CABOT

CONDUCTIVE COMPOUNDS AND CONCENTRATES

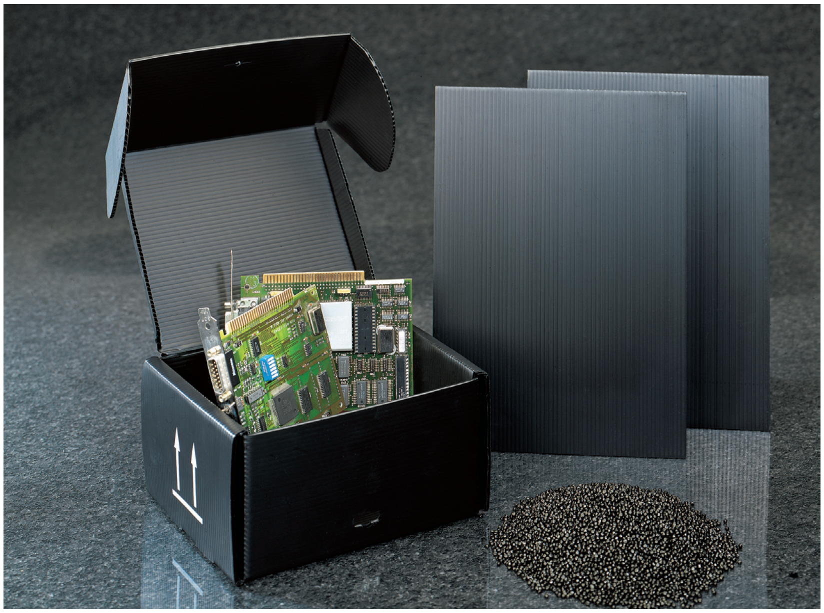
CABELEC® Conductive Compounds
Processing Guide

Contents

Introduction

CABELEC® conductive compounds are fully-formulated thermoplastic compounds that contain conductive carbon black to provide electrical conductivity in plastic end products. Conductive plastics are used to protect against premature failure or damage due to electrostatic discharge in a variety of applications such as automotive fuel systems, electronic and electrical packaging and equipment, and other plastics applications.

Cabot's comprehensive CABELEC conductive compound portfolio includes products produced with a broad array of polymers. These products can help customers meet specific electrical, rheological, and mechanical end-product performance needs. Additionally, products are available for use in a various processing methods, including blown film extrusion, sheet and profile extrusion, injection moulding, blow moulding, and others.



Processing Guide

Conductive Carbon Black

CABELEC compounds are carefully formulated products based on conductive carbon black. The type of carbon black, the addition level and the dispersion quality are key factors for achieving good conductivity – or low electrical resistivity.

Carbon black is a particulate form of industrial carbon produced by thermal cracking or thermal decomposition of a hydro-carbon raw material. Cabot produces carbon black via an oil furnace process in which petroleum distillates with high aromatic fractions are atomized into a preheated, closed furnace followed by cooling and collection of the formed carbon black particles.

Electron microscopy inspection reveals that carbon black is composed of aggregates which are fused clusters of spherical primary particles.

Figure 1: Carbon black oil furnace process

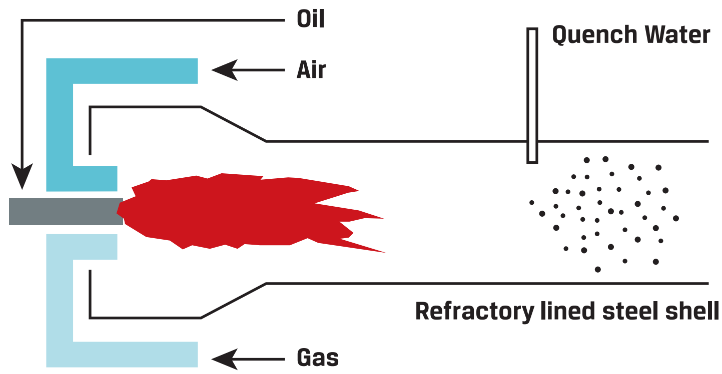
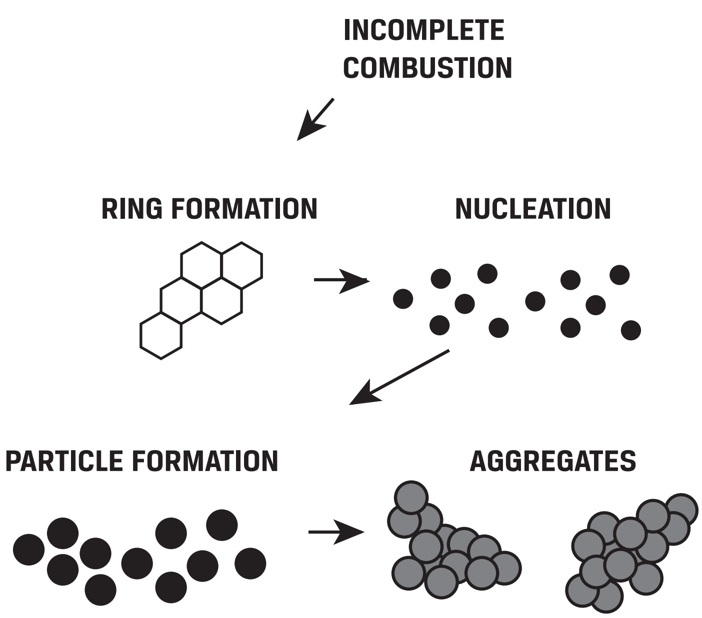


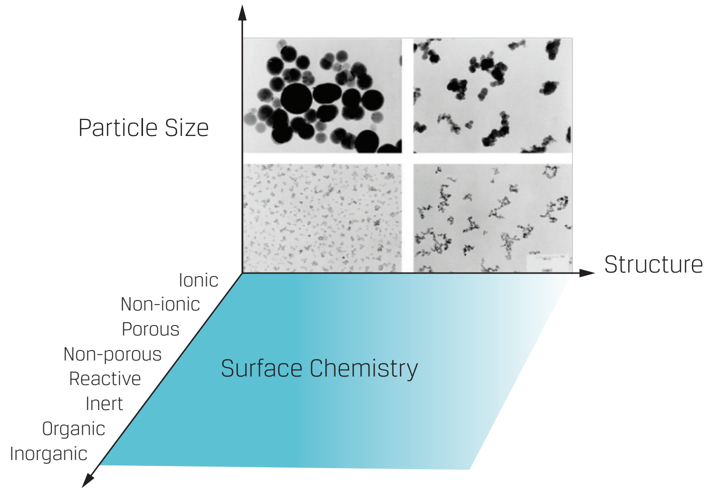
Figure 2: Carbon black oil furnace process



The morphology of carbon black is critical factor in determining carbon black performance such as conductivity. The key elements include:

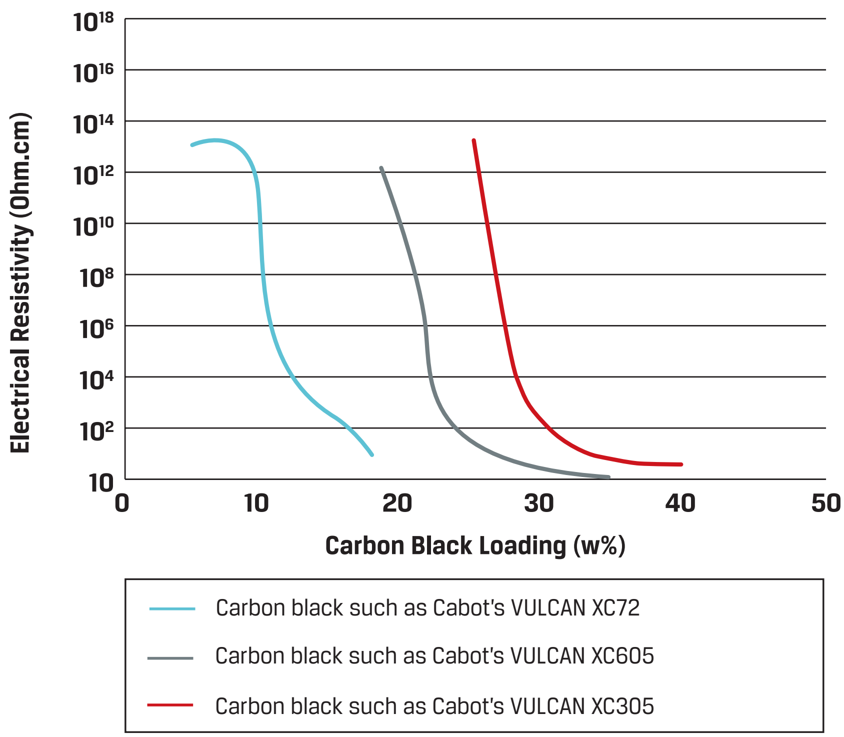
- Particle and/or aggregate size
- Structure
- Surface chemistry

Figure 3: Carbon black structure and properties



To achieve good electrical conductivity, the addition level and dispersion of carbon black in the polymer must be sufficient so that the carbon black aggregates touch or are less than 10 nm away from each other. The relationship between the quantity of carbon black added and the electrical resistivity achieved with different carbon black morphologies is shown in the percolation curves to the right.

Figure 4: Examples of percolation curves



Processing CABELEC Compounds

Predrying

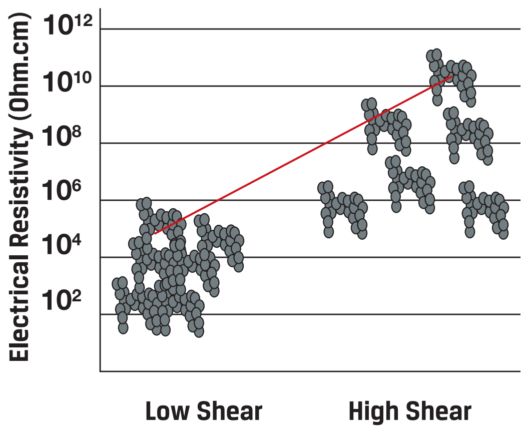
As the carbon black contained in the CABELEC compounds is hygroscopic, they should be stored in a dry place. Unless specified in the Product Data Sheet for the specific grade, CABELEC compounds need to be predried before processing. Processing an undried CABELEC compound with a high moisture content can result in deficiencies in the final product, such as surface blemishes in molded parts, holes in blown film, and other undesirable results.

Processing

CABELEC compounds can usually be processed on conventional processing equipment. To promote good electrical and mechanical properties of the material, it is advisable to process the compounds under low shear conditions. In fact, conductive carbon black filled compounds are highly shear sensitive. Too much shear can deteriorate carbon black networks and reduce conductivity.

Processing equipment and parameters should be carefully selected so that the shear generated is kept to a minimum. For more details about specific processing techniques please refer to the processing guidelines described below for specific CABELEC compounds.

Figure 5: Influence of shear on carbon black networks and electrical resistivity



Dilution

CABELEC conductive compounds are designed to provide the highest level of performance when used alone (i.e., without dilution with non-conductive materials). Progressive dilution of regrind results in correspondingly lower fractions of conductive material in the finished part. Appropriate blending and feeding procedures are required to maintain desired resistivity levels; therefore, it is advisable to measure and monitor the electrical resistivity during processing.

Purging

Due to the high carbon black content of CABELEC compounds, purging of production equipment is required to prevent discoloration of natural or light coloured materials that will be processed in the same equipment. After extrusion of CABELEC products, it is suggested to purge with a natural, high viscosity resin and to clean the screw and barrel mechanically.

Injection Moulding

Applications

Typical injection moulding applications for conductive compounds include items such as electrically conductive boxes and other types of containers for the protection of electronic components against electrostatic discharge (ESD).

Where ESD protection is required for safety reasons, conductive compounds can be injection molded to produce equipment housings, fan blades, pallets, caps, valves, and other products that can mitigate ESD.

In automotive applications, the main use of injection molded CABELEC compounds is in parts for fuel systems such as fuel inlets and filler caps.

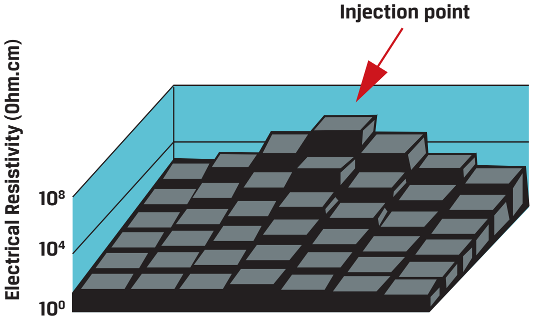
Equipment Requirements for Injection Moulding of CABELEC Compounds

CABELEC compounds can be processed on conventional injection moulding equipment under appropriate processing conditions. Low-shear processing conditions are important to achieve the most favorable electrical and mechanical properties in final products.

A general purpose screw of L/D ratio of 20-30/1 with a long feed section is suggested. The compression zone should be of low compression ratio. The nozzle can be a general purpose type of standard to large size in order to avoid any restriction of flow. Sprues can be of a standard type large enough to avoid restricting material flow. Detaching mouldings from the sprue is not normally a problem, but tapers may need to be increased for satisfactory ejection from the mold due to the reduced shrinkage. Because of the high viscosity of CABELEC products compared to neat polymers, the flow length needs to be relatively short in order to fill the mold.Therefore, gates and runners should optimally be 2/3 the wall thickness.

The flow path of the molten material in the mold influences the electrical resistivity of the molded part. Electrical resistivity will be at its highest at the injection point and will decrease progressively when moving away from this point, as demonstrated in the diagram to the right.

Figure 6: Electrical resistivity levels during molding process



Due to the generally higher stiffness of CABELEC products, reduced forces are required for the ejector pins.

Hot runners can be used but require good tool design, extremely accurate temperature control and consistent machine settings. It is also very important that the drying guidelines are strictly followed to avoid plugging of the hot runners. Material stagnation points should be avoided by rounding the end of flow channels. Trials with prototype tooling is suggested before operation with hot runners.

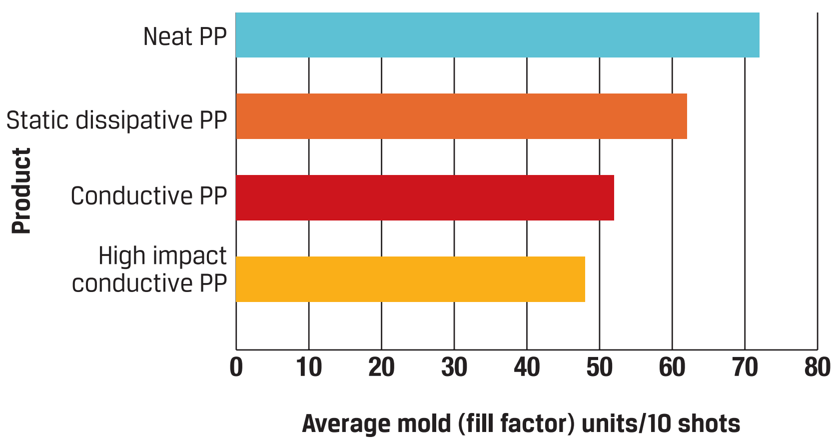
The shrinkage of CABELEC conductive compounds will be significantly less than that of natural polymers due to the presence of carbon black in the compounds. Shrinkage values are available on the product data sheets for most CABELEC compounds typically used in injection moulding.

General Guidance for Injection Moulding of CABELEC Compounds

As shown on the tables to the right, CABELEC compounds should be processed at a higher temperature than the corresponding neat polymer. However, processing cycle times will probably be similar to those for neat polymer because CABELEC compounds exhibit faster cooling.

Based on the Spiral Flow Test results, the diagrams below compare a) the flow behaviour of three CABELEC products based on polypropylene (PP) with that of a neat PP at their typical melt temperature, and b) the flow behavior of other CABELEC injection moulding products based on different polymers. The higher the average mold unit, the better the flow.

Figure 7
a) Comparison of flow of PP-based CABELEC products vs. neat PP



b) Comparison of flow of non-PP-based CABELEC products

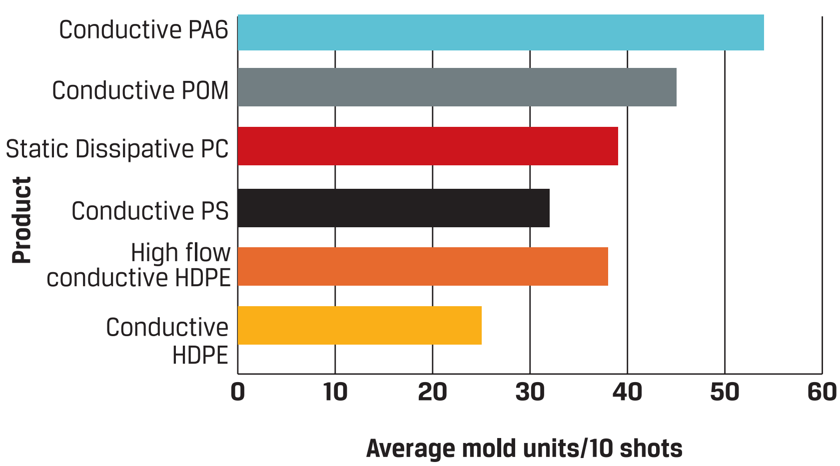


Table 1: CABELEC compounds processing suggestions

Processing parameter	Settings versus natural polymer
Barrel temperatures	10-20°C higher
Melt temperatures	10-20°C higher
Injection pressure	Lower
Back pressure	Lower
Injection speed	Lower
Cycle time	Should be optimised when other conditions have been set and required conductivity achieved

Table 2: Mold temperature recommendations for CABELEC compounds

Polymer base	Recommended mold temperature (°C)
Polyacetal	60
Polycarbonate	80-100
Polyethylene	40-50
Polypropylene	30-40
Polystyrene	30

Troubleshooting Guide for Injection Moulding

Problem	Potential Cause	Potential Corrective Actions
Lack of conductivity	Shear too high Too much regrind Dilution too great	Increase temperature, reduce injection speed and back pressure Reduce or remove regrind Reduce or remove natural resin
Inhomogeneous surface resistivity	Non-homogeneity related to mold design	Review mold design
Cavity not filled	Viscosity too high Sprues, runners or gates too narrow Shot weight too low Melt temperature too low Mold temperature too low Injection time too short	Gradually increase melt temperature 5-10°C at a time Increase size of sprue, runners, gates Increase shot weight Increase melt temperature Increase mold temperature Increase injection time
Part sticking in mold	Low shrinkage	Reduce injection speed and injection andholding pressure
Weld lines	Flow path too short	Increase barrel temperature and mold temperature
Poor surface finish	Moisture Gas entrapment Contamination on mold surface	Dry CABELEC compound according to guidelines in product data sheet Vent mold Clean mold surface
Silver streaking	Mold temperature too low Screw speed too high Moisture Melt temperature too low	Increase mold temperature Decrease screw speed Dry CABELEC compound according to guidelines in product data sheet Increase melt temperature
Brittleness of part	Back pressure too low Screw speed too high Moisture Presence of contamination	Increase back pressure Reduce screw speed Dry CABELEC compound according to guidelines in product data sheet Check for contamination
Blisters	Moisture Screw speed too high	Dry CABELEC compound according to guidelines in product data sheet Reduce screw speed
Excessive flash	Injection pressure too high Clamp pressure too low Dirt on mold faces Mold not shutting correctly	Reduce injection pressure Increase clamp pressure Clean mold faces Check mold faces for proper fit
Gas Burns	Insufficient venting of mold Injection speed too high Screw speed too high Back pressure too high Clamp pressure too high	Ensure vents are clear of obstructions, add further vents if necessary Reduce injection speed Reduce screw speed Reduce back pressure Reduce clamp pressure, increase melt temperature ifnecessary
Oversized part	Mold temperature too low Cycle time too long Injection speed too high Injection and holding pressure too high	Increase mold temperature Reduce overall cycle time Reduce injection speed Reduce injection and holding pressure
Undersized part	Holding time too low Melt temperature too low Gate too narrow Mold temperature too high	Increase holding time Increase melt temperature Increase size of gate Decrease mold temperature
Sink marks	Holding time and pressure too low Mold temperature too high Gate too narrow Gate incorrectly positioned	Increase holding time and pressure Reduce mold temperature Increase size of gate Locate gates near heavy cross sections
Warping	Molded in stress Uneven mold temperature Ejected part not cooled enough Ejectors not designed correctly	Raise melt temperature, reduce injection speed, relocate gate if necessary Check mold temperature Increase cooling time, reduce mold temperature Redesign ejectors
Voids	Moisture Mold temperature too low	Dry CABELEC compound according to guidelines in product data sheet Increase mold temperature

Blown Film Extrusion

Applications

- Film for packaging of electronic components
- Film for photographic applications
- Liners for big bags for explosive powders
- Packaging materials for explosive powders or other substances used in an explosive environment (as required by the ATEX norms)

Equipment Requirements for Blown Film Extrusion of CABELEC Compounds

CABELEC compounds can be processed on conventional blown film extruders under appropriate conditions. To promote good electrical and mechanical properties of films, CABELEC compounds should be processed under low shear conditions.

A general purpose screw of L/D ratio of 20-30/1 with a long feed section is suggested. The compression zone should have a low compression ratio. The die head geometry should be designed to avoid or minimise any restriction of flow.

General Guidance for Blown Film Extrusion of CABELEC Compounds

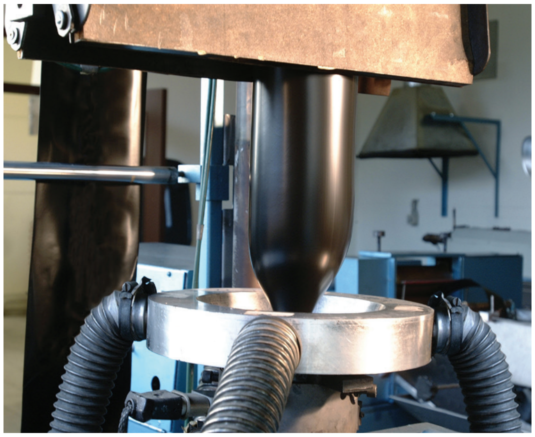
Cooling of conductive films is normally more rapid than that of transparent, non-conductive films because their high carbon black content increases thermal conductivity. This factor should be taken into account when setting the process conditions.

The surface resistivity of a film is related to the film thickness: resistivity increases as the film thickness decreases. It is also important to avoid a large blow up ratio as this will increase separation of the carbon black structures thereby reducing the conductivity of the film.

Table 3: Temperature setting suggestions for CABELEC Compounds

Processing parameter	Settings versus natural polymer
Barrel temperatures	10-20°C higher
Melt temperatures	10-20°C higher
Die temperatures	20°C higher
Extrusion speed	Lower

Coextrusion



For conductive films, coextrusion can be used provided that a high volume resistivity is acceptable. The external conductive layers can be coextruded with a non-conductive middle layer, using less-expensive polymers or recycled material which will be encapsulated in the film construction ("sandwich" structure).

Printing

Corona treatment should not be used on a conductive film. However, printing processes which do not require Corona treatment, for example laser printing, can be used.

Sealing

Conductive films can be sealed using standard sealing equipment. Because of the high thermal conductivity of CABELEC compounds with respect to unfilled polymers, it may be necessary to increase the sealing temperature.

Troubleshooting Guide for Blown Film Extrusion

Problem	Potential cause	Potential Corrective Actions
Lack of conductivity	Shear too high Too much regrind Dilution too great Stretching too high Film too thin	Increase temperature, reduce speed Reduce or remove regrind Reduce or remove natural resin Reduce blow up ratio Increase film thickness
Bad sealing strength	Thermal conductivity	Increase sealing temperature and pressure
Curling of film	Inhomogeneous cooling Difference in shrinkage between the layers of a coextruded film	Reduce line speed Adapt wall thickness
Sticking of the film during winding	Film too hot during winding	Reduce speed and/or increase air cooling
Die deposit	Moisture	Dry CABELEC compound according to guidelines in product data sheet
Voids and holes	Moisture	Dry CABELEC compound according to guidelines in product data sheet

Extrusion

Applications

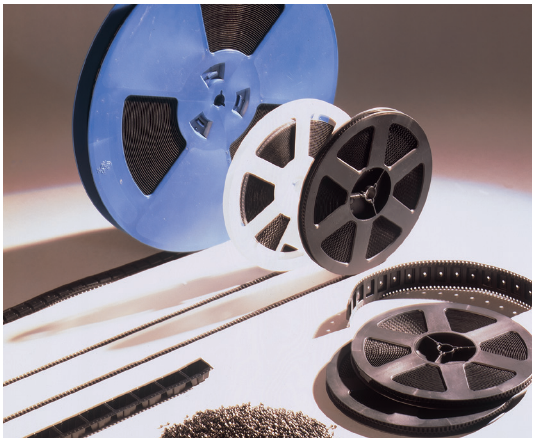
Conductive compounds are widely used in the electronics industry. Examples of applications are:

- Polystyrene carrier tapes
- Polystyrene thermoformed trays
- Polypropylene corrugated sheet
- Polyethylene/EVA foam

Conductive compounds are also used in industrial applications such as:

- Tubes, pipes, corrugated tubes for hazardous areas (mines, powder or chemical factories)
- Polyolefin monofilament fibres for antistatic big bags for handling of dangerous goods
- Conveyor belts

To facilitate compliance with ATEX norms, CABELEC conductive compounds can offer a valuable solution to producers who require conductive materials with a surface resistivity below 10^6 Ohms/sq.



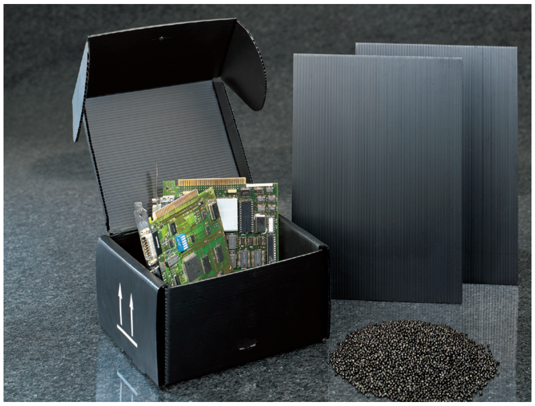
Equipment Requirements for Extrusion of CABELEC Compounds

CABELEC compounds can be processed on conventional extrusion equipment under appropriate processing conditions. To promote good electrical and mechanical properties of the extruded part, CABELEC compounds should be processed under low shear conditions.

A general purpose screw of L/D ratio of 20-30/1 with a long feed section is suggested. The compression zone should have a low compression ratio. The die can be a general purpose type of standard to large size in order to avoid any restriction of flow.

General Guidance for Extrusion of CABELEC Compounds

Processing Parameter	Settings versus Natural Polymer
Barrel temperatures	10-20°C higher
Melt temperatures	10-20°C higher
Die temperatures	20°C higher
Extrusion speed	Lower



Coextrusion

For conductive sheets, coextrusion can be used provided that a high volume resistivity is acceptable. The external conductive layers can be coextruded with a non-conductive middle layer, using less-expensive polymers or recycled material which will be encapsulated in the film construction ("sandwich" structure).

Dies

When extruding conductive sheets, it is sometimes necessary to have a temperature differential between the external and internal parts of the die (with the internal part being the hotter of the two). This is to compensate for the longer flow path of the external part of the sheet compared to the internal part. However, a temperature gradient in the sheet can cause additional shear, negatively affecting the conductivity.

Stretching

After extrusion, stretching should be very limited because it increases the distance between the carbon black structures, thereby negatively affecting the conductivity. For best results, the die gap should be the same as the sheet thickness. This is particularly important when extruding monofilaments.

Calenders

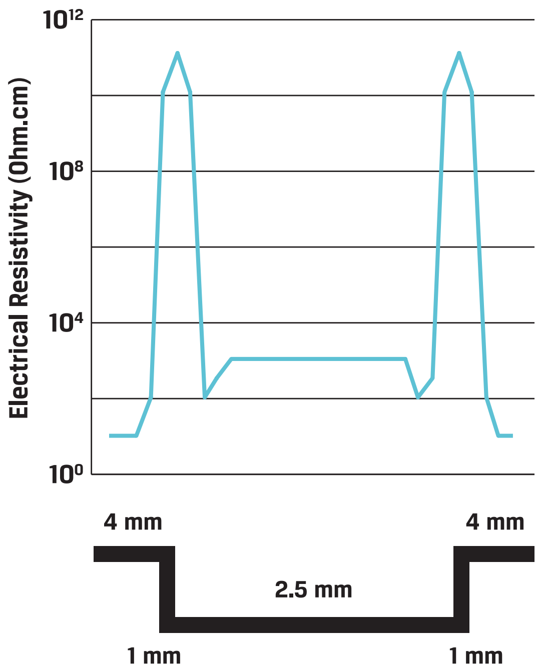
If the extruded sheet has to pass between two calenders (nips) for cooling, it is advised that the upper roll be set at a temperature 6-10° C above the lower roll. The rotating bead between the calendar rolls should be minimized. High shear generated in this bead can dramatically degrade the surface resistivity of the material.

Extruders with mixing elements, restrictions in the barrel, high compression ratios, melt pumps or tight screen packs should be avoided. Low screw speeds are advisable. It is also important to avoid beads on calender rolls, to optimise nip roll temperatures and to match extrusion and haul-off speeds.

Thermoforming

Special care needs to be taken during the thermoforming process due to the varying degrees of shear to which different parts of the sheet are subjected. Conductivity can be lost in vertical sections due to separation of the carbon black structures. The surface resistivity will be highest in the thinnest parts of the thermoformed article as illustrated in the graph to the right:

Figure 8: Influence of the thickness within the thermoformed article on its electrical resistivity



Troubleshooting Guide for Extrusion

Problem	Potential cause	Potential Corrective Actions
Lack of conductivity	Shear too high	Increase temperature, reduce speed
	Too much regrind	Reduce or remove regrind
	Dilution too great	Reduce or remove natural resin
	Material too stretched	Avoid stretching after extrusion Avoid nip beads. Ensure homogeneous cooling by adjusting temperatures of calenders and die
Inhomogeneous surface resistivity	Non-homogeneity related to thermoforming process	Increase thickness, review thermoforming process by avoiding excessive material stretching
Poor surface finish	Moisture	Dry CABELEC compound as described in product data sheet
Die deposit	Moisture	Dry CABELEC compound as described in product data sheet
Voids	Moisture	Dry CABELEC compound as described in product data sheet

Blow Moulding

Applications

CABELEC conductive compounds are used in a variety of blow moulding applications ranging from large containers such as industrial bulk containers (IBC's), drums, and jerry-cans to technical parts such as conductive automotive filler pipes. Many containers made of CABELEC compounds used for the transportation of dangerous goods are listed as BAM-certified packaging. When compared with natural polyethylene, conductive compounds show a higher sensitivity to shear, a faster cooling rate due to increased thermal conductivity and slightly higher viscosity. The most important parameters for the processing of CABELEC products are summarized in the guidelines below.

Equipment Requirements for Blow Moulding of CABELEC Compounds

CABELEC conductive compounds can be processed on most conventional continuous extrusion as well as accumulator head equipment. Screws with grooved feed zones and L/D ratios between 20 and 30 are suggested. Despite the shear sensitivity of conductive materials, typical shear and mixing elements of HDPE screws are suitable provided that appropriate precautions are taken with process conditions. With appropriate CABELEC product selection, coextruded parts and containers can be successfully produced from CABELEC products.

Conventional molds are generally suitable for the manufacture of CABELEC parts.

General Guidance for Blow Moulding of CABELEC Compounds

The main process parameters that should be considered are listed below with their corresponding comments/explanations:

Processing Parameters	Comments / Suggestions
Temperatures	Melt temperatures: typical range: 200-240°C Die lip temperature: typical range: 210-240°C Too low a die lip temperature can affect resisitivity even at higher melt temperatures. It can also generate variation in conductivity along the circumference of the parison
Piston or Ram speed	On accu-head lines, the ram speed should be kept as low as possible due to the high shear rates generated during parison formation
Screw speed	Conventional screw speed levels for natural polymers can be used
Mold closing speed	As for natural HDPE, the appropriate balance needs to be found to achieve good welding quality. An excessive speed (or too late a transition point to reduced speed) can lead to an inappropriate weld geometry
Parison cooling/mold cooling	CABELEC compounds exhibit a far higher thermal conductivity than natural polymers. As a result, parison cooling is faster. This leads to shorter cooling times but also needs to be taken into consideration for the welding line quality
Melt strength	Due to the carbon black network, CABELEC products are characterised by high melt strength levels which facilitate a tight thickness distribution profile
Mold temperatures	As for natural polyethylene, low mold tempertaures are preferable to minimise cycle time (typical cooling water temperatures: 10-25°C)

Troubleshooting Guide for Blow Moulding

Problem	Potential cause	Potential Corrective Actions
Rough surface	Melt temperature too low Die temperature too low Ram speed too high	Increase melt and die temperatures Reduce ram speed
Flow marks/surface defects	Purge effect due to high viscosity of CABELEC compounds	Complete purge of the equipment
Bubbles	Air entrapment, excessive moisture level	Vent the equipment, pre-dry material
Weld seam is too weak	Melt temperature is too low Extrusion/ram speed too low Mold closing speed inappropriate	Adjust melt temperatures Increase ram speed Adjust mold closing speed and change-over limits
Uneven appearance on mold surface	Insufficient or non homogeneous venting	Improve venting
Surface resistivity too high	Die lip temperature too low Melt temperature too low Excessive shear	Increase (significantly) die lip and melt temperature Reduce ram/piston speed
Uneven resistivity levels	Uneven parison resistivity Uneven stretching/blow up ratios	Increase head/die temperatures Verify thickness distribution

Cabot: A Proud History and Global Reach

Cabot Corporation is a global performance materials company, and we strive to be our customers' partner of choice. We have been a leading manufacturer for more than 130 years. Our global reach enables us to partner closely with our customers to meet the highest standards for performance, quality, and service.

NORTH AMERICA
Cabot Corporation Business and Technology Center
157 Concord Road
P.O. Box 7001
Billerica, MA 01821 - USA
Technical service
Tel: +1 800 462 2313
Customer service
Tel: +1 678 297 1300
Fax: +1 678 297 1245

SOUTH AMERICA
Cabot Brasil Industria e Comercio Ltda.
Rua do Paraiso 148 - 5 andar
04103-000 Sao Paolo,
SP Brazil
Tel: +55 11 2144 6400
Fax: +55 11 3253 0051

EUROPE
SIA Cabot Latvia
101 Mukusalas Street
Riga, LV-1004,
LATVIA
Tel: +371 6705 0984
Tel: +371 6705 0900
Fax: +371 6705 0985

MIDDLE EAST & AFRICA
Cabot Dubai
P.O. Box 17894
Jebel Ali Free Zone
LOB 15, Office 424
Dubai
United Arab Emirates
Tel: +971-4-8871800
Fax: +971-4-8871801

ASIA PACIFIC
Cabot China Ltd.
558 Shuangbai Road
Shanghai 201108
China
Tel: +86 21 5175 8800
Fax: +86 21 6434 5532

JAPAN
Cabot Specialty Chemicals Inc.
Sumitomo Shiba-Daimon Bldg. 3F
2-5-5 Shiba Daimon,
Minato-ku
Tokyo 105-0012
Japan
Tel: +81 3 6820 0255
Fax: +81 3 5425 4500

CABOT
cabotcorp.com