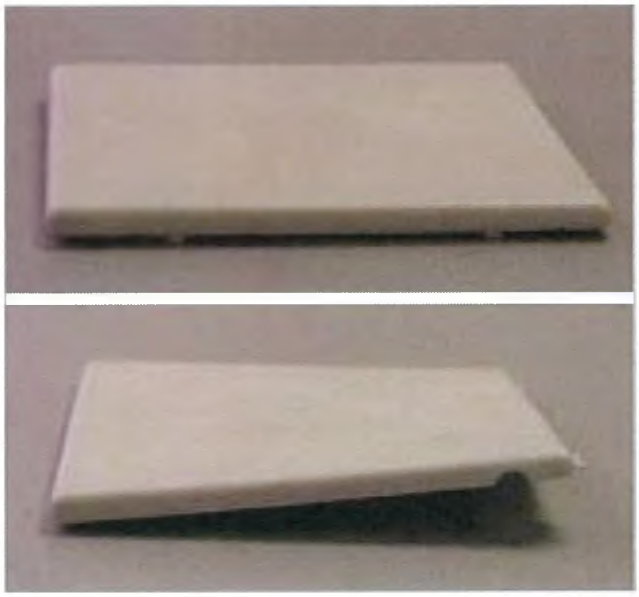


Figure 19: Processing Conditions Causing Polymer Orientation which Leads to Warping

When the mould is first filled, a hot moulding will be made. As the mould fills, the long thread-like polyethylene molecules would tend to be oriented in the direction of flow i.e. radially outwards, but as the moulding cools a radial shrinkage will occur which is greater than the shrinkage at right angles to the radius. Thus when the moulding is cold it will inevitably warp due to the difference in the stresses generated in the part. All methods of preventing the distortion of flat articles without rims or walls depend, in essence, on reducing this difference.

Mould Design

To reduce the warping in articles, multiple pin gates must be used. This system relies on reducing the length of each radial flow path and inter-mingling the melt streams, and is often adequate for low and medium density polyethylenes (see Figure 20).



Figure 20: Photos Illustrating Multiple Pin Gating and Fan Gating

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For rectangular shapes the ideal gating arrangement is a fan gate (see Figure 20) all along one edge so that flow takes place mainly along the major axis. The moulding will still shrink to a greater extent in the direction of flow, causing the major axis to be proportionately shorter than the minor axis when the moulding is cold, but it will not distort. To position a gate at the end of a rectangular article is relatively easy on small mouldings to be made on multi-impression tools, but it is not so easy on large single-impression moulds. Some machine manufacturers can arrange for off-set injection points by altering the nozzle position from the usual central point and this is a very useful feature if large flat articles are to be made from high or low density polyethylene.

Choice of Polymer

The likelihood of warping increases rapidly with increasing density of the polyethylene used: high density polyethylene mouldings warp more than those of medium density, which in turn warp more than those of low density polyethylene. If flexibility in the moulding can be tolerated, a polyethylene of low density (e.g. 0.916 g/cm^3) will give the least distortion. If the mouldings are not to be stressed and physical strength is not important, e.g. sink trays and many box lids, the best results are obtained from a low density polymer of high MFI (22-70 g/10 min, according to the lack of strength which can be tolerated).

Moulding Conditions

Obviously the ideal moulding conditions would be those which give no orientation in the moulding and thus no warping. In practice such conditions can never be achieved. It has been found that long injection dwell times and high pressures, because they reduce the overall level of shrinkage, can often reduce warpage, but these conditions give rise to packing stresses and may cause the mouldings to split across the sprue. The best compromise in moulding conditions has been found to consist of a very high melt temperature (i.e. 50°C higher than that normally used for a given polyethylene) and a very cold mould (i.e. as cold as can be achieved).

Weld Lines

Weld lines can occur in any plastic moulding when the melt stream is divided as it flows round some obstruction, or can arise through non-uniform filling of the mould caused by, for example, eccentricity of cores (see Figure 21).



Figure 21: Mouldings Illustrating the Formation of Weld Lines When Two Melt Fronts Meet

Weld lines are particularly troublesome in polyethylene mouldings which are stressed in service, because failures are likely to occur some considerable time after the part has been installed. With many plastics, weld lines are immediately obvious as a physical weakness in the moulding which is detectable by brittleness on impact or flexing. With polyethylene, the fault may not appear so serious, and it may only be when stress is applied over a period of time in service, particularly in contact with an active environment, that failure will occur. Weld lines can be minimised by the use of high melt and mould temperatures, and also by utilisation of high injection pressures. Although care must be taken not to create greater difficulties by introducing packing around the sprue. A better solution however is to avoid weld line formation wherever possible by suitable positioning of the gate. On many bottle closures for example a centre pin gate can be used instead of a side gate. The mould may cost more with centre gates, but with bottle caps in particular, which are stressed in an outwards direction, the advantages of mouldings free from weld lines are great. In many cases the additional strength conferred by centre gating will permit the use of a polyethylene of high MFI which, although poorer in resistance to environmental stress cracking, will process easier and faster. Where articles of cylindrical shape are highly stressed in an outwards direction and centre gating is not possible, serious consideration should be given to diaphragm or ring gating.

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Flow Weld Lines

These generally occur towards the end of the flow path on a thin-walled article of large surface area, e.g. certain types of buckets. They are caused by the dividing of the advancing melt front into separate streams which fail to fuse together when the mould is full. This effect is aggravated by inadequate pressure on the melt or too low a melt temperature. The weld lines formed may be barely visible to the naked eye, but they can readily be detected by immersing the moulding in carbon tetrachloride at a temperature of 50 to 70°C where fissures will open up. Such weld lines are quite common and cause splits in the walls of thin containers (see Figure 22).

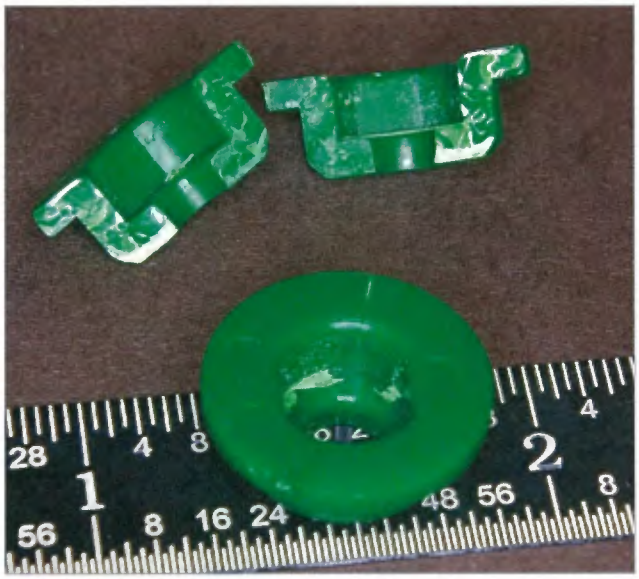


Figure 22: Failure Due to Flow Weld Lines

CONDITIONS FOR MOULDING POLYETHYLENE

In the injection moulding process the moulder is able to control several operating variables, each of which can influence the quality of the mouldings or the rate at which they are produced. These variables are:

- The temperature of the machine cylinder
- The temperature of the mould
- The 'injection variables', i.e. the injection pressure and speed, and the cycle time

The aim of the moulder must be to choose, for each particular material and moulding, the correct combination of variables which will produce perfect mouldings as easily and as quickly as possible. The position is somewhat complicated by the fact that a moulding that looks perfect may not in fact be so because of the presence of 'frozen-in strain', and therefore the choice of moulding conditions must take into account their effect, not only on the appearance of the moulding, but also on 'frozen-in strain'. In the following sections each variable will be discussed in the light of these two considerations, together with other relevant factors, such as the use of mould release agents. Finally a table, summarising some common moulding faults, their causes and remedies, is given (see Appendix 2).

Cylinder and Melt Temperatures

The melt temperature is the temperature of the polyethylene as it enters the mould. Depending on the grade of polyethylene being used, the temperature should lie in the range 160–280°C. In practice, it is not convenient to measure the melt temperature directly, and it is therefore necessary to use the machine cylinder temperature as a guide to the value of the melt temperature. The important point to note is that the cylinder temperature as indicated on the control panel instruments is not necessarily the same as the melt temperature, because the melt temperature depends on the rate at which the material passes through the cylinder and through the gate of the mould, as well as on the cylinder temperature. For example, if the shot weight is almost as large as the shot capacity and mouldings are being produced very rapidly, the material will be in contact with the heated cylinder for only a short time before being injected and may not have time to reach the temperature of the cylinder but may be as much as 30°C lower. On the other hand, in a machine of larger capacity that is working at slower output rates, the time of contact will be longer and consequently a lower cylinder temperature can be used and the difference between it and the melt temperature can be reduced to about 5°C. Similarly, a moulding containing a thick section will require a lower cylinder temperature than will a moulding of equal weight but of thinner section. This is because the thick moulding will require a longer cooling time and thus a longer cycle time than the thinner moulding; therefore the material will be in contact with the heated cylinder for a longer time and its temperature will more nearly approach that of the cylinder. A less common cause for the melt temperature to be different from the cylinder temperature is frictional heating of the material as it passes through the gate;

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if material is injected rapidly through a small gate the heat generated may be sufficient to raise the melt temperature above that of the cylinder.

From these examples it is clear that it is not possible to predict the exact cylinder temperature that must be used to obtain a given melt temperature, but that it is necessary to choose a suitable cylinder temperature as a starting point and then to make adjustments based on visual inspection of the mouldings and on considerations of 'frozen-in strain'. For grades with MFI above 20 g/10 min the suggested starting temperature is 210°C and for grades with MFI below 20 g/10 min the suggested starting temperature is 260°C.

When the cylinder temperature has been set, the injection pressure and cycle time should be adjusted to the minimum values consistent with the production of full mouldings, and moulding should then be carried out for long enough (usually 15-30 minutes) to enable conditions to settle down. The mouldings should then be inspected and tested. Testing should be conducted after conditioning for 24 hours, preferably in a constant temperature environment.

Appearance of Mouldings

If the surface of the mouldings is dull or patchy, or contains matt rings or 'chevron marks' (see Figure 12), this is an indication that the melt temperature is too low, and the cylinder temperature should be raised until mouldings with a uniform, glossy finish are obtained. If the surface finish is acceptable, but mouldings are tending to stick in the mould, the melt temperature is probably too high and the cylinder temperature should be reduced until the trouble is eliminated. These procedures are effective for all grades of *Alkathene* LDPE but it should be remembered that with materials of MFI below 0.5 g/10 min the cycle time may have to be rather long to allow the melt to reach the required temperature.

Frozen-in Strain

Melt viscosity (and hence melt temperature) is the most important factor determining 'frozen-in strain'. As highlighted in Appendix 1 the presence of 'frozen-in strain' is associated with orientation of the polyethylene molecules as they are injected into the mould cavity. At high temperatures the viscosity of the polyethylene is low and the mould is filled rapidly: only the layer of material immediately adjacent to the mould surface has frozen before the mould is filled so that during cooling the maximum relaxation of orientation can take place.

At low moulding temperatures the melt viscosity is higher, the mould fills relatively slowly, and the polyethylene freezes quickly so that relatively little relaxation of the polymer orientation can occur. It has been shown quite conclusively, not only by laboratory tests but also by extensive service trials, that mouldings made at low melt temperatures can contain enough 'frozen-in strain' to overcome the structural integrity of the part and result in failure, whereas those made under optimum conditions are perfectly satisfactory (see Figure 22).

It may be concluded that the optimum cylinder temperature is the lowest at which full, glossy mouldings can be obtained, and that under these conditions 'frozen in strain' will be at a minimum. Too high a temperature will lead to sticking and long cycles, and too low a temperature will lead to strained mouldings.

Mould Temperature

The mould temperature chosen should be that at which good mouldings can be produced with a minimum cycle time. The colder the mould the faster the melt will cool and the greater will be the tendency for 'frozen-in strain' to develop. Therefore, to reduce 'frozen-in strain' a warm mould is recommended and for the minimum amount of strain, a heated mould (as hot as possible) would be required. However, the use of a very hot mould would slow down the cooling rate and thus not only prolong the moulding cycle but also substantially increase the density of the moulding. This is particularly true for mouldings that contain thick sections. As explained in the Impact Properties section (pg. 11), certain polyethylenes can, under these conditions, be brought from the tough region into the brittle region (see Figure 16). In practice, mould temperatures in the range 30-50°C have been found to offer the best compromise between the effects of 'frozen-in strain' and notch-sensitivity. Figure 23 shows the variation of retraction with mould temperature for a constant cylinder temperature.

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5 INJECTION MOULDING

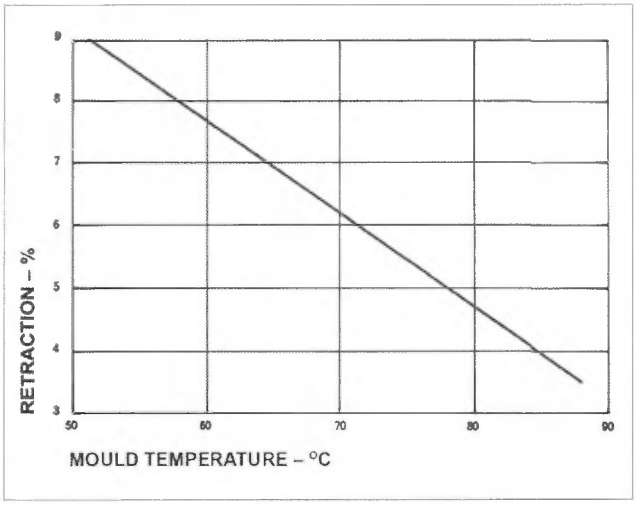


Figure 23: Variation of Retraction with Mould Temperature (Cylinder Temperature is Constant)

Because of the importance of correct mould temperature and the growing tendency to reduce cycle times it is essential, as already remarked, that in the initial designing of the mould, provisions should be made for efficient cooling; unfortunately this is a feature which is all too often overlooked with consequent difficulties in subsequent operation.

Injection Variables

The injection variables will be considered under two headings: injection pressure and dwell time; and mould filling time.

Injection Pressure and Dwell Time

To produce good mouldings, both quickly and economically, the injection pressure should be kept to a minimum and the dwell time made as short as possible. Increasing the packing of an additional volume of polyethylene into the mould during the dwell time to compensate for the shrinkage of the polyethylene due to crystallisation is also important. The degree of packing should be kept to a minimum because the excess polyethylene is forced into the mould cavity when the melt has almost solidified and therefore orientation introduced at this stage relaxes slowly. This can result in a highly strained region being formed near the sprue/gate. The strain may be sufficient to initiate stress cracking and therefore the dwell time and injection pressure must be kept to a minimum.

Figure 24 shows mouldings made from the same type of polyethylene at the same cylinder temperature, but using different injection dwell times and pressures. The samples moulded at high pressure with a long dwell time appear indistinguishable from those moulded under more favourable conditions. But when the mouldings are cut open, it can be seen that excessively high pressures and long dwell times can result in a thickening of the base near the sprue, which in extreme cases, can result in thickness increases of approximately 30%. When the mouldings were then subjected to an accelerated service test in an active environment, the effects of too much packing constituted a very serious cracking hazard.

Mould Filling Time

On some machines the injection speed can be varied virtually independently of the injection pressure by means of a flow control valve. In long, thin flow paths the polyethylene will cool rapidly and this section will contain a fairly high degree of strain. In addition, thin-walled mouldings require higher pressures to fill the mould and, therefore, packing may occur before the extremities of the flow path have been reached. The remedy is to use a higher melt temperature and as fast an injection speed as possible. On the other hand, for thick-sectioned mouldings it is often an advantage to reduce the speed of injection so as to avoid 'jetting' and turbulence which will lead to mouldings with a poor surface finish.

Summary

The moulding conditions necessary to produce good mouldings with the best appearance and the lowest amount of 'frozen-in strain' are:

- A melt temperature just high enough to give a glossy surface to the moulding
- A mould temperature of about 30-50°C
- The minimum injection pressure and dwell time

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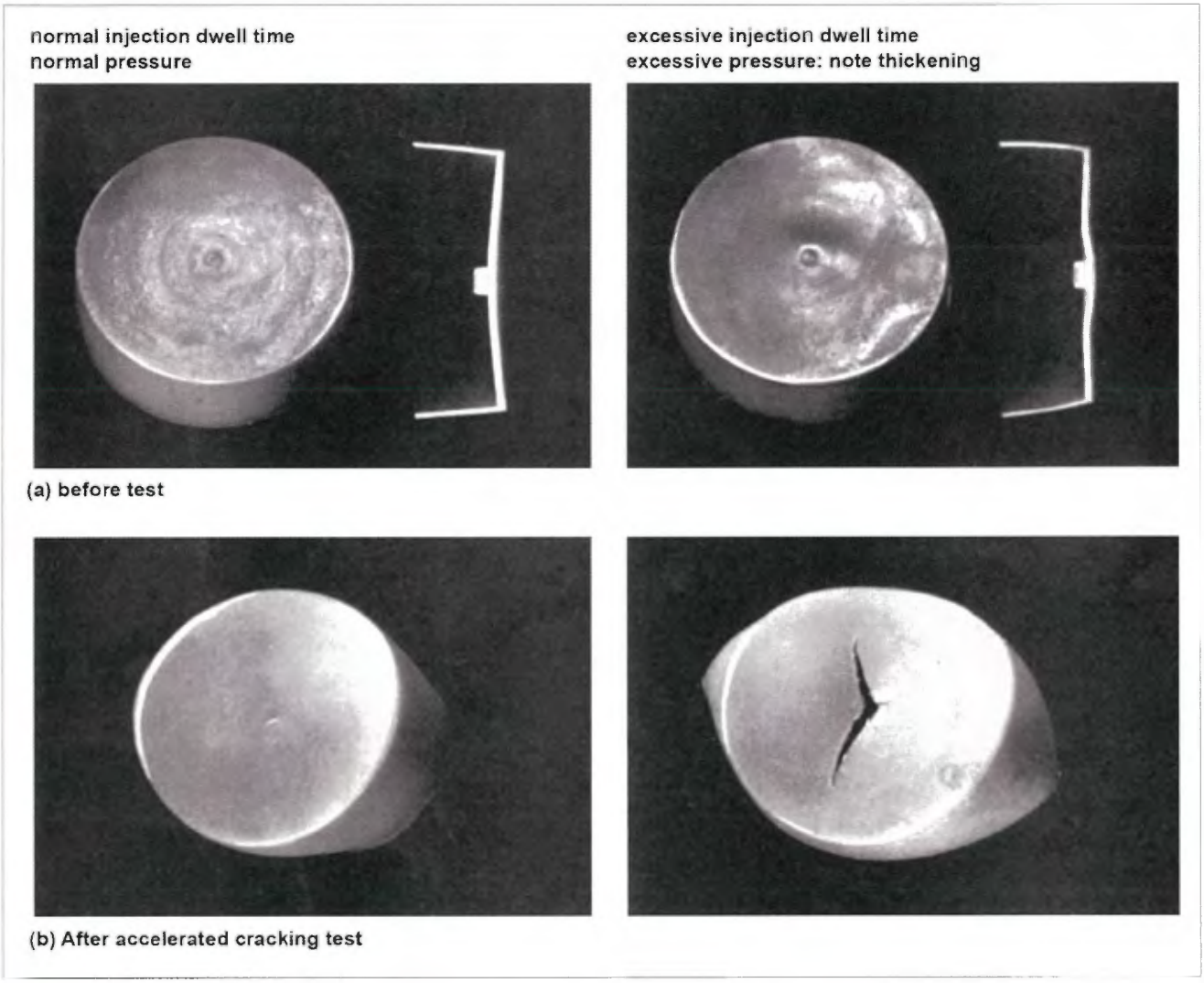


Figure 24: Effect of Injection Pressure and Dwell Time on Polyethylene Mouldings

MOULDING FAULTS

Faults in polyethylene mouldings may be divided into two classes: those that are obvious from visual inspection and those arising from the presence of 'frozen-in strain' – these can be detected only by testing. Appendix 2 lists the obvious faults that can occur, with their possible causes and remedies. Faults arising from 'frozen-in strain' have already been dealt with earlier.

In using Appendix 2 it should be noted that because the machine variables are interdependent a remedy that involves the adjustment of any one machine variable may also necessitate adjustment of the others. Alteration of the melt temperature should be gradual, in steps of 10°C, and a full cylinder of material should be injected before the results of any 10°C step are assessed. Alteration of the cycle time (which affects the length of time the material is in the cylinder and hence the melt temperature) should also be carried out gradually. Enough time should be allowed between successive adjustments to ensure that steady conditions at any one setting are obtained before the effect of that setting on the quality of the mouldings is determined.

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MOULD RELEASE AGENTS

If the correct moulding conditions have been chosen, polyethylene mouldings are unlikely to stick in the mould. If they do, and the fault cannot be corrected by adjusting the moulding conditions, mould lubricants such as stearates or fatty amides may be used. Silicone oils and greases may cause environmental stress cracking in polyethylene mouldings and therefore before they are used as mould release agents they should be tested with the moulding to see if they are suitable. If any doubt exists as to their suitability they should not be used.

DECORATING POLYETHYLENE MOULDINGS

There are several ways in which polyethylene mouldings can be decorated. These fall into two classes: those applied directly to the polyethylene surface; and those which require some form of pre-treatment of the surface. The following sections briefly deal with the various methods of pre-treatment, decoration and also with tests for the effectiveness of these processes.

Decorating Untreated Polyethylene

The following methods are commonly used:

- Hot stamping
- Labelling
- Embossing

Hot Stamping

Basically, this method consists of pressing on to the polyethylene a tape which is coated with pigment. Heat and pressure are applied via a male die and the pigment is released from the tape and fused into the polyethylene. Stamping should preferably be carried out while the moulding is still warm after being ejected from the die.

Because it is recessed, the coating obtained by hot stamping has a good degree of scratch resistance. Other advantages of this process are the absence of solvents and negating the need for drying facilities.

Labelling

Labelling is an inexpensive way of achieving a very wide range of effects. The choice of adhesive will depend on whether the label is required to be permanently fixed or easily removed.

Embossing

A relief pattern on mouldings is easily achieved by cutting the pattern in the mould. Conversely, a relief pattern on the mould produces a corresponding recessed pattern in the moulding. The embossed design can subsequently be decorated by printing or by painting. A wide range of textures and finishes can be obtained by this method.

Decorating Treated Polyethylene

Pre-treatment

Because polyethylene is non-polar and cannot be dissolved in any known solvent at room temperature it is not possible to directly apply conventional inks, paints and lacquers. There are, however, several ways in which polyethylene can be made polar. These are:

- Chlorination
- Chemical oxidation
- Flaming
- Electronic methods

Of these, chlorination is of little commercial importance, and electronic methods are usually restricted to thin films. Flaming is a versatile process which can handle any surfaces which do not contain deep or intricately shaped recesses. Chemical methods are not used so frequently, but they are the most satisfactory for parts of complex design.

Flame Treatment

Flaming a polyethylene moulding results in slight oxidation of the surface. This provides a polar surface which is required for good adhesion. The flame should be oxygen rich, of constant length and should impinge on the surface long enough to result in dulling of the surface. The exact technique will vary according to the shape of the part being treated. The essential point is that all parts of the surface should be uniformly treated.

Chemical Treatment

Chemical methods of pre-treatment involving acid etching are costly and often difficult to operate, but they are used for complicated parts and for parts to be vacuum metallised. Basically the procedure is simple:

- The moulding is immersed for 30 sec to 2 min in an acidified dichromate solution (a typical solution is 100 cm^3 of concentrated sulphuric acid, 50 cm^3 water and 15 g of potassium dichromate),
- Removed from the bath, washed thoroughly and dried.

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The big disadvantage of this method is the need to handle acid solutions; the main advantage is that every part of the surface, provided it is clean, is treated in the same way.

Tests for Pre-treatment

It is obviously desirable to be able to test the effectiveness of any pre-treatment to ensure good adhesion of the finished coating. Several tests can be used, of which those based on 'wettability' of the surface are popular because of their simplicity.

Peel Test

This test involves the use of a solvent-free, pressure sensitive tape. Such a tape has little affinity for an untreated polyethylene surface and is removed fairly easily, whereas it will bond strongly to a treated surface. A suitable tape is No. 850 supplied by Minnesota Mining and Manufacturing Co. Ltd. (3M). The tape is rolled on to the moulding by means of a rubber roller and is then peeled off under standard conditions using a tensometer. By noting the 'peel strength' recorded, a quantitative indication of the treatment level can be obtained. Since decorative coatings vary in their adhesion to polyethylene surfaces, there is no basic correlation between peel strength and adhesion. However, it has been found that treatments giving peel strengths greater than about 120 g/cm will result in satisfactory adhesion of most coatings.

Decorating Methods for Treated Surfaces

Two methods that can be used are:

- Silk-screen printing
- Vacuum metalising

Silk-screening

This is essentially a stencilling process in which the stencil takes the form of a silk, nylon or metal screen which has been made porous, by a photographic process, over areas corresponding to the design to be printed. The screen is held taut in a wooden frame which also serves as a reservoir for the ink. In use, the screen, with ink on its upper surface, is placed in contact with the article and a rubber 'squeegee' is drawn over the screen, thus forcing ink through the porous area on to the article.

Screen printing has the great advantage of low capital cost, particularly when the operation is done manually. Fully automatic units are available. The main disadvantage of silk-screening is that no more than one colour can be applied at one pass. If additional colours need to be applied, then the moulding must be dried before the next colour is applied.

Vacuum Metallising

In vacuum metallising a thin continuous layer of metal is deposited onto a prepared surface by vaporising the metal under high vacuum and condensing it on the surface. In practice, a lacquer is applied to the pre-treated polyethylene as a base coat. This serves to smooth out any imperfections and also acts as a key for the metallic film. The metallic film (usually of aluminium) is deposited, and a top coat of protective lacquer is applied. Low density polyethylene articles are successfully finished in this way. Although the flexibility of the material is a disadvantage.

Tests for Finished Coatings

Two simple but effective tests are the Scratch test and the Scotch Tape test.

Scratch Test

A good idea of the adhesion of a coating can be obtained by scratching it with a finger nail or a knife to see if it flakes.

Scotch Tape Test

In this test a length of pressure-sensitive tape such as Scotch Tape supplied by 3M is stuck on to the polyethylene moulding and then pulled off, slowly at first and then more quickly. The level of adhesion of the coating can be judged qualitatively by the degree, if any, to which the coating is removed.

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APPENDIX 1 – FROZEN-IN STRAIN

It is believed that 'frozen-in strain' develops in the following way. As the polyethylene melt is injected into the mould cavity, it is subjected to high shear forces which produce a certain degree of uncoiling of the molecular chains and causes them to be oriented in the direction of flow. The nearer the melt is to the mould surface, the greater will be the shear stress and the greater the orientation. Because the material nearest to the mould surface cools more rapidly than the material in the interior, this orientation is unable to relax and becomes frozen into position. Thus a highly oriented layer is formed, the thickness of which depends on the temperatures of the melt and of the mould surface. On the other hand, the material on the inside is insulated from the cool mould by a layer of polyethylene and consequently it remains molten until near the end of the moulding cycle. Not only is this material less oriented during mould filling, but most of the orientation that does occur can relax during the cooling stage. Therefore an injection moulded section has a composite structure consisting of a skin which is highly strained and inner layers containing a much lower degree of molecular orientation. Figure 25 is a greatly magnified picture of a section cut through an injection moulding which shows clearly the different layers that are formed. In service, the oriented chains will tend to revert to their normal, coiled configuration and this tendency is reflected in a reduction in the dimensions of a specimen parallel to the direction of flow and an increase in the dimensions at right angles to the flow. If these dimensional changes are resisted by the shape of the moulding, mechanical forces arise which can produce internal stresses large enough to cause cracking in the presence of an active environment.

At elevated temperatures the tendency for the oriented molecules to revert to their normal configuration is increased and some measure of the degree of orientation can be obtained by cutting specimens from a moulding and measuring the percentage retraction which takes place in the direction of flow when the specimens are heated. A large retraction indicates a high level of 'frozen-in strain'.

If a highly strained surface comes into contact with an active environment such as synthetic detergents or fat, a small crack may develop which is likely to propagate rapidly, especially at elevated temperatures. Depending on the particular type of polyethylene, either cracks may develop throughout the whole section or failure may be restricted to surface peeling.

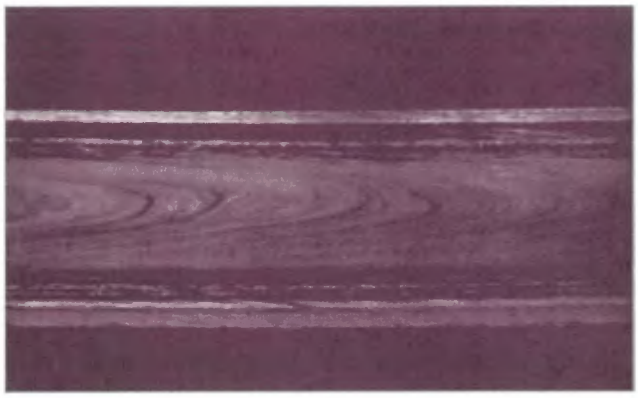


Figure 25: A Section from a Polyethylene Moulding, Showing the Layered Structure

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APPENDIX 2 – INJECTION MOULDING TROUBLESHOOTING GUIDE

Problem / Issue	Cause(s)	Potential Solution(s) / Action(s)
Brittle mouldings	Sharp corners, notches	Increase radii
	PE grade has insufficient impact strength	Use lower flow and/or lower density grade of PE
	Excessive orientation	Increase melt temperature
	Inadequate thickness	Increase thickness of moulding
Burn marks. Carbonised material at end of flow path	Insufficient venting	Increase venting
	Injection speed too high	Reduce injection speed
	Melt temperature too high	Reduce barrel and nozzle temperature settings
Delamination	Incompatible masterbatch	Ensure PE based masterbatch is used
	Contaminant	Check feed for contamination
	Material freezing prematurely	Increase temperature settings. Increase gate size
Demoulding difficulties	Poor design, insufficient draft angles	Increase draft angles, incorporate "slip"additive
	Over packing	Reduce injection speed and or second stage time/ pressure, use higher flow PE grade
	Excessive second stage	Reduce second stage pressure and/or time
Distortion	Moulded in stress/ orientation	Increase melt temperature. Use increased melt flow index grade of PE
	Ribs too thick	Employ more, but thinner ribs to impart stiffness
	Variation in thickness	Use ribs for varying thickness rather than solid walls
	Variation in mould cooling	Increase cooling channels in difficult to cool areas
	Sink marks	Increase second stage pressure and or time
	Gate freezing off too quickly	Increase gate size
Flashing	Inadequate clamp force	Increase clamp force. Move mould to a higher clamp force machine
	Excessive vent size	Reduce venting
	PE melt flow index too high	Change to a low flow grade of PE
	Excessive injection speed	Reduce injection speed
Matt or streaky surface	Gate inappropriately positioned resulting in snake – like jetting	Position gate so that the material is forced to change direction immediately upon entering the mould
	Melt disturbance resulting Matt – Gloss pattern	Increase melt temperature. Reduce injection speed
	Moisture	Dry the polyethylene or masterbatch
	Incompatible masterbatch	Change masterbatch to one with a PE base
Poor colour homogenisation	Back pressure too low	Increase back pressure
	Masterbatch not compatible	Ensure PE based masterbatch is used
	Barrel size too small, insufficient shots in barrel	Move to a larger machine
	Masterbatch add rate too low	Use masterbatch with lower pigment concentration at higher add rate
	Temperature too low	Increase temperature settings

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5 INJECTION MOULDING

Problem/Issue	Cause(s)	Potential Solution(s)/Action(s)
Short shots. Incompletely filled mouldings	PE melt flow index too low	Change to higher melt flow index grade
	Melt temperature too low	Increase melt temperature.
	Inadequate vent size	Increase venting
	Inadequate thickness	Increase thickness
	Insufficient injection speed	Increase injection speed
	Insufficient gating	Increase gate size or number
Weak weld lines	Melt temperature too low	Increase temperature settings
	Flow of polymer too low	Use higher melt flow grade
	Injection speed too low	Increase injection speed
	Gate(s) too far from weld line	Move gate or increase number of gates

Disclaimer

The proposed solutions in this guide are based on conditions that are typically encountered in the manufacture of products from polyethylene. Other variables or constraints may impact the ability of the user to apply these solutions. Qenos also refers the user to the disclaimer at the beginning of this document.

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FOI Document #13

s47F

From: s47F @qenos.com
Sent: Friday, 5 September 2014 11:47 AM
To: TARCON
Cc: s47F @qenos.com
Subject: Objection Gazette no TC 14/33, TC 1425826
Attachments: HD3690-CON item cost.xlsx; Polyethylene at a Glance 6th Edition.pdf; Book 5 injection Moulding.pdf; Qenos invoices HD3690 CON 2014.pdf; TC 1425826 objection Sep 14 signed.pdf

Dear National Manager, Tariff Branch

Please find attached Qenos' objection to Gazette no TC 14/33, TC 1425826 and supporting material.

s47F

s47F

Qenos Pty Ltd
P: s47F | M: s47F
E: s47F @qenos.com | W: www.qenos.com

5 SEP '14 11:56

FOI Document #14

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TIME SAVER

If this form was completed by a business with fewer than 20 employees, please provide an estimate of the time taken to complete this form.

Hours Minutes

SUBMISSION OBJECTING TO THE MAKING OF A TARIFF CONCESSION ORDER (TCO)

THIS FORM MUST BE COMPLETED BY A LOCAL MANUFACTURER WHO WISHES TO OBJECT TO THE GRANTING OF A TCO. THE INFORMATION PROVIDED ON THIS PAGE WILL BE FORWARDED TO THE APPLICANT FOR THE TCO. THE FORM SHOULD BE READ CAREFULLY BEFORE BEING COMPLETED.

DETAILS OF THE TCO APPLICATION TO WHICH THIS SUBMISSION REFERS

GAZETTE NO: TC 14/33 DATE: 27 August 2014

Gazetted description of goods. TC Reference Number: TC 1425826

RESINS, unpigmented polypropylene heterophasic copolymer,
proplyene based with comonomer ethylene, in pelletised form,
having ALL of the following: (refer TC 1425826)

Stated use: For the manufacture of this walled containers for food packaging
using high speed injection moulding

LOCAL MANUFACTURER DETAILS

Name: Qenos			
Business Address: 471-513 Kororoit Creek Road, Altona VIC 3018			
Postal Address *(if the same as business address write "as above")*: Private Mail Bag 3, Altona VIC 3018			
Australian Business Number (A.B.N.): 62 054 196 771		Reference:	
Company Contact: s47F [redacted]	Phone Number: s47F [redacted]	Facsimile Number: s47F [redacted]	E-mail Address: s47F [redacted] @qenos.com

DETAILS OF THE SUBSTITUTABLE GOODS PRODUCED IN AUSTRALIA

1 **Describe the locally produced substitutable goods the subject of the objection.**

"Substitutable goods" are defined in the Customs Act 1901 as "goods produced in Australia that are put, or are capable of being put, to a use that corresponds with a use (including a design use) to which the goods the subject of the application or of the TCO can be put".

High density polyethylene (HDPE) injection moulding resin.

2 **State the use(s) to which the substitutable goods are put or are capable of being put.**

Housewares, thin walled containers and closures.

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3	**Attach technical, illustrative descriptive material and/or a sample to enable a full and accurate identification and understanding of the substitutable goods.**

4	**Are you aware of any other local manufacturers producing substitutable goods?**	☐ YES ☑ NO

5 **If yes to question 4, please provide details of any goods produced in Australia which are substitutable for the goods for which a TCO is being sought, and the names and addresses of the manufacturers of those goods.**

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6 **PRODUCTION OF GOODS IN AUSTRALIA**

Goods other than unmanufactured raw products will be taken to have been produced in Australia if:

(a) the goods are wholly or partly manufactured in Australia; and

(b) not less than 1/4 of the factory or works costs of the goods is represented by the sum of:

(i) the value of Australian labour; and

(ii) the value of Australian materials; and

(iii) the factory overhead expenses incurred in Australia in respect of the goods.

Goods are to be taken to have been partly manufactured in Australia if at least one substantial process in the manufacture of the goods was carried out in Australia.

Without limiting the meaning of the expression "substantial process in the manufacture of the goods", any of the following operations or any combination of those operations DOES NOT constitute such a process:

(a) operations to preserve goods during transportation or storage;

(b) operations to improve the packing or labelling or marketable quality of goods;

(c) operations to prepare goods for shipment;

(d) simple assembly operations;

(e) operations to mix goods where the resulting product does not have different properties from those of the goods that have been mixed.

A **Are the goods wholly or partly manufactured in Australia?** ☑ YES ☐ NO

B **Does the total value of Australian labour, Australian materials and factory overhead expenses incurred in Australia represent at least 25% of the factory or works costs?** ☑ YES ☐ NO

Specify each of the following costs per unit for the substitutable goods:

- Australian labour
- Australian materials
- Australian factory overhead expenses
- Imported content

s47 [redacted]

TOTAL

Specify the date or period to which the costs relate. 12 months ending 31 Aug 2014

Attach a copy of the working papers that were used to prepare the above costing information. Those working papers should be supported by (at least two) extracts from the accounting records of the business.

C **Is at least one substantial process in the manufacture of the goods carried out in Australia?** ☑ YES ☐ NO

If yes, please specify at least one major process involved:

Conversion of Ethane gas supplied from Bass Strait into ethylene using a steam cracking process and then polymerised into polyethylene at Qenos's Altona Victoria polymer manufacturing facility.

.....

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FOI Document #14

7 PRODUCTION OF GOODS IN THE ORDINARY COURSE OF BUSINESS
(Answer 7.1 or 7.2)

7.1 SUBSTITUTABLE GOODS OTHER THAN MADE-TO-ORDER CAPITAL EQUIPMENT

Substitutable goods (other than made-to-order capital equipment) are taken to be produced in Australia in the ordinary course of business if:

(a) they have been produced in Australia in the 2 years before the application was lodged; or

(b) they have been produced, and are held in stock, in Australia; or

(c) they are produced in Australia on an intermittent basis and have been so produced in the 5 years before the application was lodged;

and a producer in Australia is prepared to accept an order to supply such goods.

A	Have the goods been produced in Australia in the last 2 years?	☑ YES ☐ NO
B	Have the goods been produced and are they held in stock in Australia?	☑ YES ☐ NO
C	If the goods are intermittently produced in Australia, have they been so produced in the last 5 years?	☑ YES ☐ NO
D	Are you prepared to accept an order for the goods?	☑ YES ☐ NO

7.2 SUBSTITUTABLE GOODS BEING MADE-TO-ORDER CAPITAL EQUIPMENT

"Made-to-order capital equipment" means a particular item of capital equipment that is made in Australia on a one-off basis to meet a specific order rather than being the subject of regular or intermittent production and that is not produced in quantities indicative of a production run. Capital equipment means goods which, if imported, would be goods to which Chapters 84, 85, 86, 87, 89 or 90 of Schedule 3 to the Customs Tariff Act 1995 would apply.

Goods that are made-to-order capital equipment are taken to be produced in Australia in the ordinary course of business if:

(a) a producer in Australia:

(i) has made goods requiring the same labour skills, technology and design expertise as the substitutable goods in the 2 years before the application; and

(ii) could produce the goods with existing facilities; and

(b) the producer in Australia is prepared to accept an order to supply the substitutable goods.

E	Have goods requiring the same labour skills, technology and design expertise as the goods the subject of the application been made in Australia in the last 2 years? If yes, describe the goods made during this period:	☐ YES ☐ NO
F	Can the goods be produced with existing facilities?	☐ YES ☐ NO
G	Are you prepared to accept an order for the goods?	☐ YES ☐ NO

8	What was the first date on which you were prepared to accept an order?	1 / 1 / 1980
	Are the goods still in production?	☑ YES ☐ NO
	If the answer is no, when did production cease?	/ /
	If production has ceased and goods are held in stock, please estimate the date by which stock is expected to be sold, based on past sales information and attrition rate of the local goods.	/ /

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9 **Provide any additional information in support of your objection.**

Cost analysis based on the bill of materials (provided) for Qenos grade HD3690 packaged in 20 tonne bulk containers for local delivery. Sample customer invoices have also been provided.

This product has been in production for several decades - the answer to question 8 on the first date on which Qenos was prepared to accept an order is indicative only.

A copy of Qenos' product guide "Polyethylene at a glance" and Qenos' technical guide on injection moulding have been provided in response to question 3.

NOTES

(a) Section 269K and 269M of the *Customs Act 1901* require that a submission opposing the making of a TCO be in writing, be in an "approved form", contain such information as the form requires, and be signed in the manner indicated in the form. **This is the approved form for the purposes of those sections.**

(b) A submission will be date stamped on the day it is first received in Canberra by an officer of Customs. The submission is taken to have been lodged on that day.

(c) For the submission to be taken into account, it must be lodged with Customs:
- no later than 50 days after the gazettal day for an application for a TCO;
- no later than 14 days after the gazettal day for an amended application for a TCO; or,
- where the Chief Executive Officer has invited a submission, within the period specified in the invitation.

(d) **Every question on the form must be answered.**

(e) Where the form provides insufficient space to answer a question, an answer may be provided in an attachment. The attachment should clearly identify the question to which it relates.

(f) Unless otherwise specified, all information provided should be based on the situation as at the date of lodgement of the TCO application.

(g) Customs may require an objector to substantiate, with documentary evidence, information provided in relation to the objection.

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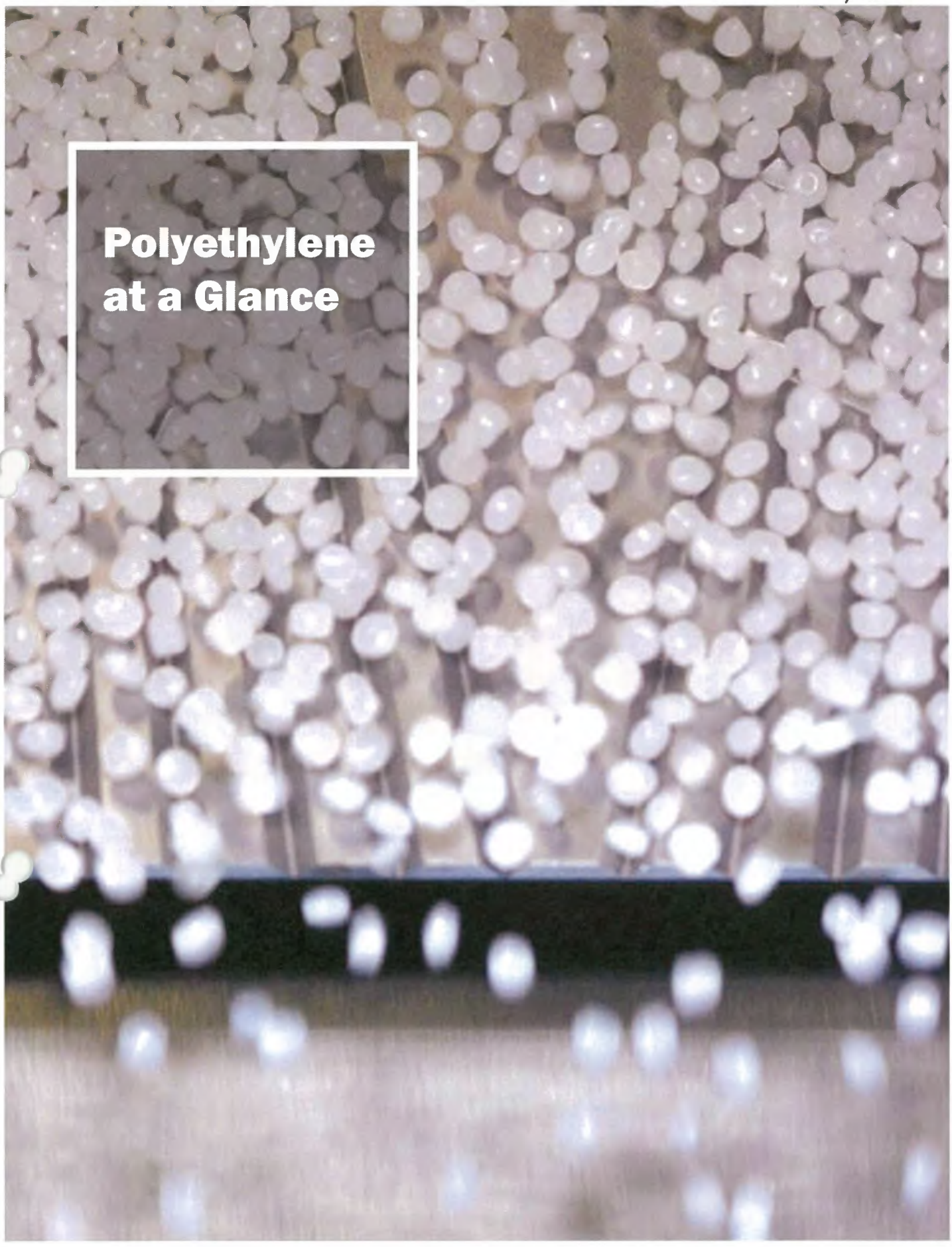
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Polyethylene at a Glance

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Alkadyne™ PE100 Pipe Extrusion Grades

Grade	Melt Index* (g/10 min@ 190°C, 5.00kg)	Density# (g/cm³)	Applications
HDF193B	0.3	0.961(1)	High Density black PE100 type resin certified to AS/NZS 4131, for use in pressure pipes and fittings. Excellent low sag properties and throughput, suitable for the majority of PE100 pipe dimensions.
HDF145B	0.2	0.961(1)	High Density black PE100 type resin certified to AS/NZS 4131, for use in pressure pipes and fittings. Exceptional low sag properties and throughput, suitable for the most challenging pipe dimensions.
HDF193N	0.3	0.952(1)	High Density natural resin for extrusion into a full range of non standard pipe products and as a base for PE100 type striping and jacket compounds.

Notes: (1) ASTM D1505/D2839

Alkadyne™ PE Pipe Extrusion Grades

Grade	Melt Index* (g/10 min @ 190°C, 5.00kg)	Density# (g/cm³)	Applications
MD0898	0.7	0.952(1)	Medium Density black PE80B type resin certified to AS/NZS 4131 for use in pressure pipes and fittings.
MD0592	0.6	0.942(1)	Medium Density natural resin for extrusion into a full range of non standard pipe products and as a base for PE80 type striping and jacket compounds.
GM7655	0.6	0.954(1)	High Density natural high molecular weight resin for extrusion into a full range of non standard pipe products.
MDF169	1.0	0.943(1)	Medium Density natural high molecular weight resin for extrusion into a full range of non standard pipe products.
LL0228	1.7(2)	0.923(1)	Linear Low Density resin for use in pipe extrusion applications.

Notes: (1) ASTM D1505/D2839 (2) D1238@190°C, 2.16kg

Alkadyne™ PE Wire and Cable Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
MD0592	0.12	0.942(1)	Designed for extrusion into a full range of wire and cable products where natural Medium Density resins are required.
MD0898-1	0.12	0.953(1)	Designed as general purpose jacketing compound for buried wires and cables where abrasion and cut through resistance is required.

Notes: (1) ASTM D1505/D2839

Alkatane™ HDPE Tape and Monofilament Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
GF7740F2	0.4	0.950(1)	Extrusion applications including stretched tape, monofilament, tarpaulins, and over-pouches for medicinal products.

Notes: (1) ASTM D1505/D2839

Alkatuff® LLDPE Rotational Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
LL711UV	3	0.938	Applications requiring excellent ESCR, chemical resistance(1), stiffness, toughness and UV protection, such as water and chemical tanks, septic systems and kayaks.
LL705UV	5	0.935	Applications requiring high ESCR, chemical resistance(1), toughness, stiffness and high level UV stabiliser, such as leisure craft, playground equipment and agricultural tanks.
LL755	5	0.935	Applications requiring high ESCR, chemical resistance(1), toughness and stiffness. Incorporation of suitable UV stabilisation is required for outdoor applications.
LL710UV	10	0.930	High speed intricate applications requiring good ESCR, chemical resistance(1), toughness and UV protection, such as consumer goods and playground equipment.

Notes: (1) The level of chemical resistance is a function of product design and environmental conditions. Contact Qenos for further information.

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

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Alkathene® LDPE Film Grades				Additives		Applications							
Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Antiblock	Slip[2]	Heavy Duty Bags	Shrink	Produce	Carry Bags	Bread	Cling Wrap	Freezer Film	Overwrap
XDS34	0.30	0.922	Heavy duty sacks, pallet wrap and industrial applications requiring heavy gauge film. Additive free.			✓	✓						
LDF433	0.45	0.925	Heavy duty sacks, pallet wrap and industrial applications requiring medium to heavy gauge film with increased stiffness.	✓		✓	✓						
LDD201	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags and shrink film and for use as a blend component.			✓	✓						
LDD203	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags and shrink film requiring antiblock, and for use as a blend component.	✓		✓	✓						
LDD204	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags and shrink film where a medium level of slip is required.	✓	M	✓	✓						
LDD205	0.45	0.922	General purpose medium to heavy gauge film for heavy duty bags, frozen food and produce bags where a high level of slip is required or for use as a blend component.	✓	H	✓	✓	✓				✓	
LDH210	1.0	0.922	Bundle shrink and other medium gauge film applications such as produce bags, carry bags and for blending into other film grades.				✓	✓	✓				
LDH215	1.0	0.922	General purpose medium gauge film for produce bags and carry bags, frozen food where a high level of slip is required or for use as a blend component.	✓	H			✓	✓				
XJF143	2.5	0.921	Additive free, general purpose low gauge film for overwrap and other applications and for use as a blend component.										✓
LDJ226	2.5	0.922	Bundle shrink, low gauge shrink film and general purpose applications where a medium level of slip and antistatic are required.	✓	M[1]		✓		✓				✓
LD0220MS	2.5	0.922	High quality low gauge film for lamination and overwrap applications where a medium level of slip is required.	✓	M								✓
LDJ225	2.5	0.922	High quality, low gauge film primarily intended for bread bags and overwrap but also general purpose applications where a very high level of slip is required.	✓	VH					✓			✓
XLF197	5.5	0.920	High quality, very thin gauge and high clarity film primarily intended for food and packaging wrap and for drycleaning film. Additive free.								✓		

Notes: [1] Based on antistat additive [2] VH = Very High Slip, H = High Slip, M = Medium Slip

Alkatuff® LLDPE Film Grades				Additives			Applications								
Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Antiblock	Slip[1]	Processing Aid	Heavy Duty Bags	Stretch	Agricultural Film	General Purpose	Garbage Bags	Lamination	FFS	Freezer Film	Overwrap
LL438	0.8	0.922	Heavy duty sacks, agricultural films,lamination and form, fill and seal packaging where enhanced toughness and sealing characteristics are desired.			✓	✓		✓	✓		✓	✓	✓	
LL501	1.0	0.925	General purpose industrial, agricultural and heavy duty films and as a blend component to improve film handling in converting and packaging operations.				✓			✓					
LL601	1.0	0.925	General purpose industrial, agricultural and heavy duty films and as a blend component to improve film handling in converting and packaging operations.	✓	H					✓	✓				✓
LL425	2.5	0.918	High quality cast film for applications that require toughness, high clarity and processability.					✓							

Notes: [1] VH = Very High Slip, H = High Slip, M = Medium Slip

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

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Alkamax® mLLDPE Film Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Additives			Applications												
				Antiblock	Slip(1)	Processing aid	Heavy Duty Bags	Stretch	Produce	Carry Bags	Bread	Agricultural Film	General Purpose	Ice Bags	Lamination	FFS	Freezer Film	Overwrap	Liners
ML1810PN	1.0	0.918	Heavy duty bags, industrial and agricultural films, and form, fill and seal applications and ice bags where outstanding toughness, sealing and hot tack properties are desirable or for downgauging of existing film structures.			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ML1810PS	1.0	0.918	Heavy duty bags,industrial and form, fill and seal applications and ice bags where outstanding toughness, sealing, hot tack properties and high slip are desirable or for downgauging of existing film structures.	✓	H	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
ML2610PN	1.0	0.926	Heavy duty bags, lamination, industrial and form, fill and seal applications where outstanding stiffness, toughness, optical and sealing properties are desirable or for downgauging of existing film structures.			✓	✓		✓	✓	✓		✓		✓	✓	✓		✓
ML1710SC	1.0	0.917	Stretch cling films (with addition of appropriate cling additive) and other film applications where outstanding toughness, optical and sealing properties are desirable or for downgauging of existing film structures.			✓		✓				✓							

Notes: (1) VH = Very High Slip, H = High Slip, M = Medium Slip

Alkatane™ HDPE Film Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications	Applications			
				Carry Bags	General Purpose	Liners	Barrier Film
GM4755F	0.10	0.955(1)	Carry bags and liners where high impact, toughness and stiffness are desirable and as a blend component into LDPE and LLDPE films for heavy duty applications.	✓	✓	✓	
HDF895	0.80	0.960(1)	Moisture barrier and blend component into LDPE and LLDPE films to enhance stiffness. Blend component in core layer for high clarity coextruded films.	✓	✓	✓	✓

Notes: (1) ASTM D1505/D2839

Alkatane™ HDPE Blow Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
HD0840	0.06	0.953(1)	Large part blow mouldings, especially blow moulded self-supported drums and tanks (25 - 220 litres). Exceptional ESCR.
HD1155	0.07	0.953(1)	Large part blow mouldings, including 25 litre to 220 litre tanks and drums. Exceptional ESCR.
GM7655	0.09	0.954(1)	Blow moulded containers including household and industrial chemical (HIC). Suitable for larger part mouldings. Exceptional ESCR.
GF7660	0.30	0.959(1)	Household and industrial chemical (HIC) containers, including detergent and pharmaceutical bottles. Excellent ESCR.
GE4760	0.60	0.964(1)	Blow moulded water, dairy and fruit juice bottles.
HD5148	0.83	0.962(1)	High speed dairy packaging applications and other thin walled bottles such as milk, cream, fruit juice and cordial.

Notes: (1) ASTM D1505/D2839

Qenos imported polymers and additives

Complementing our Australian manufactured Polyethylene grades, Qenos acts as a local distributor for a wide range of imported polymers and additives including rubbers, elastomers, adhesives, plastomers, EVA, BOPP Film, EPS, antioxidants and titanium dioxide. For the full Qenos range, please refer to the Qenos website, Customer Service or your Account Manager.

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

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Alkathene® LDPE Extrusion Coating Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
XLC177	4.5	0.923	Applications including milkboard and fabric extrusion coating where very good drawdown, low moisture vapour transmission rates and excellent hot tack are desirable. Additive free.
WNC199	8.0	0.918	Liquids packaging and other sensitive food packaging laminates where excellent heat seal, low extractables, good melt strength and low odour and taint are desirable. Additive free.
LDN248	7.6	0.922	Liquids packaging and other sensitive food packaging laminates where low extractables and low odour and taint are desirable. Additive free.
LD1217	12	0.918	Liquids packaging and other sensitive food packaging laminates where high line speed, low neck-in, low extractables and low odour and taint are desirable. Additive free.

Alkathene® LDPE Injection Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
XDS34	0.3	0.922	Small part injection moulded caps and closures. Additive free.
WJG117	1.7	0.918	Thick section mouldings, caps and closures, industrial containers where a high level of toughness is desirable. Additive free.
XJF143	2.5	0.921	Injection moulded caps and closures, and thick-walled sections. Additive free.
LDN248	7.6	0.922	Injection moulded caps and closures. Additive free.
WRM124	22	0.920	High flow resin for reseal lids, housewares and toys where excellent gloss, low warpage and flow to toughness ratio are desirable. Additive free.
LD6622	70	0.922	High flow resin for lids and other thin wall injection moulding applications. Additive free.

Alkatuff® LLDPE Injection Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
LL820	20	0.925	Injection moulding and compounding applications such as housewares and lids.

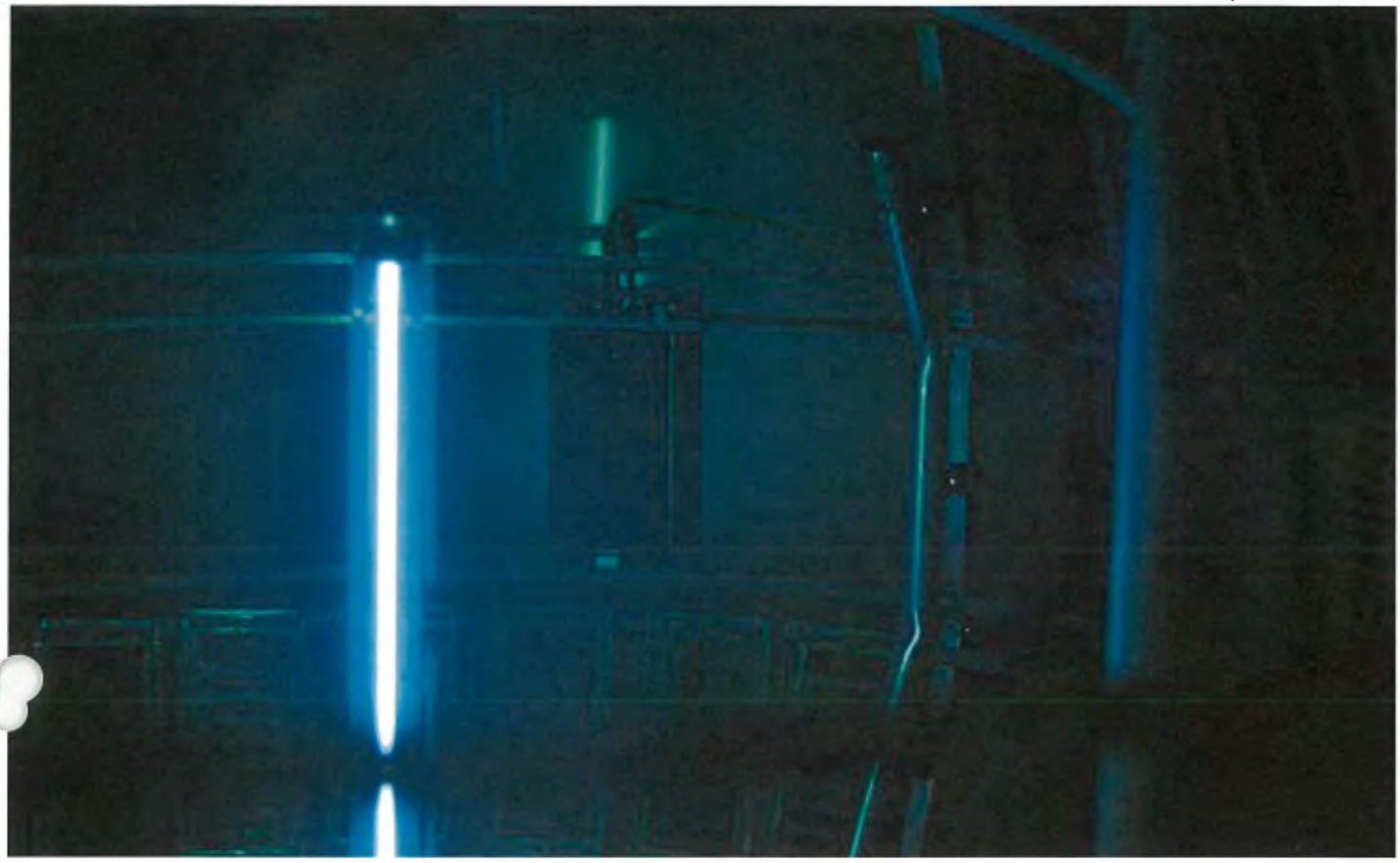
Alkatane™ HDPE Injection Moulding Grades

Grade	Melt Index* (g/10 min @ 190°C, 2.16kg)	Density# (g/cm³)	Applications
HD0390	4	0.955	Stackable crates for transport, storage and bottles and industrial mouldings where very good mechanical properties are desirable.
HD0397UV	4	0.955	Mouldings requiring long-term weatherability, including mobile garbage bins, crates, and industrial mouldings where very good mechanical properties are desirable.
HD0490	4.5	0.955	Stackable crates for transport, storage and bottles, and industrial mouldings where very good mechanical properties are desirable.
HD0499UV	4.5	0.955	Mouldings requiring long-term weatherability, including mobile garbage bins, crates, and industrial mouldings where very good mechanical properties are desirable.
HD0790	7	0.956	Industrial pails, crates, closures and sealant cartridges where a good balance between flow and impact resistance is desirable.
HD1090	10	0.956	Industrial pails, crates, closures and sealant cartridges where a good balance between flow and impact resistance is desirable.
HD1099UV	10	0.956	Mouldings requiring long term weatherability including industrial pails, crates, and tote boxes where a good balance between flow and impact resistance is desirable.
HD2090	20	0.956	Housewares, thin-walled containers and closures where excellent mould flow and flexibility is required.
HD3690	36	0.956	Housewares, thin-walled mouldings and closures where excellent mould flow and flexibility is required.

*Melt Index according to ASTM D1238 unless otherwise annotated #Density according to ASTM D1505 unless otherwise annotated

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qenos.com

Front Cover: Pellet geometry and pellet quality can have a significant effect on material flow and the efficiency of feeding polyethylene into an extruder. Qenos measures pellet quality using a pellet shape and size distribution analyser, a device that photographs around 10,000 pellets in 4 minutes, digitally analyses the images and generates a report on pellet quality. Where a drift in the pellet quality is detected, adjustments are made proactively to maintain high product integrity.

Rear Cover: The standard for UV performance for PE Water Tanks specified in AS/NZS 4766 PE Tanks for the Storage of Chemicals and Water is 8,000 hours of uninterrupted exposure to an intense and specifically developed UV light source. Qenos exhaustively tests the long term UV performance of its Rotational Moulding Resins under conditions of controlled irradiance, chamber temperature and humidity and repeated rain cycles. Alkatuff® 711UV achieves a class leading UV performance exceeding 20,000 hours against the required standards, ensuring that Alkatuff® 711UV is "Tough in the Sun".

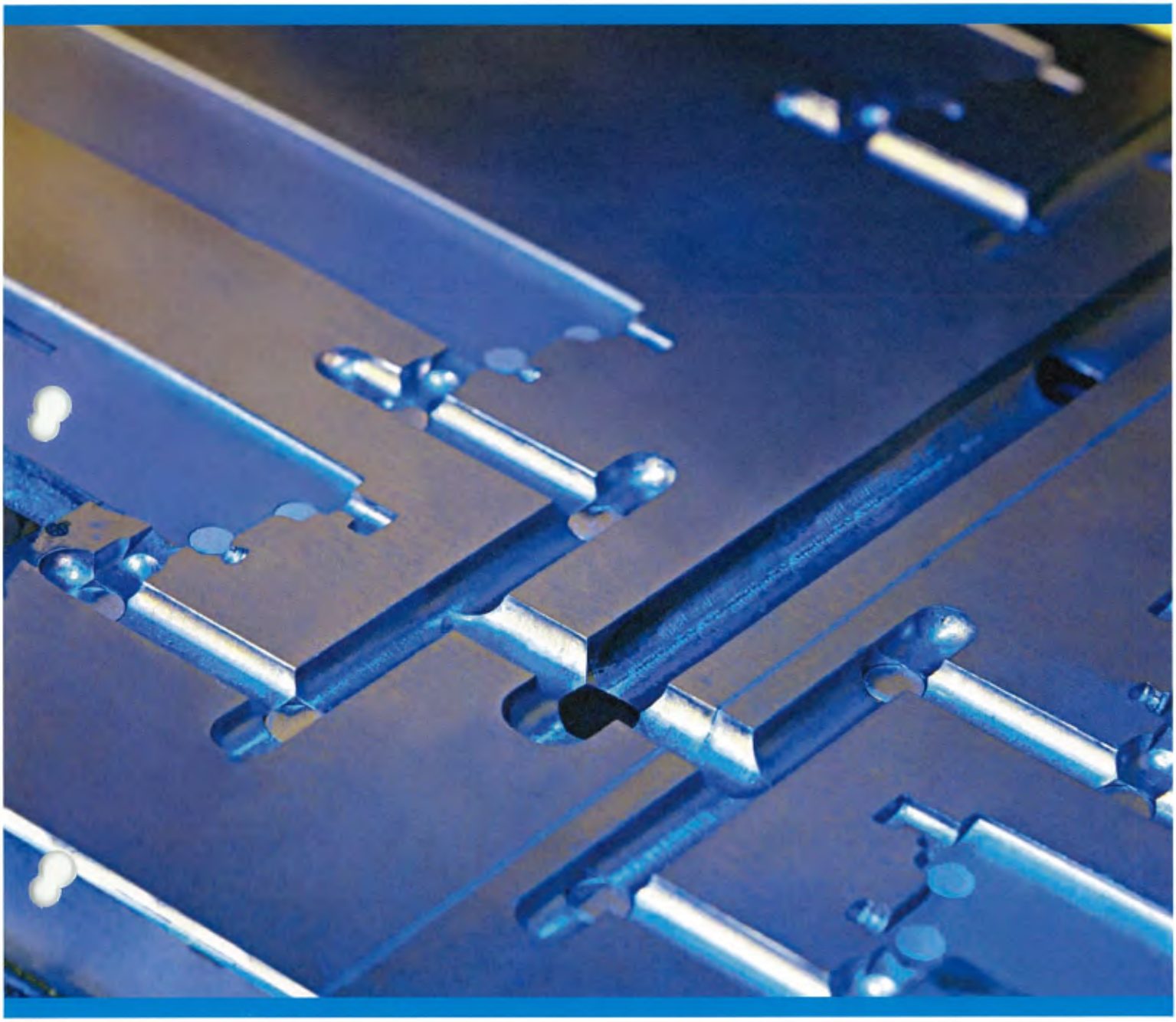
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5 INJECTION MOULDING

TECHNICAL GUIDE

Alkathene® Alkatuff® Alkatane™

FOI Document #18



Front Cover:
Qenos produces injection moulded products for applications including caps, pails, crates, sealant cartridges, mobile garbage bins, produce bins, housewares and lids. A full range of *Alkatane* HDPE, *Alkathene* LDPE and *Alkatuff* LLDPE grades are available across the Melt Index and density spectrum. In addition, Qenos distributes a number of speciality polymers suitable for injection moulding.

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INJECTION MOULDING

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5 INJECTION MOULDING

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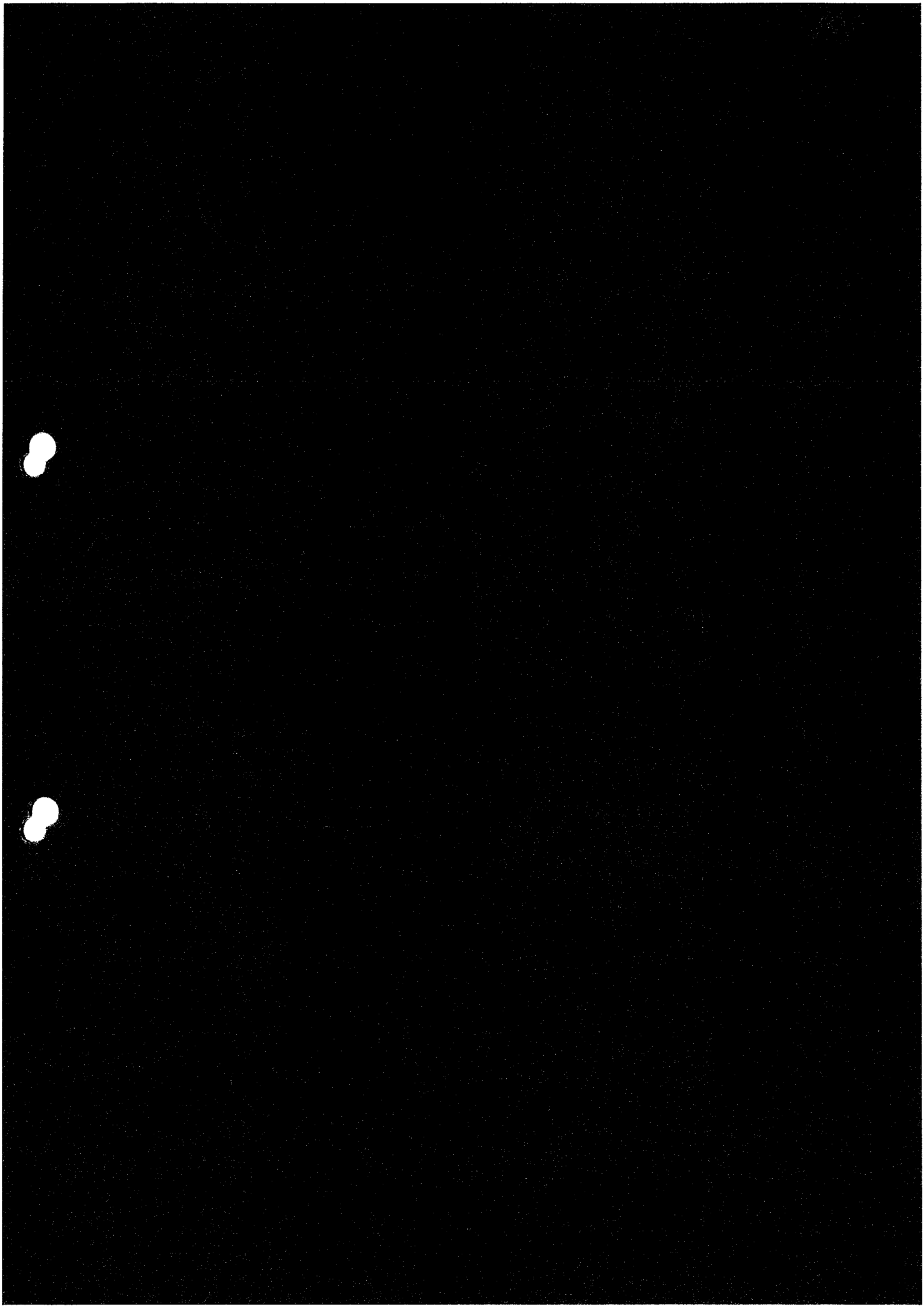
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INTRODUCTION

The purpose of this document is to provide an introduction to the processing of polyethylene by injection moulding. The effects of Melt Flow Index (MFI) and density on moulding characteristics and on the properties of the finished moulding are discussed, in the light of which, recommendations are made as to the desirable values of these two factors for stressed and unstressed applications.

Mould design is considered with special reference to questions of shrinkage and distortion and examples are given to illustrate these points. The moulding process itself is discussed in some detail, guidance being given on all the operations which have to be carried out. Moulding faults, causes and remedies are also summarised.

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INTRODUCTION

Injection moulding is one of the most widely used processes for converting thermoplastic raw materials into finished products. Fundamentally, a solid polymer is plasticated into a molten mass via thermal and frictional heating and once a suitable volume of melt has been produced, the polymer is injected into the mould to form the finished part (see Figures 1 and 2).

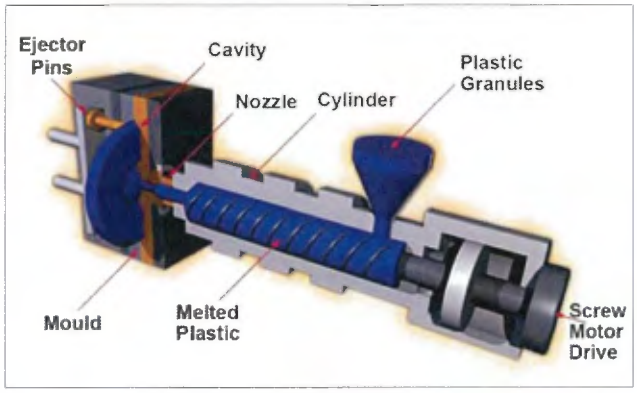


Figure 1: Schematic Representation of an Injection Moulding Machine



Figure 2: Finished Moulded Part including Sprue Injection Point

Injection Moulding is fundamentally simple, easy to operate and is capable of producing a very wide variety of industrial and domestic articles. Of all thermoplastics, polyethylene is one of the easiest to injection mould. The resin flows easily into difficult cavities, its viscosity changes smoothly as the melt temperature increases and it can be processed over a wide temperature range without decomposition.

However, this very ease of processing often leads to the use of moulding conditions which are not the most suitable for producing the finished part. Also, because almost all of the many different types of polyethylene can be moulded on standard equipment, the polyethylene type that is most suitable for a particular application is not always chosen.

EFFECT OF TYPE OF POLYETHYLENE ON PROCESSING AND PROPERTIES OF MOULDINGS

To obtain polyethylene mouldings which will withstand long and arduous service two important questions must be answered:

a. Which type of polyethylene should be used?

b. What are the correct moulding conditions?

To do this it is necessary to know how the different types of polyethylene used for injection moulding differ from each other: first, in the way in which they are processed and second, in the physical properties of the moulded article.

Classification of Polyethylenes

The most important variables which characterise a polyethylene are its Melt Flow Index (MFI) and density.

Melt Flow Index (MFI)

MFI is a measure of melt viscosity at low shear rates and is defined as the weight in grams of polyethylene extruded in 10 minutes from a special plastometer under a given load at 190°C. Thus, a low MFI corresponds to a high melt viscosity. Figure 3 shows how the MFI is related to the number average molecular weight of the polymer.

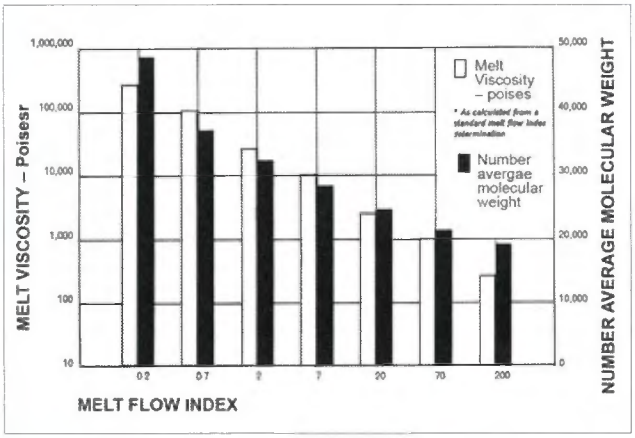


Figure 3: Relation between MFI (g/10 min) and Number Average Molecular Weight

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DENSITY

Density is related to the crystallinity of the polyethylene and is measured in g/cm³.

Because polyethylene molecules are long and contain branches, complete crystallisation cannot take place when polyethylene is cooled from the molten state, and amorphous regions occur between the crystallites. The smaller the number of branches, the more crystalline the polyethylene will be and the higher its density.

Although MFI and density are the most important variables which characterise a polyethylene, it must be emphasised that all polyethylenes with the same MFI and density are not necessarily identical. Each polyethylene producer has specific manufacturing processes and by varying reactor conditions it is possible, while maintaining a constant MFI and density, to alter various features of the polymer such as the molecular weight distribution and the degree of long and short chain branching that cause changes in the processing behaviour and the physical properties of the polymer.

Effect of MFI and Density on Moulding Characteristics

The injection moulding process is shown diagrammatically in Figures 4 and 5. For any given machine and mould, the MFI and density of the polyethylene will considerably affect the injection dwell and cooling times in the cycle. The injection time is not significantly affected and the mould opening, extraction, and mould closing times are not affected by the MFI or density of the polymer.

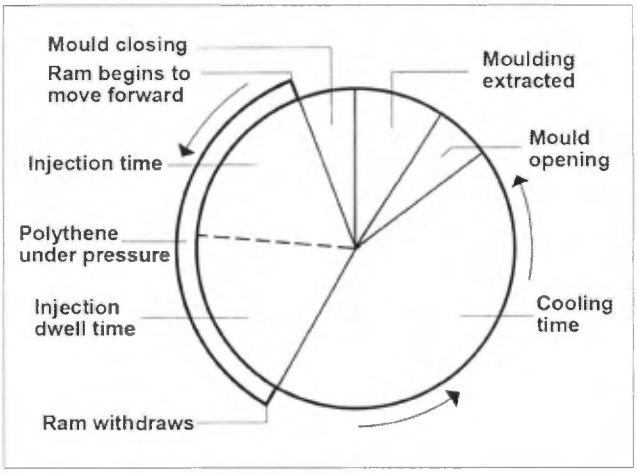


Figure 4: Injection Moulding Cycle

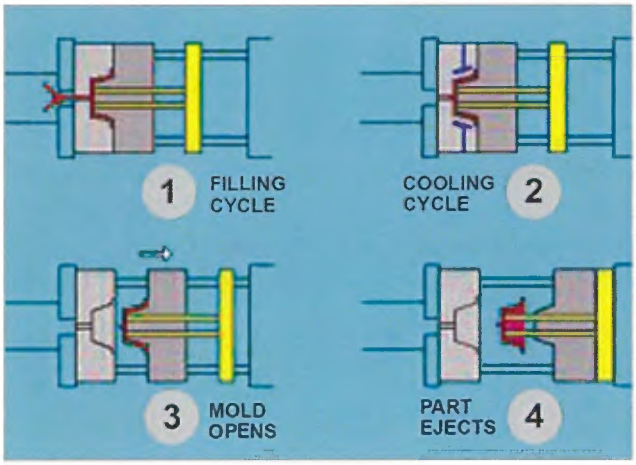


Figure 5: Pictorial Representation of the Injection Moulding Cycle

As far as the polyethylene is concerned the output of any injection moulding machine depends predominantly on two factors:

- The time taken for the polyethylene to reach moulding temperature
- The time taken for the polymer to be cooled sufficiently in order for the moulding to be removed.

A convenient method of assessing the effect of different types of polyethylene on output rate is to plot the number of mouldings which can be made in one hour against the cylinder temperature used. Although the design of the mould and the type of machine affect output greatly, for any given mould on a particular machine an output curve can be obtained by finding for each cylinder temperature the fastest possible cycle which gives mouldings acceptable in all respects except for that of surface gloss, i.e. the minimum injection dwell time, pressure, and cooling time have been used. A typical curve for a plunger machine is shown in Figure 6. It will be noticed that, at first, as the temperature increases the output also increases. The reason for this is that at low temperatures a long cycle is necessary to melt the granules thoroughly, but as the temperature increases, the melting time becomes shorter and therefore the cycle is also shortened. A point is soon reached, however, when the time taken to melt the granules is no longer the limiting factor. The greater parameter of importance is then the time taken for the mouldings to cool to a temperature at which they can be extracted easily from the mould. Beyond this point, as the melt temperature increases the cycle time has to be extended and the output consequently falls.

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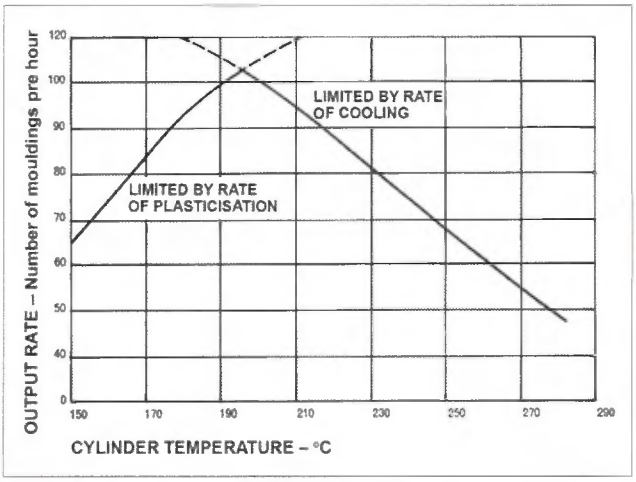


Figure 6: Variation in Output Rate of Mouldings with Cylinder Temperature

Figure 7 shows the effect of density on output rate for polyethylenes of the same MFI. It indicates that the higher the density, the higher the output rate on the cooling side of the curve at any given cylinder temperature. The reason for this is that mouldings of higher density can be extracted from the mould at higher temperatures because they are more rigid at these temperatures than are mouldings of lower density. The higher density materials, however, require higher cylinder temperatures to produce adequate melting of the granules, particularly if the amount of material being handled is near the plasticising capacity of the machine, and the use of such temperatures may slow down the output rate.

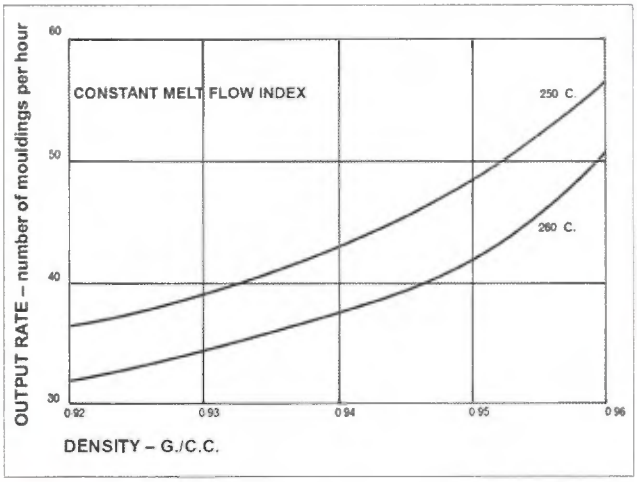


Figure 7: Effect of Density on Output Rate for Polymers of the Same MFI

To use injection moulding machines most efficiently, the cylinder temperature should be chosen so that the output is at its peak. There are, however, two factors which frequently prevent this being done, namely, the necessity to fill the mould, and the desire to obtain mouldings with a good surface finish. These factors are discussed below.

MOULD FILLING

In practice, there are some moulds for which it is not possible to draw an output curve over the whole range of cylinder temperatures because the mould cannot be filled at the lower temperatures. Therefore, the moulding temperature which has to be used is the lowest temperature at which the mould can be filled, and this may restrict the output. In order to attain as close to the maximum theoretical output, good mould filling properties are obviously desirable in a polyethylene.

The spiral flow test was devised to assess the mould filling properties of materials. It involves the measurement of the length of spiral obtained when moulding under standard conditions using the special mould shown in Figure 8. In order to compare different types of polyethylene the cylinder temperature, mould temperature, cycle time, injection speed and pressure are all held constant, and under these conditions the length of spiral obtained gives a good comparative evaluation of the mould filling properties of the polyethylenes being used.

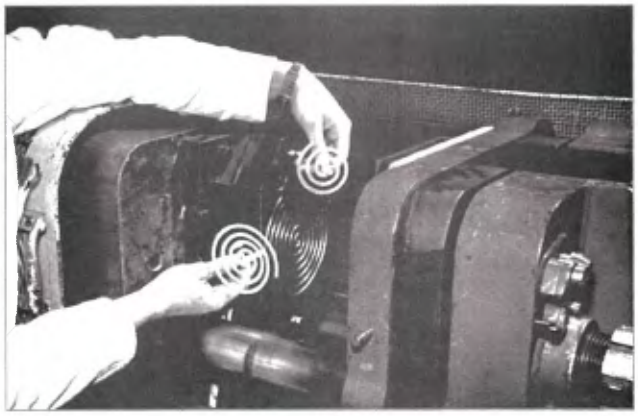


Figure 8: Spiral Flow Mould

Figure 9 shows that the main factor which influences ease of mould filling is MFI. Although density undoubtedly has an effect on the spiral flow length, for polymers with constant MFI this effect is relatively small.

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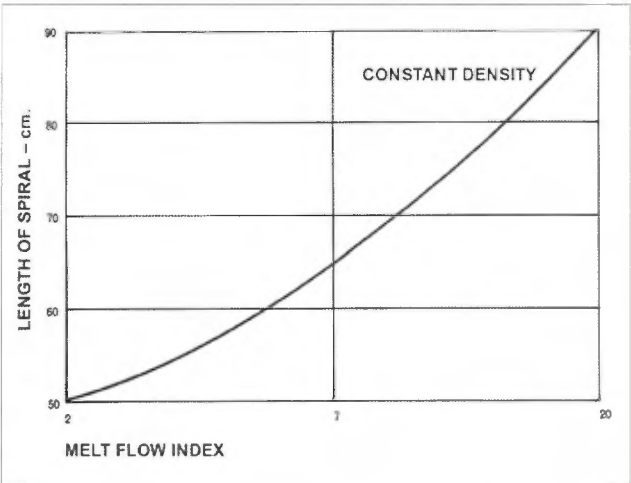


Figure 9: Effect of MFI on the Mould Filling Properties of Polyethylenes of Constant Density

A feature of the spiral flow test is that it can be applied to all injection moulding materials. Figure 10 shows a chart on which the spiral flow length has been plotted against a series of cylinder temperatures for a range of polymers. For most materials the temperatures used range from the lowest at which a readable flow length can be obtained to the highest that can be used without degrading the material. However for polyethylenes of high MFI, with the particular equipment used, the upper temperature was set by the first observance of "flashing" (thin films of excess polymer) on the moulded part.

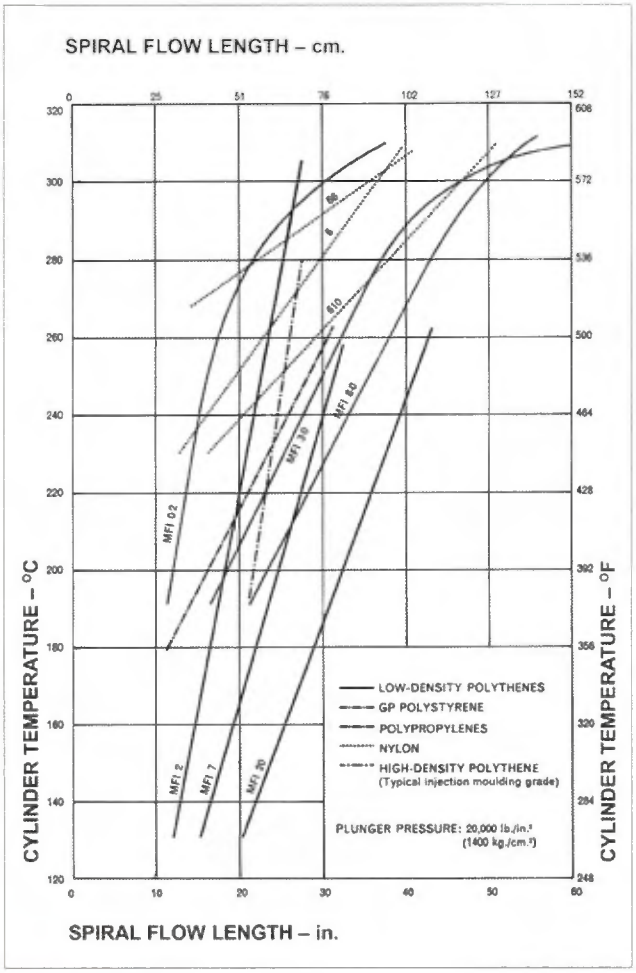


Figure 10: Spiral Flow Curves for some Typical Thermoplastics

Surface Finish

The second factor which may prevent moulding being carried out at the peak of the output curve is the requirement to obtain a good surface finish on the moulded article. It can be seen from Figure 11 that the gloss of a polyethylene moulding improves with increasing cylinder temperature and that mouldings produced at the lower temperatures have 'chevron' marks or rings on the surface (see Figure 12). When mouldings with an even, glossy surface are required it may be necessary to mould at a cylinder temperature which is higher than that which corresponds to the fastest output rate.

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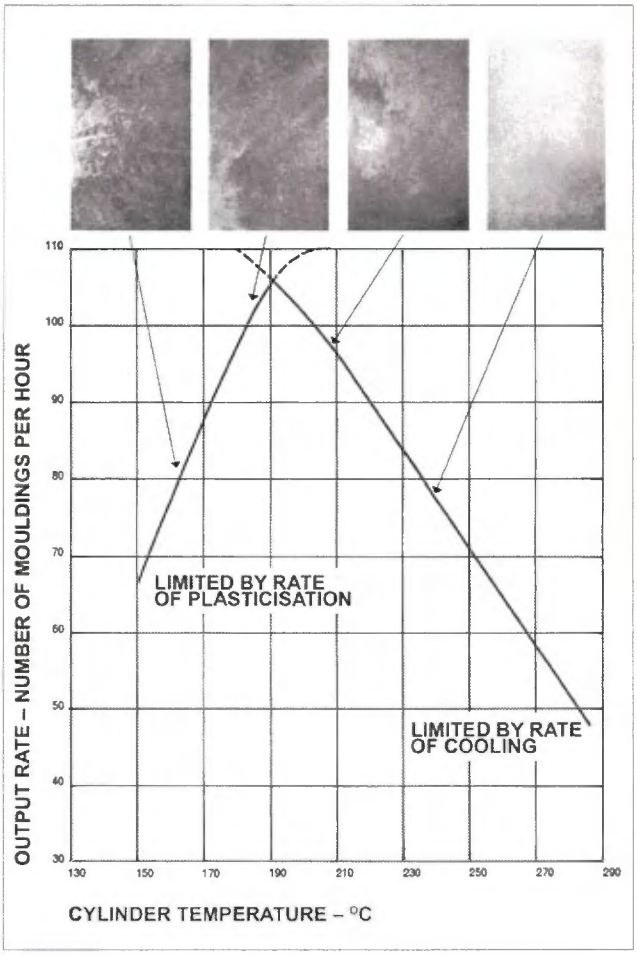


Figure 11: Variations of Surface Gloss of Mouldings with Cylinder Temperature

Gloss is assessed both visually and by measuring the light reflected from the surface of mouldings made under standard conditions. By the latter method, gloss/temperature curves can be plotted as shown in Figure 13. This not only shows the effect of cylinder temperature on gloss, but also the very marked effect of MFI. With a higher MFI, high-gloss mouldings can be produced at a lower cylinder temperature which allows for a faster output (see Figure 13).



Figure 12: Photo Illustrating 'Chevron' Rings on an Injection Moulded Surface

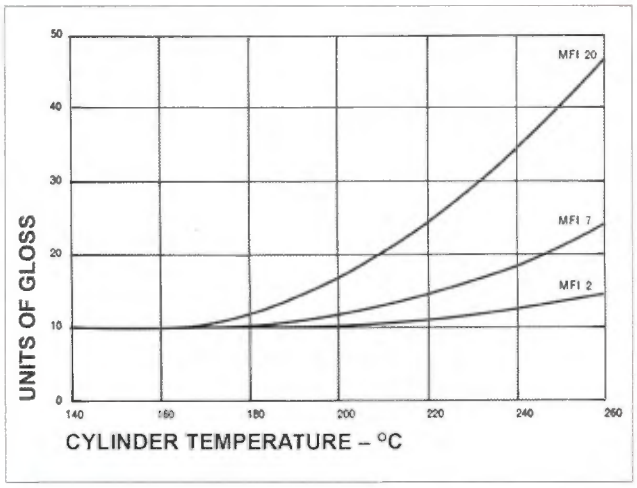


Figure 13: Effect of MFI and Temperature on Gloss

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Summary

It can be concluded that a high MFI is the characteristic mainly responsible for ease of moulding and high output rates. The higher the MFI, the lower the cylinder temperature which can be used to obtain adequate mould filling and acceptable surface finish, and consequently, in most cases, the higher the output will be. For resins with a constant MFI, the degree to which an increase in density leads to higher or lower outputs will depend mainly on the size of the moulding in relation to the size of the machine. For adequate melting of the granules, higher density polyethylenes require higher cylinder temperatures than do the lower density polyethylenes, and melting is more likely to be a limiting factor.

Thus, as far as processing is concerned, the type of polyethylene chosen should have as high an MFI as possible. However, the choice of both MFI and density must also take into account the physical properties required in the finished moulding, and this subject is discussed in the next section.

EFFECT OF MFI AND DENSITY ON THE PROPERTIES OF POLYETHYLENE MOULDINGS

The physical properties of polyethylene which are of particular importance in injection moulded articles are:

- Stiffness
- Impact properties
- Resistance to environmental stress cracking
- Resistance to mechanical stress cracking

Stiffness

The main factor determining the stiffness of a moulding is the density of the polyethylene. Figure 14 shows how the stiffness (as measured by the 100 sec tensile modulus) increases rapidly with increasing density. In the lower density range a change in density of as little as 0.007 g/cm³ will double the stiffness. Figure 14 also shows the effect of temperature on stiffness.

MFI has virtually no effect on stiffness.

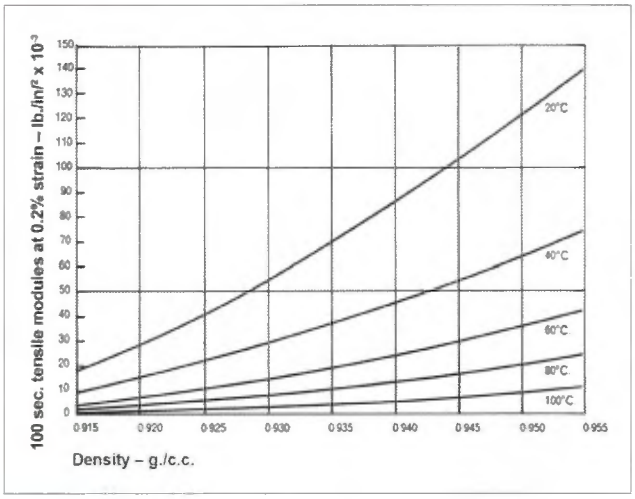


Figure 14: Variation of Stiffness and Density with Temperature

Impact Properties

One of the outstanding properties of low density polyethylene is its toughness; when subjected to impact it will stretch and cold-draw before it breaks, rather than fail in a glass-like manner. On the other hand, medium and high density polyethylenes can fail in a way that is unknown in low density polyethylenes. This type of failure is known as brittle failure. It is quite different from the tough failure of low density materials and is particularly noticeable in mouldings which have sharp notches or scratches on the surface. The usual impact tests for plastic materials are difficult to apply to both brittle and tough types of polyethylene and therefore a special test had to be devised. For this an impact machine is used (see Figure 15) in which small specimens (1 x 1 x 0.16 cm) are notched to a depth of 0.020 cm and subjected to a blow from a pendulum. The energy lost by the pendulum in striking the specimens is termed the impact energy, although much of this energy is expended in bending the specimen as the pendulum swings past it. Polyethylene specimens are rarely broken by the first blow, and therefore after a short rest period they are given a second blow. The energy absorbed by this second blow, expressed as a percentage of the energy absorbed by the first blow, is termed the fracture resistance. This quantity is found to be a useful measure of the amount of damage caused by the first blow.

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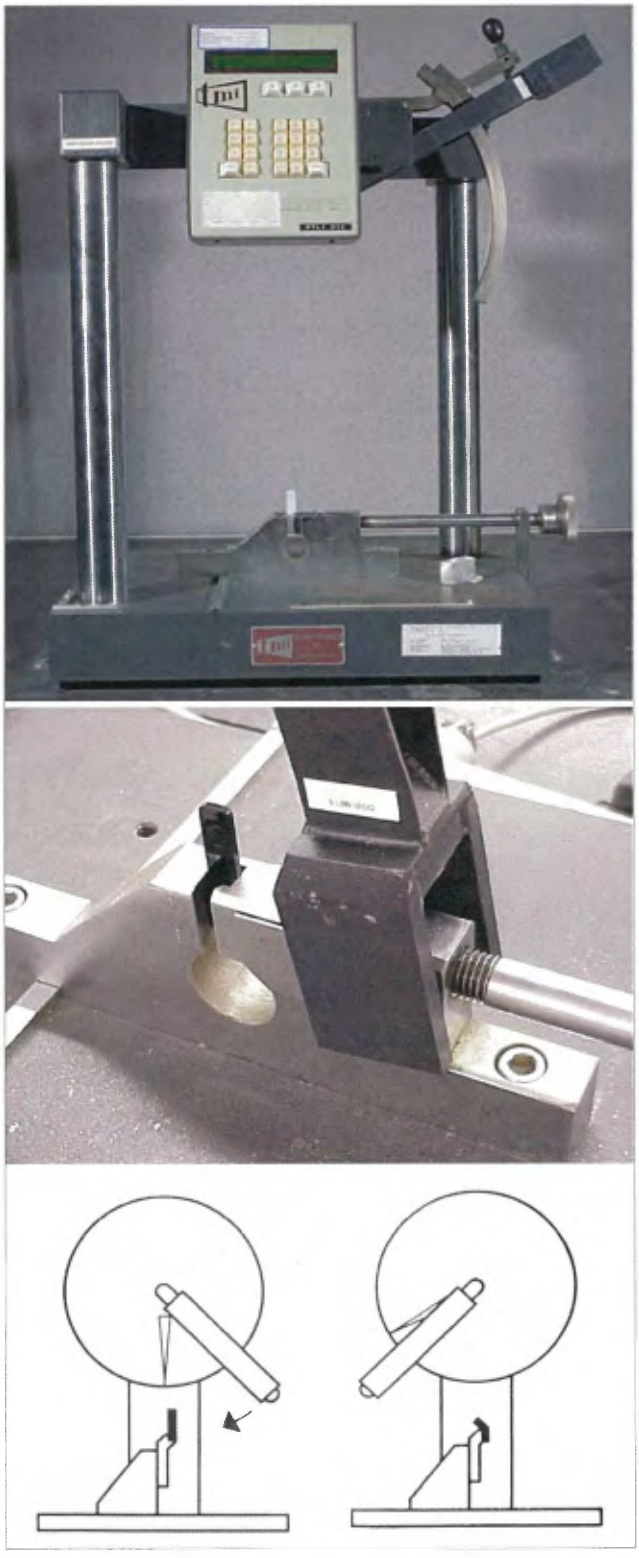


Figure 15: Impact Machine Showing Sample Holder and Process of Use

Impact energy and fracture resistance depend on both MFI and density, as may be seen from Figure 16. For some polyethylenes the impact energy may increase at first with increasing density and then decrease. This initial increase in impact energy is due to the contribution from the energy used in bending a specimen of increased stiffness. Ultimately, however, the increase in density trends towards brittleness, which becomes the dominant factor and results in the measured impact energy falling to very low levels. It can be seen quite clearly that in order to avoid brittleness the higher density polyethylenes must have a low MFI. Consequently, if toughness is required in the higher density polyethylenes, poorer processability, poorer mould filling and, in general, higher processing temperatures will be required. It can also be seen that with polyethylenes of lower density, a much wider choice of MFI is possible without sacrificing toughness.

The dependence of brittle failure on density is also complicated by the fact that the density of any polyethylene is affected by its rate of cooling from the molten state. This effect is illustrated opposite in Table 1.

Values for densities quoted in the literature usually refer to specimens prepared in a standard way involving slow cooling. In injection moulding, however, the polyethylene is cooled rapidly and the molecular chains have no time in which to pack into their equilibrium positions and consequently the density is reduced to below the equilibrium value. Subsequently, over time, the density increases towards its equilibrium value, a process which is very slow but which is accelerated at elevated temperatures. Provided that a polyethylene is chosen with a density and MFI such that the polyethylene, when cooled at the slowest rate found in injection moulding, lies in the 'tough' region in Figure 16, no detrimental change to the mouldings impact strength will arise. But if a polyethylene in the 'brittle' region is chosen (for example, a material with a MFI of 20 g/10 min and a density greater than 0.927 g/cm^3) mouldings produced under conditions of rapid cooling will appear to be tough initially, because of the decrease in density, but may become brittle as the density increases over time.

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Table 1: Effect of Cooling Rate on the Density of Polyethylene (MFI 20)

Cooling Rate	Density g/cm³		
Annealed at 140°C and cooled at 5°C per hour	0.918	0.923	0.927
Annealed at 140°C and cooled at 30°C per hour	0.916	0.921	0.925
Fast cooled in injection moulding	0.913	0.919	0.922

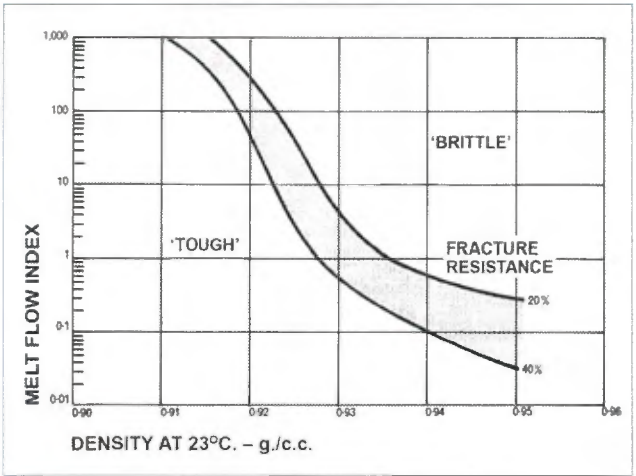


Figure 16: Variations in the "Tough Brittle" Transition (as defined by fracture resistance contours at 40% and 20%) with MFI and Density

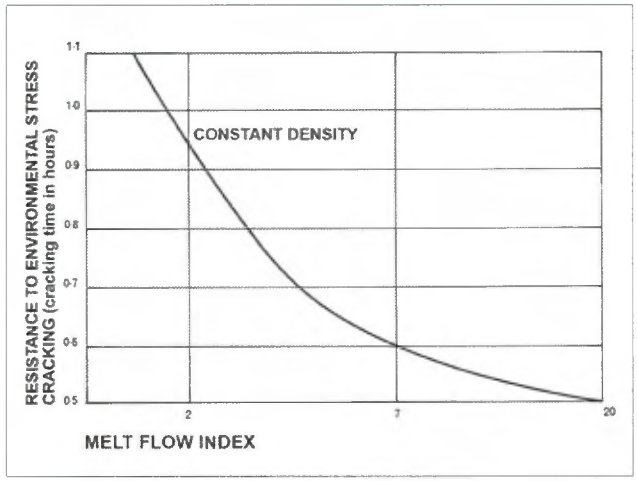


Figure 17: Resistance of Polyethylenes of Different MFI to Environment Stress Cracking

Environmental Stress Cracking

Environmental stress cracking is the name given to a phenomenon by which polyethylene under high stresses may crack in contact with certain active environments such as detergents, fats and silicone fluids.

The resistance of polyethylene to environmental stress cracking decreases rapidly as the MFI is increased. Figure 17 indicates how test specimens of polyethylenes of different MFI and of constant density behave when subjected to a severe stress in the presence of an active environment. Comparison of polyethylenes of constant MFI but of different densities is more complicated because in such tests the specimens are tested under constant strain and therefore the higher density polyethylenes will be under greater stress because they are stiffer. Nevertheless, the comparison is a valid one because in many applications, for example, screwing down a bottle closure or forcing a washing-up bowl into a sink, it is the deformation which is constant rather than the stress.

In practice it is important that high MFI polymers, even of low density, should not be used for applications in which they will be severely stressed when in contact with active environments. For such applications a polyethylene of low MFI is essential and the higher the density of the polyethylene the lower the MFI must be.

A typical application for which a polyethylene of low MFI is preferred in order to reduce the hazards of environmental stress cracking is that of closures used in contact with liquid detergents, soap solutions and certain cosmetics.

It is important however not to exaggerate the seriousness of environmental stress cracking. It has been found that the majority of mouldings made from polyethylene are not subjected to severe enough stressing in service to cause failure, even though they may be in contact with active environments. For example, most polyethylene housewares are in daily contact with both detergents and fats, and yet the externally applied stresses to which they are subjected to are not sufficient to cause failure through environmental stress cracking.

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Careful consideration needs to be made of the choice of polymer that will meet the demands of the finished product and the environment(s) that it will be exposed to (e.g. oils, fats, alkalis, acids and temperature, etc.). To make the best resin selection, customers are advised to discuss their specific end product requirements with their Qenos Technical Service Representative.

Mechanical Stress Cracking

Under certain conditions the moulding process itself can create high levels of internal stress in polyethylene. This is due to the semi-crystalline nature of the polymer which enters the mould in a molten state and undergoes crystallisation as the resin solidifies. The different polyethylenes undergo different degrees of crystallisation which is dependent on their molecular structure.

In general, the polyethylenes can be ranked in terms of their crystalisability/shrinkage in the following order:

HDPE ≥ LLDPE ≥ LDPE

The internal stress that is also commonly referred to as 'frozen in strain' or 'residual strain' may cause similar effects to those seen where polyethylene is exposed to external stresses in service.

The occurrence of 'frozen in strain' is due to both the crystalline nature of the resins used and also as a result of the moulding conditions and the design of the finished part (see Conditions for Moulding Polyethylene section on pg. 18).

Once a polyethylene has been selected (HDPE, LLDPE, LDPE) for fabrication of the finished part, internal stresses can be negated/minimised through careful mould design and by controlling the processing conditions on the injection moulding machine.

Many mouldings, however, are also subjected in service to externally applied mechanical stresses which can cause cracking. Examples of such mouldings are those containing metal inserts (e.g. knobs) and those used for interference applications (e.g. snap-on closures, ferrules or feet for tubular furniture). For such finished parts careful selection of the polymer is important. Within the polyethylenes a balance is required between the MFI (e.g. for ease of processing) and the density (e.g. which affects the level of shrinkage) in order to minimise the level of internal stress.

Generally, higher density polyethylenes would require a lower MFI and vice versa. For example, a polyethylene of MFI 20 g/10 min should generally not exceed a density of 0.918 g/cm^3. Although such "rules of thumb" are only general recommendations, other considerations of mould design and the generation of weld lines in the finished part are factors that need to be reviewed when assessing the strength of the moulding.

For articles not expected to be stressed in service, cracking caused by 'frozen-in strain' is the hazard to be avoided. A polyethylene of higher MFI is preferable because it is easier to mould such a polyethylene to give a low level of 'frozen-in strain'.

Summary

In general, polyethylenes of high MFI and low density are most commonly used for injection moulding because they give the highest outputs, have the best mould filling properties, and give the glossiest mouldings. For applications in which mouldings are likely to be stressed in service, polyethylenes of low MFI must be used. If increased stiffness is required, polyethylenes of higher density are necessary, but these must have a lower MFI to prevent them from becoming brittle and to improve resistance to environmental and mechanical stress cracking. For non-stressed applications 'frozen-in strain' is the hazard to be avoided and a polyethylene of higher MFI is preferred. Provided that these few simple principles are followed, articles giving a long and satisfactory service life can be moulded from polyethylene without difficulty.

SOME ASPECTS OF DESIGNING MOULDS FOR POLYETHYLENE

A detailed examination of mould design is outside the scope of this booklet. There are however, three problems affecting mould design which, although not peculiar to low density polyethylene, occur frequently with this material and which can conveniently be discussed here. These are:

- Shrinkage
- Distortion
- Weld lines

Shrinkage of Polyethylene Mouldings

The influence of moulding conditions and the shape of mouldings is so great that it is almost impossible to predict the exact shrinkage of polyethylene mouldings. It is recommended therefore that trials under controlled moulding conditions should be carried out before the mould is hardened and polished. The mould may then be adjusted accordingly. To allow for any after-shrinkage the dimensions of mouldings should not be checked until at least 24 hours after removing the mouldings from the mould.

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Measurements must be checked in all important dimensions because mould shrinkage varies with the direction of flow, and checking only one dimension and applying proportional corrections to the others may lead to major inaccuracies.

The following major variables affect mould shrinkage.

- **Melt temperature:** the higher the melt temperature, the greater the shrinkage will be
- **Mould temperature:** the higher the mould temperature, the greater the shrinkage will be
- **Injection dwell time and injection pressure:** shrinkage will be smaller for longer injection dwell times and higher pressures
- **Thickness of section:** the thicker the moulded section, the slower the cooling and the greater the contraction of the moulding will be
- **Orientation:** shrinkage will be greater in the direction of flow than at right angles to it
- **Density:** shrinkage is greater with polyethylenes of higher density e.g. a polyethylene of density 0.930 g/cm^3 will shrink more than a polyethylene of density 0.918 g/cm^3
- **Gating:** shrinkage is usually greater when pin gates are used than when sprue gates are used

Because the above variables have such a marked effect on shrinkage, it is clear that in order to maintain accurate dimensions, close control of moulding conditions is essential. Cooling channels must provide adequate and even control of mould temperature over the whole mould. Cycle time control is of equal importance, especially for precision work. Injection pressures should be controlled and the values checked regularly on a gauge.

A point which must always be kept in mind when specifications call for close moulding tolerances is that the coefficient of thermal expansion of polyethylene is high and that a change of 5°C in room temperature will alter the length of a moulding by as much as 0.001 cm/cm.

Some examples of shrinkage are illustrated in Figure 18. Because it is usually on small mouldings that close dimensional control is required, Figure 18 shows where sink marks and warping are likely to occur in such finished items.

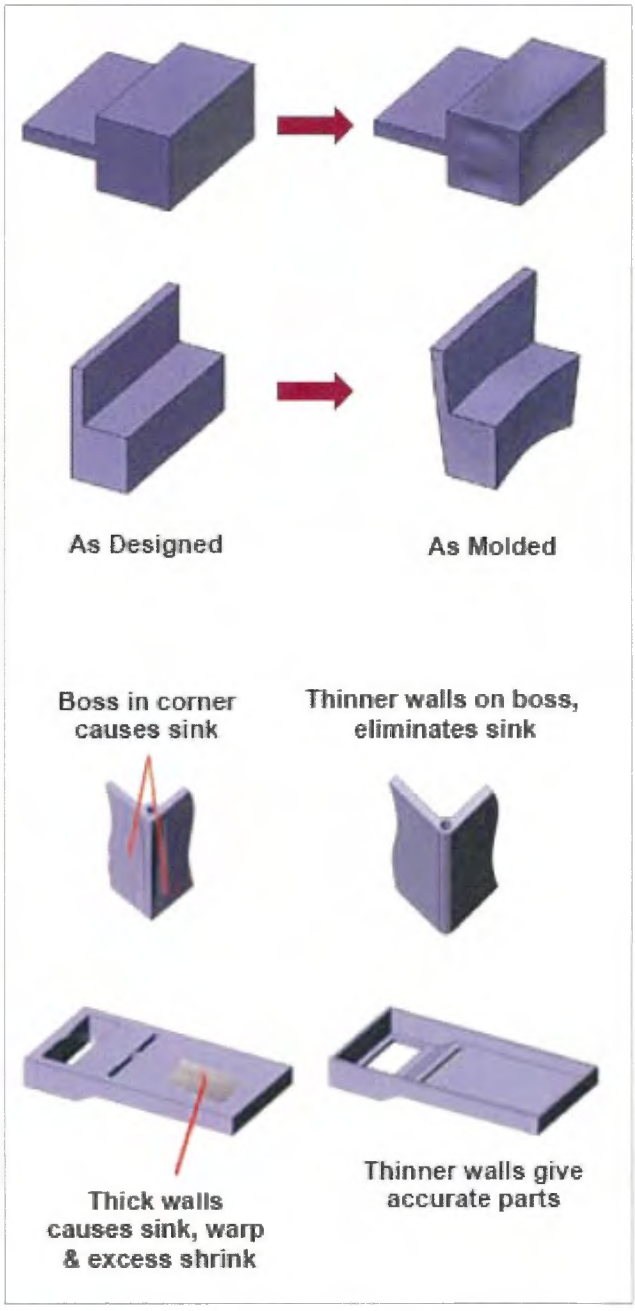


Figure 18: The Effects of Processing Conditions on Shrinkage and Warping

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Distortion of Polyethylene Mouldings

Distortion or warping of polyethylene mouldings can be a problem on flat articles which do not have a solid rim or walls to keep the base firmly held in position. The explanation of this warping is mainly due to polymer orientation and differential crystallisation across the moulding (see Figure 19).

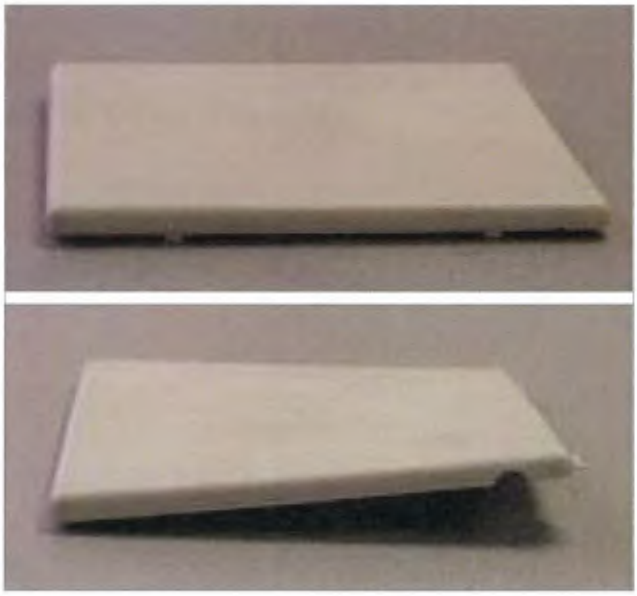


Figure 19: Processing Conditions Causing Polymer Orientation which Leads to Warping

When the mould is first filled, a hot moulding will be made. As the mould fills, the long thread-like polyethylene molecules would tend to be oriented in the direction of flow i.e. radially outwards, but as the moulding cools a radial shrinkage will occur which is greater than the shrinkage at right angles to the radius. Thus when the moulding is cold it will inevitably warp due to the difference in the stresses generated in the part. All methods of preventing the distortion of flat articles without rims or walls depend, in essence, on reducing this difference.

Mould Design

To reduce the warping in articles, multiple pin gates must be used. This system relies on reducing the length of each radial flow path and inter-mingling the melt streams, and is often adequate for low and medium density polyethylenes (see Figure 20).



Figure 20: Photos Illustrating Multiple Pin Gating and Fan Gating

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For rectangular shapes the ideal gating arrangement is a fan gate (see Figure 20) all along one edge so that flow takes place mainly along the major axis. The moulding will still shrink to a greater extent in the direction of flow, causing the major axis to be proportionately shorter than the minor axis when the moulding is cold, but it will not distort. To position a gate at the end of a rectangular article is relatively easy on small mouldings to be made on multi-impression tools, but it is not so easy on large single-impression moulds. Some machine manufacturers can arrange for off-set injection points by altering the nozzle position from the usual central point and this is a very useful feature if large flat articles are to be made from high or low density polyethylene.

Choice of Polymer

The likelihood of warping increases rapidly with increasing density of the polyethylene used: high density polyethylene mouldings warp more than those of medium density, which in turn warp more than those of low density polyethylene. If flexibility in the moulding can be tolerated, a polyethylene of low density (e.g. 0.916 g/cm^3) will give the least distortion. If the mouldings are not to be stressed and physical strength is not important, e.g. sink trays and many box lids, the best results are obtained from a low density polymer of high MFI (22-70 g/10 min, according to the lack of strength which can be tolerated).

Moulding Conditions

Obviously the ideal moulding conditions would be those which give no orientation in the moulding and thus no warping. In practice such conditions can never be achieved. It has been found that long injection dwell times and high pressures, because they reduce the overall level of shrinkage, can often reduce warpage, but these conditions give rise to packing stresses and may cause the mouldings to split across the sprue. The best compromise in moulding conditions has been found to consist of a very high melt temperature (i.e. 50°C higher than that normally used for a given polyethylene) and a very cold mould (i.e. as cold as can be achieved).

Weld Lines

Weld lines can occur in any plastic moulding when the melt stream is divided as it flows round some obstruction, or can arise through non-uniform filling of the mould caused by, for example, eccentricity of cores (see Figure 21).



Figure 21: Mouldings Illustrating the Formation of Weld Lines When Two Melt Fronts Meet

Weld lines are particularly troublesome in polyethylene mouldings which are stressed in service, because failures are likely to occur some considerable time after the part has been installed. With many plastics, weld lines are immediately obvious as a physical weakness in the moulding which is detectable by brittleness on impact or flexing. With polyethylene, the fault may not appear so serious, and it may only be when stress is applied over a period of time in service, particularly in contact with an active environment, that failure will occur. Weld lines can be minimised by the use of high melt and mould temperatures, and also by utilisation of high injection pressures. Although care must be taken not to create greater difficulties by introducing packing around the sprue. A better solution however is to avoid weld line formation wherever possible by suitable positioning of the gate. On many bottle closures for example a centre pin gate can be used instead of a side gate. The mould may cost more with centre gates, but with bottle caps in particular, which are stressed in an outwards direction, the advantages of mouldings free from weld lines are great. In many cases the additional strength conferred by centre gating will permit the use of a polyethylene of high MFI which, although poorer in resistance to environmental stress cracking, will process easier and faster. Where articles of cylindrical shape are highly stressed in an outwards direction and centre gating is not possible, serious consideration should be given to diaphragm or ring gating.

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Flow Weld Lines

These generally occur towards the end of the flow path on a thin-walled article of large surface area, e.g. certain types of buckets. They are caused by the dividing of the advancing melt front into separate streams which fail to fuse together when the mould is full. This effect is aggravated by inadequate pressure on the melt or too low a melt temperature. The weld lines formed may be barely visible to the naked eye, but they can readily be detected by immersing the moulding in carbon tetrachloride at a temperature of 50 to 70°C where fissures will open up. Such weld lines are quite common and cause splits in the walls of thin containers (see Figure 22).

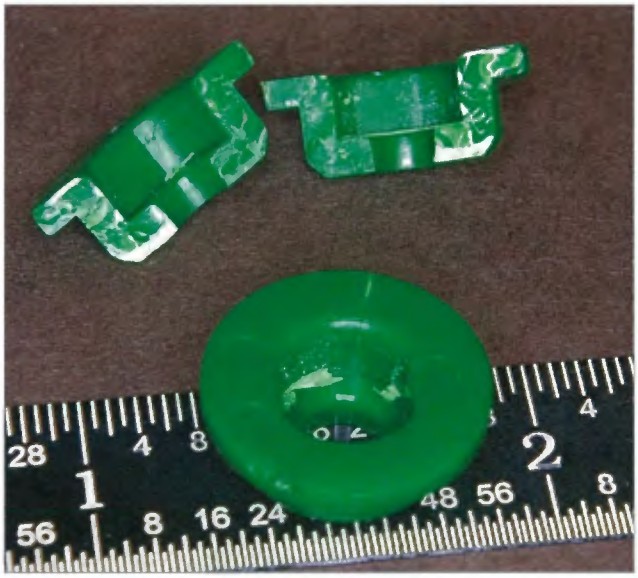


Figure 22: Failure Due to Flow Weld Lines

CONDITIONS FOR MOULDING POLYETHYLENE

In the injection moulding process the moulder is able to control several operating variables, each of which can influence the quality of the mouldings or the rate at which they are produced. These variables are:

- The temperature of the machine cylinder
- The temperature of the mould
- The 'injection variables', i.e. the injection pressure and speed, and the cycle time

The aim of the moulder must be to choose, for each particular material and moulding, the correct combination of variables which will produce perfect mouldings as easily and as quickly as possible. The position is somewhat complicated by the fact that a moulding that looks perfect may not in fact be so because of the presence of 'frozen-in strain', and therefore the choice of moulding conditions must take into account their effect, not only on the appearance of the moulding, but also on 'frozen-in strain'. In the following sections each variable will be discussed in the light of these two considerations, together with other relevant factors, such as the use of mould release agents. Finally a table, summarising some common moulding faults, their causes and remedies, is given (see Appendix 2).

Cylinder and Melt Temperatures

The melt temperature is the temperature of the polyethylene as it enters the mould. Depending on the grade of polyethylene being used, the temperature should lie in the range 160–280°C. In practice, it is not convenient to measure the melt temperature directly, and it is therefore necessary to use the machine cylinder temperature as a guide to the value of the melt temperature. The important point to note is that the cylinder temperature as indicated on the control panel instruments is not necessarily the same as the melt temperature, because the melt temperature depends on the rate at which the material passes through the cylinder and through the gate of the mould, as well as on the cylinder temperature. For example, if the shot weight is almost as large as the shot capacity and mouldings are being produced very rapidly, the material will be in contact with the heated cylinder for only a short time before being injected and may not have time to reach the temperature of the cylinder but may be as much as 30°C lower. On the other hand, in a machine of larger capacity that is working at slower output rates, the time of contact will be longer and consequently a lower cylinder temperature can be used and the difference between it and the melt temperature can be reduced to about 5°C. Similarly, a moulding containing a thick section will require a lower cylinder temperature than will a moulding of equal weight but of thinner section. This is because the thick moulding will require a longer cooling time and thus a longer cycle time than the thinner moulding; therefore the material will be in contact with the heated cylinder for a longer time and its temperature will more nearly approach that of the cylinder. A less common cause for the melt temperature to be different from the cylinder temperature is frictional heating of the material as it passes through the gate;

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if material is injected rapidly through a small gate the heat generated may be sufficient to raise the melt temperature above that of the cylinder.

From these examples it is clear that it is not possible to predict the exact cylinder temperature that must be used to obtain a given melt temperature, but that it is necessary to choose a suitable cylinder temperature as a starting point and then to make adjustments based on visual inspection of the mouldings and on considerations of 'frozen-in strain'. For grades with MFI above 20 g/10 min the suggested starting temperature is 210°C and for grades with MFI below 20 g/10 min the suggested starting temperature is 260°C.

When the cylinder temperature has been set, the injection pressure and cycle time should be adjusted to the minimum values consistent with the production of full mouldings, and moulding should then be carried out for long enough (usually 15-30 minutes) to enable conditions to settle down. The mouldings should then be inspected and tested. Testing should be conducted after conditioning for 24 hours, preferably in a constant temperature environment.

Appearance of Mouldings

If the surface of the mouldings is dull or patchy, or contains matt rings or 'chevron marks' (see Figure 12), this is an indication that the melt temperature is too low, and the cylinder temperature should be raised until mouldings with a uniform, glossy finish are obtained. If the surface finish is acceptable, but mouldings are tending to stick in the mould, the melt temperature is probably too high and the cylinder temperature should be reduced until the trouble is eliminated. These procedures are effective for all grades of *Alkathene* LDPE but it should be remembered that with materials of MFI below 0.5 g/10 min the cycle time may have to be rather long to allow the melt to reach the required temperature.

Frozen-in Strain

Melt viscosity (and hence melt temperature) is the most important factor determining 'frozen-in strain'. As highlighted in Appendix 1 the presence of 'frozen-in strain' is associated with orientation of the polyethylene molecules as they are injected into the mould cavity. At high temperatures the viscosity of the polyethylene is low and the mould is filled rapidly: only the layer of material immediately adjacent to the mould surface has frozen before the mould is filled so that during cooling the maximum relaxation of orientation can take place.

At low moulding temperatures the melt viscosity is higher, the mould fills relatively slowly, and the polyethylene freezes quickly so that relatively little relaxation of the polymer orientation can occur. It has been shown quite conclusively, not only by laboratory tests but also by extensive service trials, that mouldings made at low melt temperatures can contain enough 'frozen-in strain' to overcome the structural integrity of the part and result in failure, whereas those made under optimum conditions are perfectly satisfactory (see Figure 22).

It may be concluded that the optimum cylinder temperature is the lowest at which full, glossy mouldings can be obtained, and that under these conditions 'frozen in strain' will be at a minimum. Too high a temperature will lead to sticking and long cycles, and too low a temperature will lead to strained mouldings.

Mould Temperature

The mould temperature chosen should be that at which good mouldings can be produced with a minimum cycle time. The colder the mould the faster the melt will cool and the greater will be the tendency for 'frozen-in strain' to develop. Therefore, to reduce 'frozen-in strain' a warm mould is recommended and for the minimum amount of strain, a heated mould (as hot as possible) would be required. However, the use of a very hot mould would slow down the cooling rate and thus not only prolong the moulding cycle but also substantially increase the density of the moulding. This is particularly true for mouldings that contain thick sections. As explained in the Impact Properties section (pg. 11), certain polyethylenes can, under these conditions, be brought from the tough region into the brittle region (see Figure 16). In practice, mould temperatures in the range 30-50°C have been found to offer the best compromise between the effects of 'frozen-in strain' and notch-sensitivity. Figure 23 shows the variation of retraction with mould temperature for a constant cylinder temperature.

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5 INJECTION MOULDING

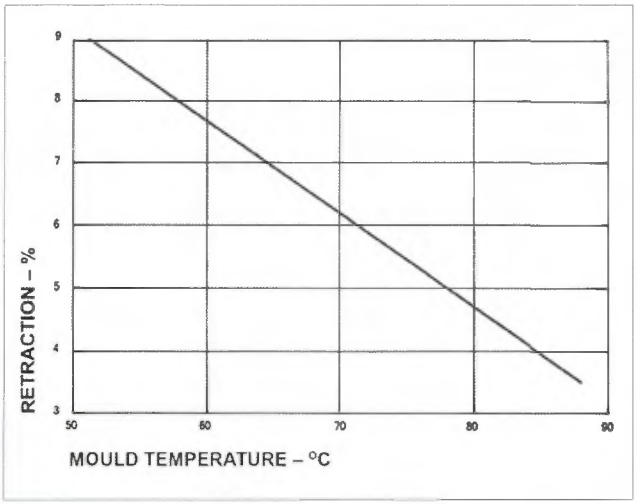


Figure 23: Variation of Retraction with Mould Temperature (Cylinder Temperature is Constant)

Because of the importance of correct mould temperature and the growing tendency to reduce cycle times it is essential, as already remarked, that in the initial designing of the mould, provisions should be made for efficient cooling; unfortunately this is a feature which is all too often overlooked with consequent difficulties in subsequent operation.

Injection Variables

The injection variables will be considered under two headings: injection pressure and dwell time; and mould filling time.

Injection Pressure and Dwell Time

To produce good mouldings, both quickly and economically, the injection pressure should be kept to a minimum and the dwell time made as short as possible. Increasing the packing of an additional volume of polyethylene into the mould during the dwell time to compensate for the shrinkage of the polyethylene due to crystallisation is also important. The degree of packing should be kept to a minimum because the excess polyethylene is forced into the mould cavity when the melt has almost solidified and therefore orientation introduced at this stage relaxes slowly. This can result in a highly strained region being formed near the sprue/gate. The strain may be sufficient to initiate stress cracking and therefore the dwell time and injection pressure must be kept to a minimum.

Figure 24 shows mouldings made from the same type of polyethylene at the same cylinder temperature, but using different injection dwell times and pressures. The samples moulded at high pressure with a long dwell time appear indistinguishable from those moulded under more favourable conditions. But when the mouldings are cut open, it can be seen that excessively high pressures and long dwell times can result in a thickening of the base near the sprue, which in extreme cases, can result in thickness increases of approximately 30%. When the mouldings were then subjected to an accelerated service test in an active environment, the effects of too much packing constituted a very serious cracking hazard.

Mould Filling Time

On some machines the injection speed can be varied virtually independently of the injection pressure by means of a flow control valve. In long, thin flow paths the polyethylene will cool rapidly and this section will contain a fairly high degree of strain. In addition, thin-walled mouldings require higher pressures to fill the mould and, therefore, packing may occur before the extremities of the flow path have been reached. The remedy is to use a higher melt temperature and as fast an injection speed as possible. On the other hand, for thick-sectioned mouldings it is often an advantage to reduce the speed of injection so as to avoid 'jetting' and turbulence which will lead to mouldings with a poor surface finish.

Summary

The moulding conditions necessary to produce good mouldings with the best appearance and the lowest amount of 'frozen-in strain' are:

- A melt temperature just high enough to give a glossy surface to the moulding
- A mould temperature of about 30-50°C
- The minimum injection pressure and dwell time

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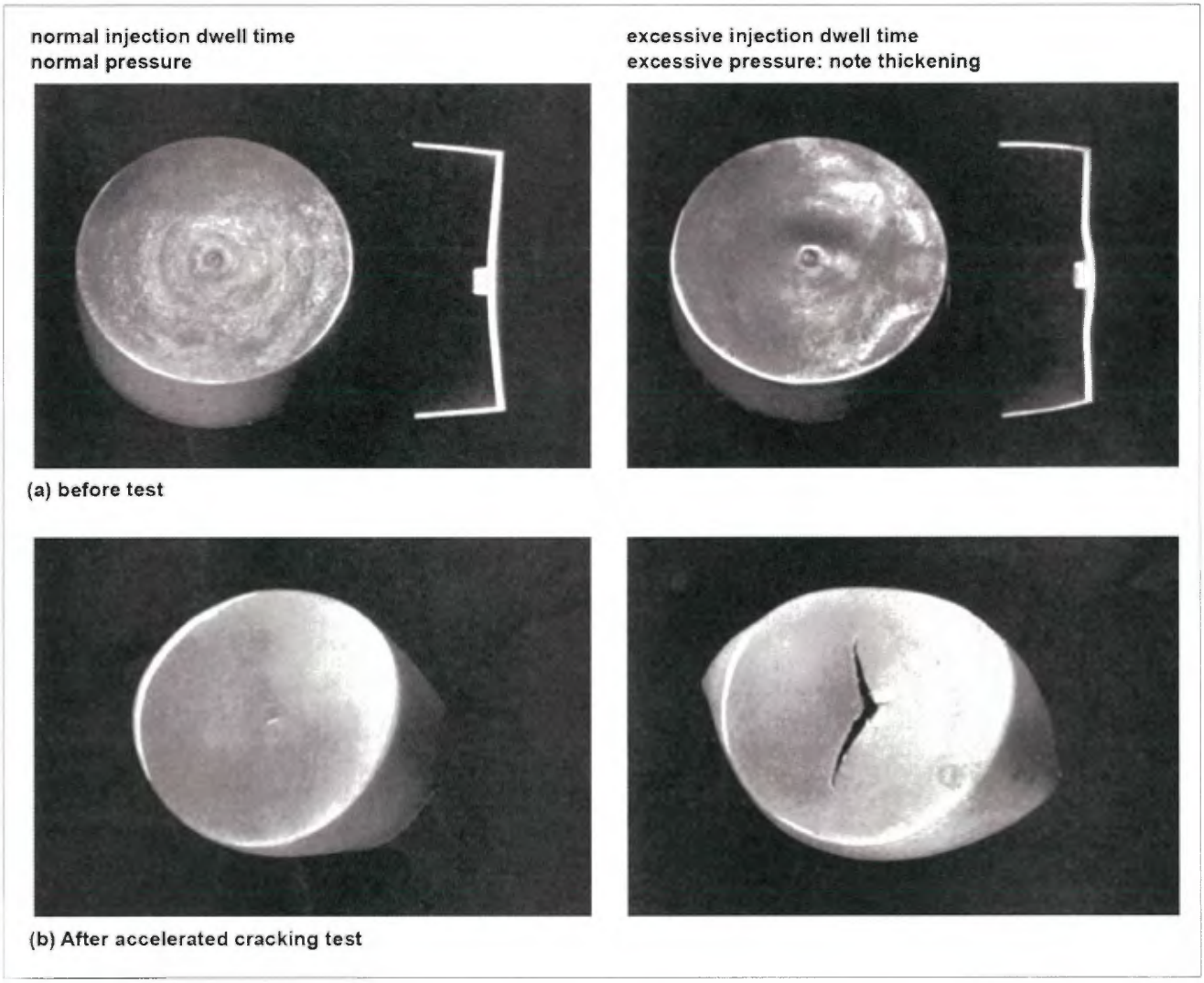


Figure 24: Effect of Injection Pressure and Dwell Time on Polyethylene Mouldings

MOULDING FAULTS

Faults in polyethylene mouldings may be divided into two classes: those that are obvious from visual inspection and those arising from the presence of 'frozen-in strain' – these can be detected only by testing. Appendix 2 lists the obvious faults that can occur, with their possible causes and remedies. Faults arising from 'frozen-in strain' have already been dealt with earlier.

In using Appendix 2 it should be noted that because the machine variables are interdependent a remedy that involves the adjustment of any one machine variable may also necessitate adjustment of the others. Alteration of the melt temperature should be gradual, in steps of 10°C, and a full cylinder of material should be injected before the results of any 10°C step are assessed. Alteration of the cycle time (which affects the length of time the material is in the cylinder and hence the melt temperature) should also be carried out gradually. Enough time should be allowed between successive adjustments to ensure that steady conditions at any one setting are obtained before the effect of that setting on the quality of the mouldings is determined.

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MOULD RELEASE AGENTS

If the correct moulding conditions have been chosen, polyethylene mouldings are unlikely to stick in the mould. If they do, and the fault cannot be corrected by adjusting the moulding conditions, mould lubricants such as stearates or fatty amides may be used. Silicone oils and greases may cause environmental stress cracking in polyethylene mouldings and therefore before they are used as mould release agents they should be tested with the moulding to see if they are suitable. If any doubt exists as to their suitability they should not be used.

DECORATING POLYETHYLENE MOULDINGS

There are several ways in which polyethylene mouldings can be decorated. These fall into two classes: those applied directly to the polyethylene surface; and those which require some form of pre-treatment of the surface. The following sections briefly deal with the various methods of pre-treatment, decoration and also with tests for the effectiveness of these processes.

Decorating Untreated Polyethylene

The following methods are commonly used:

- Hot stamping
- Labelling
- Embossing

Hot Stamping

Basically, this method consists of pressing on to the polyethylene a tape which is coated with pigment. Heat and pressure are applied via a male die and the pigment is released from the tape and fused into the polyethylene. Stamping should preferably be carried out while the moulding is still warm after being ejected from the die.

Because it is recessed, the coating obtained by hot stamping has a good degree of scratch resistance. Other advantages of this process are the absence of solvents and negating the need for drying facilities.

Labelling

Labelling is an inexpensive way of achieving a very wide range of effects. The choice of adhesive will depend on whether the label is required to be permanently fixed or easily removed.

Embossing

A relief pattern on mouldings is easily achieved by cutting the pattern in the mould. Conversely, a relief pattern on the mould produces a corresponding recessed pattern in the moulding. The embossed design can subsequently be decorated by printing or by painting. A wide range of textures and finishes can be obtained by this method.

Decorating Treated Polyethylene

Pre-treatment

Because polyethylene is non-polar and cannot be dissolved in any known solvent at room temperature it is not possible to directly apply conventional inks, paints and lacquers. There are, however, several ways in which polyethylene can be made polar. These are:

- Chlorination
- Chemical oxidation
- Flaming
- Electronic methods

Of these, chlorination is of little commercial importance, and electronic methods are usually restricted to thin films. Flaming is a versatile process which can handle any surfaces which do not contain deep or intricately shaped recesses. Chemical methods are not used so frequently, but they are the most satisfactory for parts of complex design.

Flame Treatment

Flaming a polyethylene moulding results in slight oxidation of the surface. This provides a polar surface which is required for good adhesion. The flame should be oxygen rich, of constant length and should impinge on the surface long enough to result in dulling of the surface. The exact technique will vary according to the shape of the part being treated. The essential point is that all parts of the surface should be uniformly treated.

Chemical Treatment

Chemical methods of pre-treatment involving acid etching are costly and often difficult to operate, but they are used for complicated parts and for parts to be vacuum metallised. Basically the procedure is simple:

- The moulding is immersed for 30 sec to 2 min in an acidified dichromate solution (a typical solution is 100 cm^3 of concentrated sulphuric acid, 50 cm^3 water and 15 g of potassium dichromate),
- Removed from the bath, washed thoroughly and dried.

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The big disadvantage of this method is the need to handle acid solutions; the main advantage is that every part of the surface, provided it is clean, is treated in the same way.

Tests for Pre-treatment

It is obviously desirable to be able to test the effectiveness of any pre-treatment to ensure good adhesion of the finished coating. Several tests can be used, of which those based on 'wettability' of the surface are popular because of their simplicity.

Peel Test

This test involves the use of a solvent-free, pressure sensitive tape. Such a tape has little affinity for an untreated polyethylene surface and is removed fairly easily, whereas it will bond strongly to a treated surface. A suitable tape is No. 850 supplied by Minnesota Mining and Manufacturing Co. Ltd. (3M). The tape is rolled on to the moulding by means of a rubber roller and is then peeled off under standard conditions using a tensometer. By noting the 'peel strength' recorded, a quantitative indication of the treatment level can be obtained. Since decorative coatings vary in their adhesion to polyethylene surfaces, there is no basic correlation between peel strength and adhesion. However, it has been found that treatments giving peel strengths greater than about 120 g/cm will result in satisfactory adhesion of most coatings.

Decorating Methods for Treated Surfaces

Two methods that can be used are:

- Silk-screen printing
- Vacuum metalising

Silk-screening

This is essentially a stencilling process in which the stencil takes the form of a silk, nylon or metal screen which has been made porous, by a photographic process, over areas corresponding to the design to be printed. The screen is held taut in a wooden frame which also serves as a reservoir for the ink. In use, the screen, with ink on its upper surface, is placed in contact with the article and a rubber 'squeegee' is drawn over the screen, thus forcing ink through the porous area on to the article.

Screen printing has the great advantage of low capital cost, particularly when the operation is done manually. Fully automatic units are available. The main disadvantage of silk-screening is that no more than one colour can be applied at one pass. If additional colours need to be applied, then the moulding must be dried before the next colour is applied.

Vacuum Metallising

In vacuum metallising a thin continuous layer of metal is deposited onto a prepared surface by vaporising the metal under high vacuum and condensing it on the surface. In practice, a lacquer is applied to the pre-treated polyethylene as a base coat. This serves to smooth out any imperfections and also acts as a key for the metallic film. The metallic film (usually of aluminium) is deposited, and a top coat of protective lacquer is applied. Low density polyethylene articles are successfully finished in this way. Although the flexibility of the material is a disadvantage.

Tests for Finished Coatings

Two simple but effective tests are the Scratch test and the Scotch Tape test.

Scratch Test

A good idea of the adhesion of a coating can be obtained by scratching it with a finger nail or a knife to see if it flakes.

Scotch Tape Test

In this test a length of pressure-sensitive tape such as Scotch Tape supplied by 3M is stuck on to the polyethylene moulding and then pulled off, slowly at first and then more quickly. The level of adhesion of the coating can be judged qualitatively by the degree, if any, to which the coating is removed.

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APPENDIX 1 – FROZEN-IN STRAIN

It is believed that 'frozen-in strain' develops in the following way. As the polyethylene melt is injected into the mould cavity, it is subjected to high shear forces which produce a certain degree of uncoiling of the molecular chains and causes them to be oriented in the direction of flow. The nearer the melt is to the mould surface, the greater will be the shear stress and the greater the orientation. Because the material nearest to the mould surface cools more rapidly than the material in the interior, this orientation is unable to relax and becomes frozen into position. Thus a highly oriented layer is formed, the thickness of which depends on the temperatures of the melt and of the mould surface. On the other hand, the material on the inside is insulated from the cool mould by a layer of polyethylene and consequently it remains molten until near the end of the moulding cycle. Not only is this material less oriented during mould filling, but most of the orientation that does occur can relax during the cooling stage. Therefore an injection moulded section has a composite structure consisting of a skin which is highly strained and inner layers containing a much lower degree of molecular orientation. Figure 25 is a greatly magnified picture of a section cut through an injection moulding which shows clearly the different layers that are formed. In service, the oriented chains will tend to revert to their normal, coiled configuration and this tendency is reflected in a reduction in the dimensions of a specimen parallel to the direction of flow and an increase in the dimensions at right angles to the flow. If these dimensional changes are resisted by the shape of the moulding, mechanical forces arise which can produce internal stresses large enough to cause cracking in the presence of an active environment.

At elevated temperatures the tendency for the oriented molecules to revert to their normal configuration is increased and some measure of the degree of orientation can be obtained by cutting specimens from a moulding and measuring the percentage retraction which takes place in the direction of flow when the specimens are heated. A large retraction indicates a high level of 'frozen-in strain'.

If a highly strained surface comes into contact with an active environment such as synthetic detergents or fat, a small crack may develop which is likely to propagate rapidly, especially at elevated temperatures. Depending on the particular type of polyethylene, either cracks may develop throughout the whole section or failure may be restricted to surface peeling.

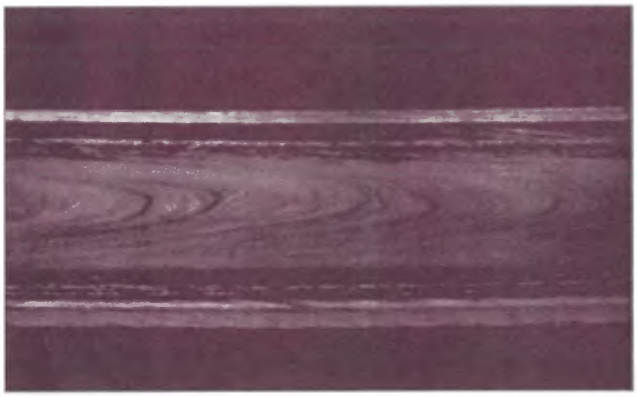


Figure 25: A Section from a Polyethylene Moulding, Showing the Layered Structure

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APPENDIX 2 – INJECTION MOULDING TROUBLESHOOTING GUIDE

Problem/Issue	Cause(s)	Potential Solution(s)/Action(s)
Brittle mouldings	Sharp corners, notches	Increase radii
	PE grade has insufficient impact strength	Use lower flow and/or lower density grade of PE
	Excessive orientation	Increase melt temperature
	Inadequate thickness	Increase thickness of moulding
Burn marks. Carbonised material at end of flow path	Insufficient venting	Increase venting
	Injection speed too high	Reduce injection speed
	Melt temperature too high	Reduce barrel and nozzle temperature settings
Delamination	Incompatible masterbatch	Ensure PE based masterbatch is used
	Contaminant	Check feed for contamination
	Material freezing prematurely	Increase temperature settings. Increase gate size
Demoulding difficulties	Poor design, insufficient draft angles	Increase draft angles, incorporate "slip"additive
	Over packing	Reduce injection speed and or second stage time/ pressure, use higher flow PE grade
	Excessive second stage	Reduce second stage pressure and/or time
Distortion	Moulded in stress/ orientation	Increase melt temperature. Use increased melt flow index grade of PE
	Ribs too thick	Employ more, but thinner ribs to impart stiffness
	Variation in thickness	Use ribs for varying thickness rather than solid walls
	Variation in mould cooling	Increase cooling channels in difficult to cool areas
	Sink marks	Increase second stage pressure and or time
	Gate freezing off too quickly	Increase gate size
Flashing	Inadequate clamp force	Increase clamp force. Move mould to a higher clamp force machine
	Excessive vent size	Reduce venting
	PE melt flow index too high	Change to a low flow grade of PE
	Excessive injection speed	Reduce injection speed
Matt or streaky surface	Gate inappropriately positioned resulting in snake – like jetting	Position gate so that the material is forced to change direction immediately upon entering the mould
	Melt disturbance resulting Matt – Gloss pattern	Increase melt temperature. Reduce injection speed
	Moisture	Dry the polyethylene or masterbatch
	Incompatible masterbatch	Change masterbatch to one with a PE base
Poor colour homogenisation	Back pressure too low	Increase back pressure
	Masterbatch not compatible	Ensure PE based masterbatch is used
	Barrel size too small, insufficient shots in barrel	Move to a larger machine
	Masterbatch add rate too low	Use masterbatch with lower pigment concentration at higher add rate
	Temperature too low	Increase temperature settings

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Problem/Issue	Cause(s)	Potential Solution(s)/Action(s)
Short shots. Incompletely filled mouldings	PE melt flow index too low	Change to higher melt flow index grade
	Melt temperature too low	Increase melt temperature.
	Inadequate vent size	Increase venting
	Inadequate thickness	Increase thickness
	Insufficient injection speed	Increase injection speed
	Insufficient gating	Increase gate size or number
Weak weld lines	Melt temperature too low	Increase temperature settings
	Flow of polymer too low	Use higher melt flow grade
	Injection speed too low	Increase injection speed
	Gate(s) too far from weld line	Move gate or increase number of gates

Disclaimer

The proposed solutions in this guide are based on conditions that are typically encountered in the manufacture of products from polyethylene. Other variables or constraints may impact the ability of the user to apply these solutions. Qenos also refers the user to the disclaimer at the beginning of this document.

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