MEGOLON® LSHF Compounds

(low smoke, halogen-free)

Extrusion Guideline

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1.0 MEGOLON® cable extrusion compounds

1.1 Composition

In general, compounds from the MEGOLON® range are composed of polymers and co-polymers of olefins filled with mineral fillers to give the desired level of flame retardance. They contain appropriately selected antioxidants to give the desired level of stability and processing additives to aid extrusion performance. UV stabilisers and colour pigmentation are also added as appropriate.

1.2 Method of manufacture

Most MEGOLON® compounds are made by mixing the ingredients together in a continuous compounding mixer. Since the mixing process is a reactive one, the point of addition of each ingredient is critical in terms of both time and temperature. Following mixing, the compound is extruded and filtered through a suitably sized wire mesh screen and then pelletised.

The pellets are cooled by water and then dried by a centrifugal process (spun dry) before being packaged up in the familiar octoboxes; the pellets themselves are heat sealed inside a moisture proof liner.

1.3 Packaging and labelling

MEGOLON® is packaged in heat-sealed moisture proof bags contained inside cardboard octoboxes. Quantities are 500kg or 1000kg - all boxes are mounted on wooden pallets and labelled.

1.4 Storage and shelf life

MEGOLON® when kept sealed in original packaging and stored in dry conditions at ambient temperatures, is expected to possess a shelf life of six months from date of delivery. After this time, we recommend that a representative sample of the goods be tested to check that it continues to meet the quality control specification for the product(s).

1.5 Pre-drying

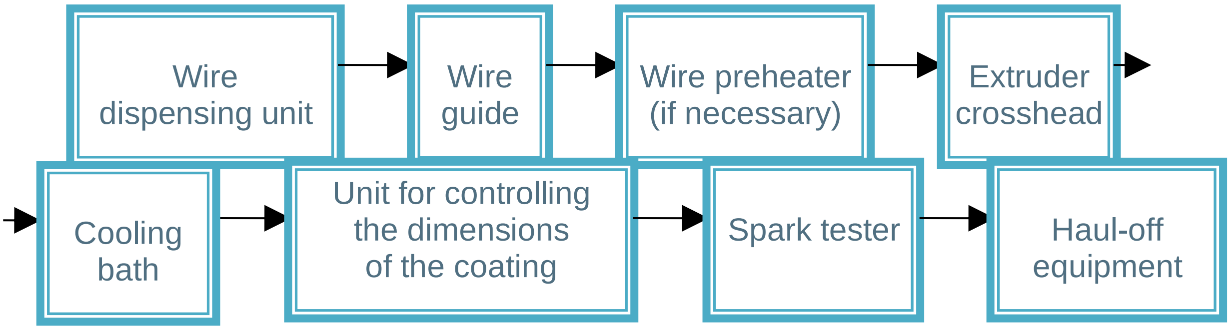
In most cases where the extrusion melt temperature is to be maintained at 165ºC to 170ºC, pre-drying will not be necessary. However, if the melt temperature is expected to rise above 170ºC, or if the material has been stored in a humid environment, or if the material has been stored for an extended period of time, it may well be necessary to dry the material before extrusion.

If this is the case, then Mexichem Specialty Compounds would suggest that a temperature of 60ºC to 70ºC for several hours, preferably in a desiccant hopper, would be adequate.

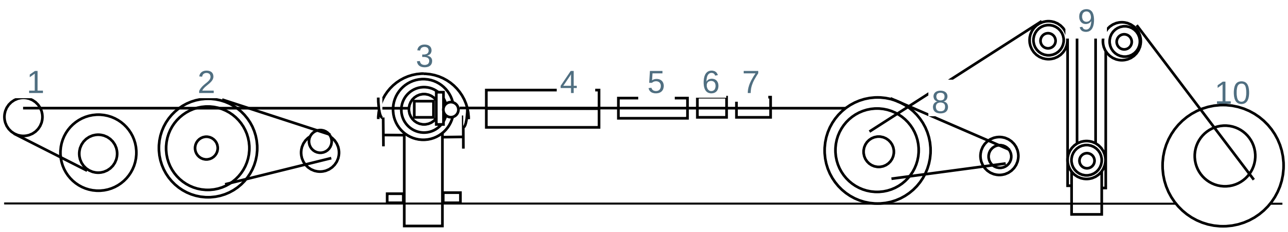
2.0 Extrusion of MEGOLON® compounds

2.1 General description of a wire coating plant

(a) **Diagram**



(b) **Typical layout**



Typical layout above illustrates a cable extrusion line with (1) input drum, (2) capstan wheel, (3) extruder, (4) cooling trough, (5) spark tester, (6) diameter gauge, (7) eccentricity gauge, (8) capstan wheel, (9) tension controller & (10) output drum.

2.2 The extruder

The purpose of the extruder is to convert solid granular material into a homogeneous plastic melt, and to pump the melt at a steady and controlled rate through a shaping die. Extruders can be used to fabricate hoses, window profiles, conduit, stationary goods, sheet materials, straws, drainpipes and gutters, as well as wires and cables. The essential details of a thermoplastic extruder are shown in FIGURE 1.

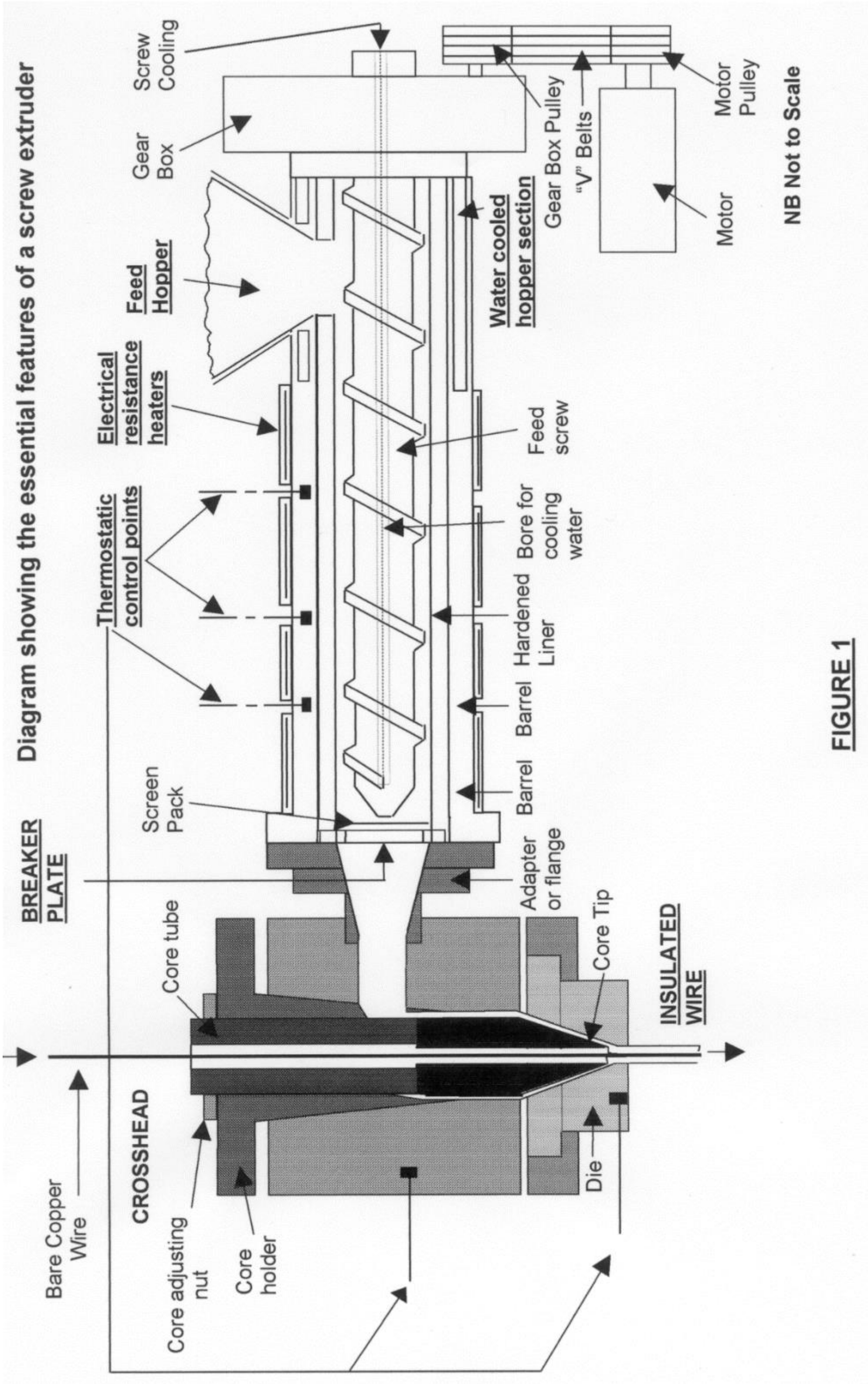


Diagram showing the essential features of a screw extruder
BREAKER PLATE
Thermostatic control points
Electrical resistance heaters
Feed Hopper
Gear Box
Screw Cooling
Bare Copper Wire
CROSSHEAD
Core adjusting nut
Core holder
Core tube
Screen Pack
Barrel
Barrel
Hardened Liner
Bore for cooling water
Feed screw
Water cooled hopper section
Gear Box Pulley
"V" Belts
Motor
Motor Pulley
NB Not to Scale
Adapter or flange
Core Tip
Die
INSULATED WIRE

FIGURE 1

There are two parameters which describe the size of an extruder - the diameter (D) and the L/D *(L over D)* ratio.

The **D**iameter is the inner diameter of the extruder barrel into which the screw fits, the larger the screw diameter the greater the output per revolution.

The L/D ratio is the ***L***ength of the barrel compared to its ***D***iameter. Commonly encountered L/D ratios are 18:1, 20:1. 24:1 and 25:1. The longer the barrel length the greater the time needed for compound to pass through the extruder at any specified particular screw speed. This time is known as the Residence Time. For PVC and PE, as line speed increases, the screw speed increases and hence the residence time decreases. If the residence time decreases too much, then ungelled (unmolten) material can appear in the extrudate. Residence time, and hence line speed, can then be increased by moving to a longer barrel.

The power to turn the extruder screw is supplied by an electric motor. The vast majority of extruders are fitted with a DC (direct current) motor as this type has excellent speed control characteristics. Occasionally an AC (alternating current) motor is encountered but these motors are not as tolerant to load increases and have a tendency to slow down. Vernier controls allow the operator to control the speed of the extruder and the speed of the line. A master control then enables these two to be adjusted in synchronisation with each other.

The motor is normally linked to the gearbox via "V" belts and pulleys. Occasionally the motor may be connected to the gearbox directly. The motor/pulley/gear box assembly, collectively known as the transmission, is designed to deliver a particular torque and speed range to the extruder screw.

The extruder has a number of controlled heating zones. The convention is to number the zones on the barrel beginning at the feed hopper and progressing down the barrel. The actual number of zones will depend on the length of the barrel and the size of the heater bands, and can vary depending on the manufacturer. Normally each heater band, and hence each zone, has an independent controller which uses a thermocouple to monitor the actual temperature. Controllers can be of either the analogue (moving needle) or digital type and also often control fans or blowers to cool the appropriate zone if there is a temperature overrun.

In many extruders, the temperature of the screw can now be independently controlled, usually by passing a temperature-controlled fluid (oil or pressurised water) through the centre of the screw. This facility is usually used only for cooling the screw.

2.3 The screw

The purpose of the screw is to flux and melt the thermoplastic and to pump the melt at a constant rate into the crosshead. Important factors in the design of an extrusion screw are the compression ratio, the channel depth and the screw pitch.

The compression ratio is the ratio of the swept volume in the feed zone to that in the metering zone. Typical compression ratios are 2.5:1 & 3.5:1 for PVC or polyethylene.

The channel depth controls the amount of shear or friction developed in the extrusion process; the more shallow the channel, the higher the shear. The pitch can be varied down the length of the screw and can have an influence on mixing capabilities and the compression ratio.

A number of speciality screw designs exist, amongst them being barrier screws, Maddock screws and 'MEGOLON®' screws.

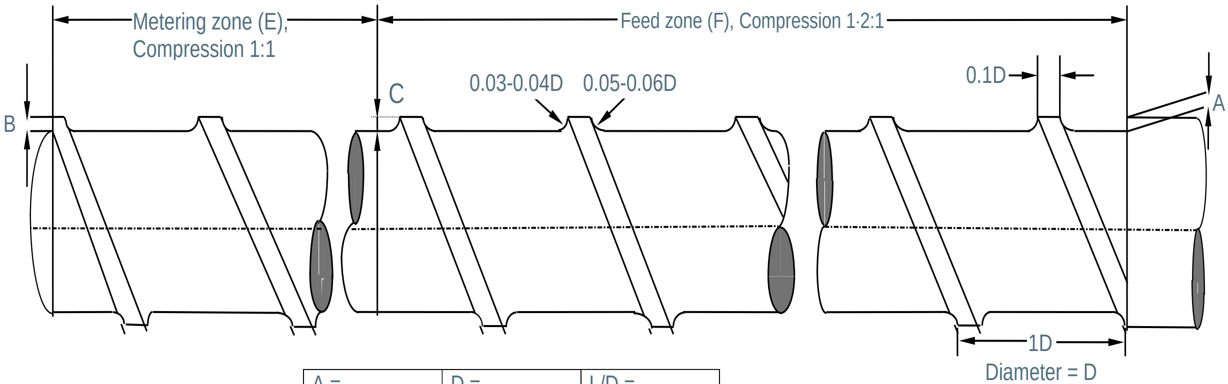
There are a number of different types of barrier screw, but probably the most well known is the Maillefer BM type. These consist of a screw with a single helix upon which is superimposed a second helix which has a smaller flight height and a longer pitch.

A Maddock screw is a mixing screw with flutes parallel to the axis of the screw. We would not recommend a screw of this type for processing MEGOLON®.

The MEGOLON® screw is a fairly simple design in that it has a single flight, with deep channels and a low compression ratio. The design of a MEGOLON® screw is copyright to Mexichem Specialty Compounds as per the attached schematic screw drawing – see FIGURE 2.

We recommend an extrusion screw made to the design of FIGURE 2 for the extrusion of MEGOLON® compounds.

 We would suggest that our Technical Department be consulted in order to determine specific design requirements.



A =	D =	L/D =
B =	E =	
C =	F =	

<u>Schematic Megolon Screw Design</u>
Screw design for the extrusion of thermoplastic, non-halogenated, fire retardant compounds.
(By agreement with Mexichem Specialty Compounds)

<u>FIGURE 2</u>

2.4 The breaker plate and screen pack

The objective of the breaker plate is to create a pressure (known as the back-pressure) at the end of the screw to ensure a homogeneous melt is achieved. The breaker plate consists of a circular steel plate with many holes parallel to the axis of the barrel, so that the melt can flow through. The screen pack consists of one or more wire meshes sited on the screw side of the breaker plate (for support), and acts as a sieve or filter for the melt. The screw creates sufficient melt pressure to force the melt through the screen pack.

There are various meshes available and are normally denoted by their mesh size, which is related to the number of wires in a fixed length. The higher the mesh number, the smaller the hole size. The following meshes are commonly encountered:-

Mesh size	Hole size
20	800 micron
40	400 micron
60	250 micron
80	200 micron
100	140 micron

Usually as the mesh size increases and the size of the holes decreases, then the resistance to flow (and of course backpressure) increases.

We normally recommend employing a breaker plate without screen pack when extruding MEGOLON® - all compound manufactured is screened at the production stage through a 100 mesh pack.

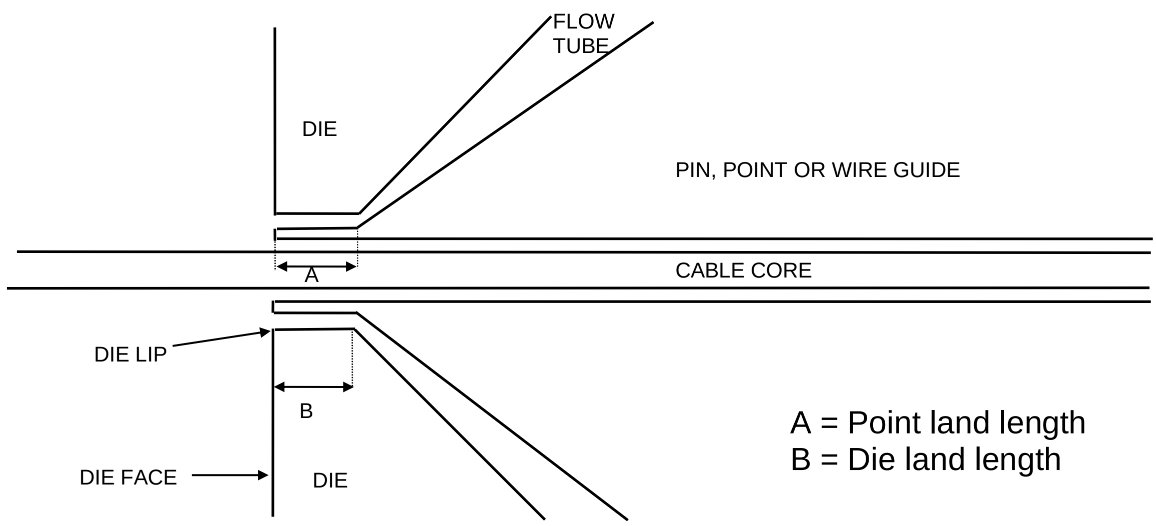
The maximum melt pressure occurs at the end of the screw, before the breaker plate, and if a pressure transducer is fitted, it will normally be located in this region.

2.5 The crosshead and tooling

The crosshead is designed to turn the direction of the flow of the melt through 90ºC, to alter the shape of the melt from a solid profile as exiting from the flange, to a hollow profile prior to presentation to the die sets (wire guides and dies).

The die sets or tools for a given crosshead have the same external dimensions so that they can be located into the crosshead, but have different internal dimensions in order that they can accommodate wires and cables of various diameters. A single crosshead will be able to cope with a minimum and maximum diameter core.

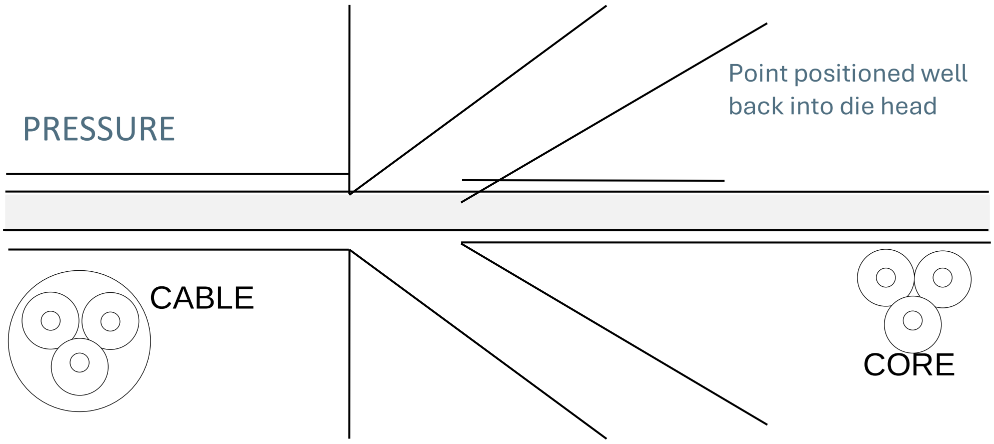
2.5.1 General description of tooling



2.6 Extrusion techniques (pressure or tubing processes)

2.6.1 Pressure extrusion

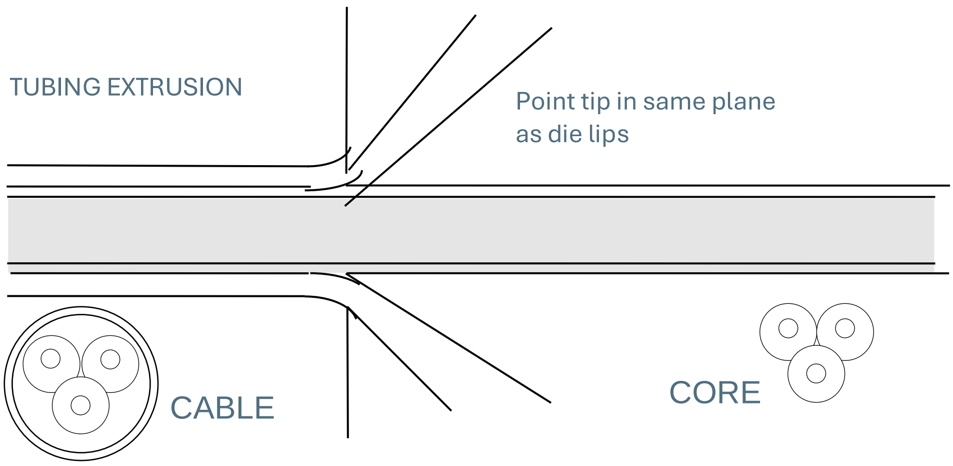
A pressure extrusion technique is employed when it is desired to fill the interstitial voids in a cable design. The purpose of the technique is to ensure that the molten polymer is forced into the gaps between the laid up cores. In this case the tip is positioned well back from the die lips, and usually the tip will have no land. This set up allows the molten extrudate to be forced into the gaps in the cable, thus exerting a pressure on the laid up core. Normally the die diameter is approximately the same size as the finished cable.



Filler compounds are almost always pressure extruded, as are most insulation compounds.

2.6.2 Tubing Extrusion

A tubing technique uses less material than a pressure technique, and also provides a cable with greater flexibility. The purpose of the technique is essentially to lay the cable core inside a tube (or jacket).

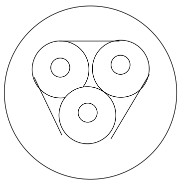


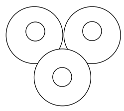
The tubing set- up involves the tip of the point being positioned in the same plane as the die face. The core commonly passes through the die and point at a higher speed than the extrudate flows through the die. This causes the melt to be elongated and pulled down onto the cable core. The degree of elongation is measured as the Draw Down Ratio. A Draw Down Balance of 1 ensures that the sheath is drawn down evenly in proportion. Tubing technique is commonly used for sheathing.

We recommend that knife-edged tooling (tooling WITHOUT lands) is used for extruding MEGOLON® compounds.

We recommend a tubing set up for extruding a MEGOLON® sheath using a draw down ratio of 1.5 and a draw down balance of 1

2.6.3 There is a “half-way house”, sometimes called **Semi-pressure extrusion**, with a technique similar to tubing. The point is positioned slightly back into the die lips, but not as far as in a true pressure technique. A semi pressure technique does not fill the laid-up core like a pressure technique, but ensures that the tube grips the laid up core firmly.


CABLE


CORE

2.7 Water bath

The water bath consists of a trough containing cold water into which the cable passes to cool the extrudate. For MEGOLON® compounds it is usually desirable to have the water bath as close to the head as possible in order to reduce the possibility of gassing.

2.8 Spark tester

This device creates a strong electrical field (5 - 10 kV usually) on the outside of the cable. If there is an imperfection in the jacket (i.e. a pinhole or porosity), the voltage is discharged as a spark, which triggers an alarm and a counter or cable marker.

2.9 Pay-off and Take-up

A pay-off device feeds the extruder with the appropriate wire or core and normally consists of a device to hold and rotate a cable drum. A take-up coils the jacketed cable or insulated wire onto a suitable cable drum.

2.10 Printing

There are various ways of printing cable for identification purposes. Generally, if a customer is already using a particular method, then MEGOLON® compounds generally work well with methods used for printing of polyethylene.

As an alternative way of marking, cables are often embossed with a metallic wheel which has a reverse legend engraved on the surface. The wheel is placed in contact with the cable before it passes into the water bath and pressure is applied. The molten jacket flows slightly into the engraving leading to a raised or embossed surface.

2.11 Extrusion parameters

(a) Melt temperature measurement

The output from the thermocouples on the zone temperature controllers do not give an accurate idea of the actual melt temperature as these thermocouples are sited within the barrel walls some distance from the melt. The most accurate method is to use a hand held probe or an infra red probe. The hand held probe can only be used during a bleed trial as the surface of the extrudate is severely marked. An infra red probe is a non-contacting method and can measure melt temperature on the cable as it is being extruded.

(b) Screw speed measurement

It is normally a relatively easy task to manually time a fixed number of revolutions on the screw and calculate the true rotational speed. This can then be compared to the indicated speed and any instrument errors accounted for.
The screw speed indicator normally takes its signal from a tachometer attached to the motor. If the pulley ratios have been changed since the machine was installed then the screw speed indicator could be significantly inaccurate. The manual check will confirm the validity of the speed indicator.

(c) Motor current and voltage

The motor current is normally indicated by a digital or analogue device and can be read directly. The motor voltage can be calculated from the details given on the motor nameplate. As the screw is normally coupled directly to the motor by a fixed ratio, then the motor voltage is directly proportional to the screw speed.

(d) Head pressure

The maximum melt pressure occurs at the end of the screw (before the breaker plate if one is used) and it is here that a point for a pressure transducer is positioned. However, most extruders in the industry are not fitted with pressure transducers but valuable comparative information can be gained if one is fitted. The output from the transducer can be displayed either in analogue or digital format.

(e) Output

Output is best measured by performing a bleed trial. At a given screw speed, the extrudate is gathered for a fixed period and then weighed. To obtain the output in kg/hr, multiply the output for 36 seconds (in kg) by 100. It is usual to measure the output over a range of screw speeds, and a linear increase in output with screw speed is normally found.

2.12 Useful calculations

(a) Draw down ratio

This is normally required to be known when performing a tubing extrusion (where the cable core is travelling faster than the extrudate exits the die lips). Hence the melt is "drawn down".

$$\text{Draw down ratio (DDR)} = \frac{(Die^2 - Tip^2)}{(OD^2 - ID^2)}$$

where

where	Die	=	diameter of the die aperture
	Tip	=	tip diameter of the point or pin
	OD	=	outside diameter of the finished cable
	ID	=	inside diameter of the cable sheath (or outside diameter of the cable core)

We recommend a tubing set up for extruding a MEGOLON® sheath using a draw down ratio of 1.5

(b) Draw down balance

To ensure that orientation (draw down) of the compound takes place uniformly over the thickness of the cable sheathing, the concept of draw down balance was developed. It can be shown that, ideally, the ratio of the diameter of the point and die should be the same as the ratio of the diameters of the cable and its core i.e. the draw down balance should equal 1. Mathematically, this can be expressed as follows:-

$$\text{Draw down balance (DDB)} = \frac{(Die/Tip)}{(OD/ID)} = 1 \text{ (ideally)}$$

We recommend using a draw down balance of 1 for extruding a MEGOLON® sheath

(c) Die selection

The use of the above equations can help in the selection of a particular set of extrusion tools. The target cable sizes will normally be known (i.e. the OD and ID). The equations can then be used to derive the following <u>ideal</u> tool sizes:-

$$Die = OD \times \sqrt{(DDR)}$$
$$= 1.225 \times OD \quad \text{for MEGOLON® sheathing}$$

$$Tip = ID \times \sqrt{(DDR)}$$
$$= 1.225 \times ID \quad \text{for MEGOLON® sheathing}$$

However, in many cases the cable manufacturer will require the extrusion point to act as a guide tube for the core on its path through the extrusion head. If this is the case, then the diameter of the point (Tip) will

usually be defined by the size of the laid up core, so for a given draw down ratio, the only unknown is the die aperture size (Die). This can be calculated from the following equation:-

$$\text{Die} = \sqrt{1.5\,(OD^2 - ID^2) + Tip^2} \qquad \text{for MEGOLON}^{®} \text{ sheathing}$$

2.13 Troubleshooting

2.13.1 Porosity

Sometimes called gassing or foaming. During extrusion, any moisture present in the compound will appear as superheated steam and act as a blowing agent so producing porosity. When the melt temperature exceeds 180ºC to 185ºC then this effect is almost certainly due to premature activation of the filler fire retardant mechanism. If the effect appears at temperatures below 180ºC, then the MEGOLON® has probably absorbed a small amount of moisture during storage and now needs to be dried – see paragraph 1.5.

Porosity can be diagnosed by slicing the section with a sharp blade to find a myriad of very small bubbles distributed throughout the extruded section. The surface will take on an “orange peel” effect.

Any tendency to a porous extrudate can be minimised by quenching the hot material as soon as possible, i.e. moving the water bath as close to the extrusion head as possible.

2.13.2 Air entrapment

One of the purposes of the compression zone of an extruder screw is to eliminate the air from between the compound granules during the gelling (melting) process. A MEGOLON® screw has deep channels and low compression and can sometimes give rise to air entrapment in the melt. As the screw speed is increased, the residence time decreases and it becomes possible for partially gelled material to be delivered at the extrusion head. This may well contain some entrapped air.

The fault generally appears as discrete blisters or bubbles at irregular intervals in the extrudate. When the section is sliced through the blister with a sharp blade the solid portion of the extrudate is generally completely homogeneous with no sign of porosity.

The insertion of a screen pack to increase back pressure can have some effect, but the correct solution is either to slow the machine down again, or move to an extruder with either a higher L/D ratio or larger diameter (or both).

2.13.3 Melt fracture

This is sometime referred to as “Sharkskin”. The surface of the extrudate can become dull and very rough (hence “Sharkskin”) due to the surface being abraded as the material flows through the die lips. The solution is to raise the temperature of the die, but taking care not to raise it so high that surface porosity is induced. Melt fracture is not a common problem with MEGOLON®.

2.13.4 Die drool and Tramlines

Die drool is sometimes referred to as bearding. On prolonged running, a deposit can build up on the outside of the die. Provided it stays on the die there is no problem, but when it breaks away it can leave a ring around the cable. The problem seems to be associated with very small surface flaws on the die lips; hence any tools used should be of good quality. Various solutions have been proposed, the best of which would seem to be to round off the knife-edges of the tooling with a very small radius (0.2mm has been suggested). Other reports suggest that die drool can be limited by adopting a modified pressure set up using a knife-edged die in combination with a landed core point – the land here should be modest, typically 3 to 5mm.

Just recently reports have reached us about a form of internal die drool where the ring is formed on the core point. This obviously could be a more serious problem since, if the ring were to break away, then a lump in the cable would be the result.

Tramlines are parallel lines which appear on the cable surface due to poor quality notched or chipped dies. The solution is simply to move to better quality tooling.

2.13.5 **Spark test faults**

Contamination by metal, wood, paper or other foreign material can cause a spark fault. The contaminant need only be very small especially in thin walled cables that are being drawn down. The drawing of the melt around the foreign particle causes the melt to become too thin, and in bad cases a hole appears. The spark tester will detect the fault. If the faults are marginal then a screen pack may well help. Otherwise rejection of the material will probably be the result. Badly dispersed filler, or filler with over-size particles or grit will show the same effect as contaminants.

2.13.6 **Ringing**

Sometimes the appearance of rings is noticed forming on a cable during extrusion. The rings usually (but not always) occur at regular intervals down the cable.

Diagram 1 : the standard tubing extrusion arrangement with established extrudate flow.

Diagram 2 : note that the tooling is landed with narrow/long flow channels. With this arrangement it is possible that the melt pressure at the die lips is quite low so that, when drawing down the extrudate, the point at which the melt separates from the die can move back into the head. This in turn causes an increase in the stress in the melt.

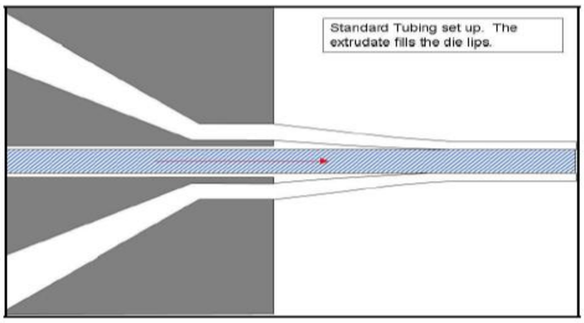


Diagram 1

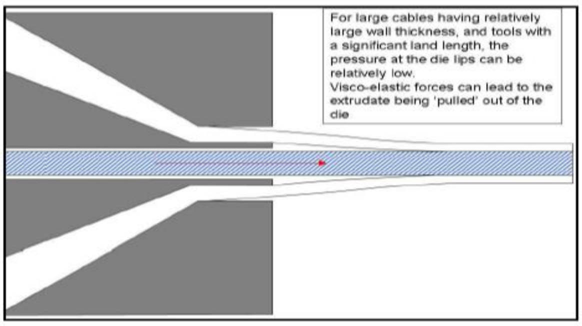


Diagram 2

Diagram 3 : this process continues until the yield strength of the melt is exceeded and the melt becomes thin or "necks". When this occurs, the stress in the melt becomes very low on the extruder side of the "neck", and so the extrudate starts again to fill the land.

Diagram 4 : as the cable moves down the line, the "neck" has formed a ring around the cable at the point where the jacket thickness is reduced.

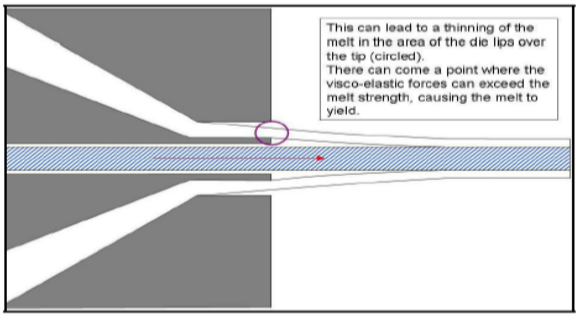


Diagram 3

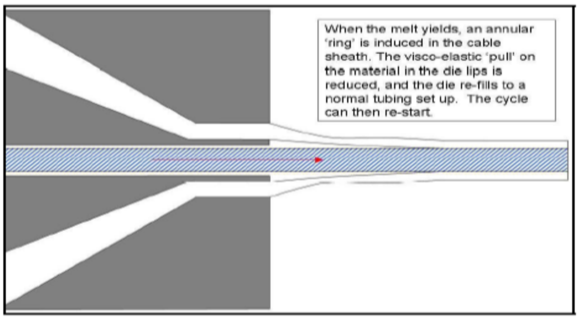
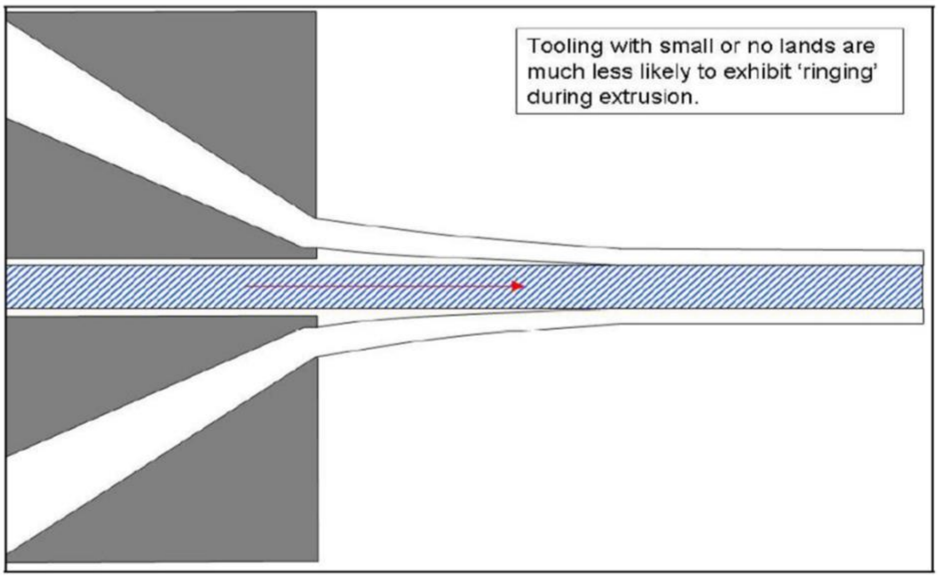


Diagram 4

The condition of the melt has now returned to that of Diagram 1 and the cycle can repeat, thus leading to a series of rings around the cable.

The frequency of the rings is dependent on many factors including the size of the cable, the diameter of the die, the outer diameter of the point, the melt temperature, the draw down ratio and the extrusion speed. It is therefore very difficult to predict the frequency by which the rings occur.

RECOMMENDED TOOLING



2.13.7 **Shrinkage**

Also referred to as Shrinkback. When extruded under normal conditions - such as those advised by Mexichem Specialty Compounds - whether using either a tubing or pressure setup, a shrinkage of less than 4% should be observed when carrying out any of the usual tests (involving heating a sample in an oven at a specific temperature and for a specific time) such as IEC 60811-1-3 clauses 10 and 11.

However, for many applications nowadays, often (but not always) associated with fibre optic cabling, levels of shrinkage much less than this are now required – sometimes well less than 1%. To achieve this objective, some or all of the following process guidelines may need to be observed.

Colour concentrate (masterbatch)

- Too much additive can sometimes lead to reduction of expected properties, including shrinkage. Do not use more additives than needed.

Drawdown

- Generally the higher the draw down ratio used, then the more shrinkage results. To combat this, try reducing the drawdown ratio by choice of the extrusion tooling.

Mixing and Melt temperature

- The compound must be properly gelled in the extruder to achieve best results. Extruders used should preferably have an L/D of at least 24 and be equipped with an appropriate screw for gelling MEGOLON® materials. As a further precaution, a breaker plate can be used with or without a screen pack (a recommended screen pack could be 20/60/100 mesh)
- Use a melt temperature in the range 165°C – 175°C. Too high a temperature can lead to the formation of micro-porosity in the extrudate; too low a temperature can lead to excessive retained stress within the extrudate.

Cooling

- This can be critical in the process to avoid/reduce shrinkage. Initially the water bath may be too close to the head – try moving it further away somewhat. If this does not solve the problem, then gradient cooling may be necessary in 3 stages (sometimes 2 may be adequate). The first cooling trough should be filled with water at near to 80°C; the second trough should contain water at around 50°C; and the last one should be at factory ambient temperature.

Line speed

- If the line speed is too fast, then the time available for cooling the extrudate before haul-off may be inadequate. If the equipment allows, multiple passes through the cooling system may be possible. If not, then a lower line speed should be tried.

Copper conductors (insulation process)

- The copper must be clean and free from any greases or wire drawing lubricants. The use of felt or cloth wipes is recommended just prior to entry to the extrusion head.
- Extrusion onto a cold conductor may cause excessive retained stress in the extrudate. To avoid this, conductor pre-heating can be used. The best method is by use of an induction pre-heater prior to the extrusion head; this should be set at around 100°C. If this equipment is not available then a gas torch can be tried, but the temperature is not easily controllable and so could prove unreliable.
- If tension at any stage in the process is too high then the conductor itself may be drawn down so either breaking the adhesion between the conductor and the insulation, or stretching down the insulation as well thus causing an increase in retained stress.

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