CONDUCTIVE COMPOUNDS

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CABELEC® Compounds Processing Guide




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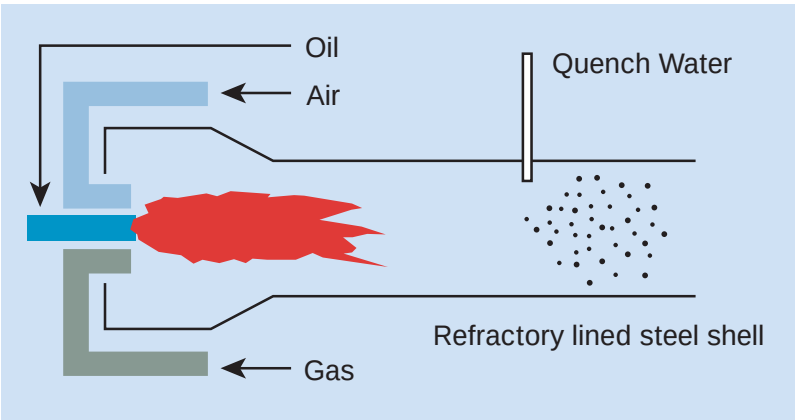
CABELEC compounds are a range of compounds that are electrically conductive thereby reducing the risk of electrostatic discharge. The conductive properties of the compounds are permanent. CABELEC compounds are based on a large variety of thermoplastic polymers and are designed to fulfil specific requirements related to electrical, rheological and mechanical properties. A range of CABELEC compounds is available for different processing techniques such as blown film extrusion, sheet and profile extrusion, injection moulding, blow moulding, etc.

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.

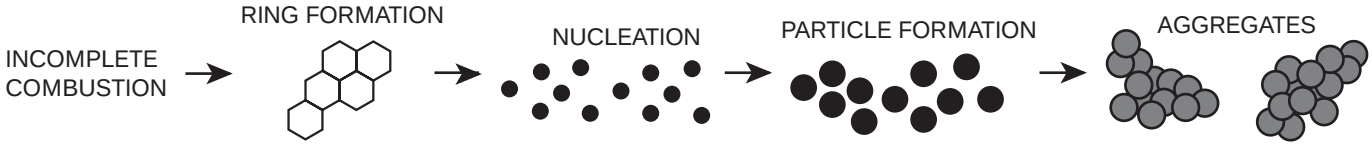
Carbon black is a particulate form of industrial carbon produced by thermal cracking or thermal decomposition of a hydrocarbon raw material. Many processes historically have been used to produce carbon black, but the most important now is the oil furnace process. It consists of atomising a heavy aromatic fraction of petroleum distillate into a preheated, closed furnace followed by cooling and collecting the formed carbon particles.

Carbon Black Oil Furnace Process



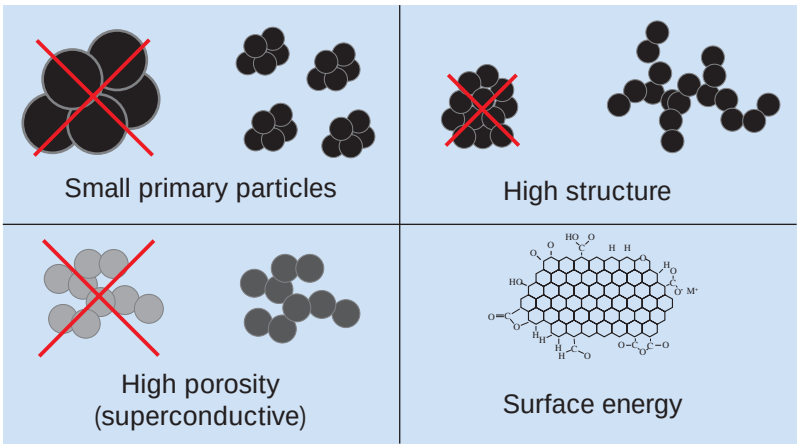
Electron microscopy inspection reveals that carbon black is composed of aggregates, which resemble fused clusters of spherical primary particles.

Carbon black oil furnace process



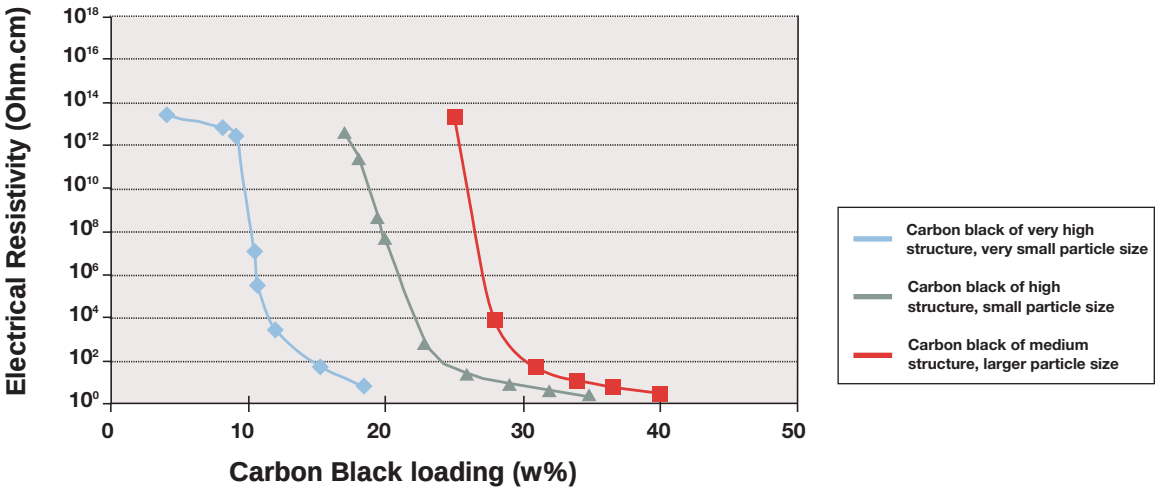
Both the aggregate size and shape, and the primary particle size, are controlling factors in determining carbon black performance. The following characteristics are key for a carbon black of good electrical conductivity:

Carbon black structure & properties



The addition level of carbon black in the polymer must be sufficient so that the carbon black particles 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 is shown in the percolation curves below.

Examples of percolation curves



Processing CABELEC compounds

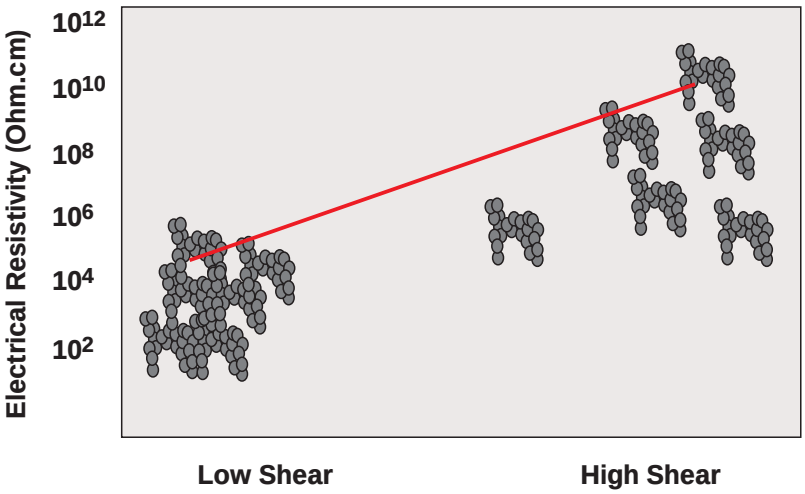
Predrying

As the carbon black contained in the compounds is hygroscopic, CABELEC compounds should be stored in a dry place. Before processing – unless specified in the Product Data Sheet for the specific grade – the compounds need to be predried. Processing a compound having too high a moisture content will result in, for example, surface blemishes in the injection moulded part, holes in the blown film, and so on.

Processing

CABELEC compounds can usually be processed on conventional processing equipment. To ensure good electrical and mechanical properties of the material, it is strongly recommended that the compounds be processed under low shear conditions. In fact, conductive carbon black filled compounds are highly shear sensitive. Too much shear deteriorates the carbon black structure and will result in higher electrical resistivity of the manufactured item.

Influence of shear on carbon black structure and electrical resistivity



Processing equipment and parameters should be carefully selected so that the shear generated is kept to a minimum. For more details please refer to the specific CABELEC processing sections.

Dilution

CABELEC products provide optimum performance when used alone i.e. without dilution with non-conductive raw materials. For this reason we do not recommend dilution. In some processing techniques dilution is performed via addition of regrind. One should keep in mind the fact that the regrind is increasingly "diluted " resulting in progressively lower fractions of conductive material in the finished part. Appropriate blending and feeding procedures are required to maintain the desired resistivity levels. Rigorous testing of the electrical resistivity is also strongly recommended.

Purging

After a CABELEC production run purging of the equipment is required. Due to its high carbon black content, CABELEC can be problematic when changing to a natural or light coloured material. It is generally recommended 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 container for the protection of electronics components against electrostatic discharge (ESD).

Where ESD protection is required for safety reasons, conductive compounds are injection moulded to produce equipment housings, fan blades, pallets, caps, valves and so on.

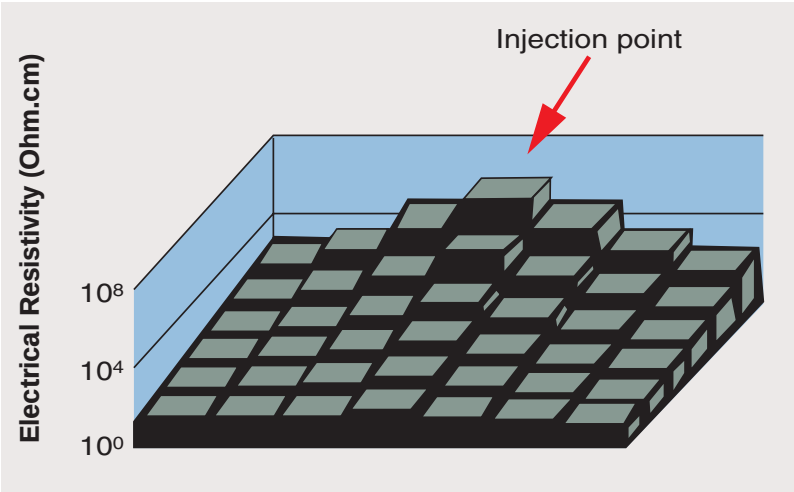
In automotive applications the main use of injection moulded CABELEC compounds is in parts for fuel systems such as fuel inlets and filler caps.

Equipment requirements for injection moulding of CABELEC compounds

CABELEC compounds can be processed on conventional injection moulding equipment although it is important to select the optimum processing conditions. To ensure good electrical and mechanical properties of the injected part, it is strongly recommended that the CABELEC compound be processed under conditions of low shear.

A general purpose screw of L/D ratio of 20-30/1 with a long feed section is recommended. 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 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 due to the reduced shrinkage for satisfactory ejection from the mould. Due to the high viscosity of CABELEC grades compared to virgin polymers, the flow length needs to be relatively short in order to fill the mould. Therefore gates and runners should optimally be $^{2}/_{3}$rd the wall thickness.

Inevitably there is an effect of the flow path of the molten material in the mould on the electrical resistivity of the moulded 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 following diagram:



Due to the generally higher stiffness of CABELEC grades, 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. Note that proto-type tooling can be a worthwhile exercise.

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

Optimum guidelines for processing of CABELEC compounds

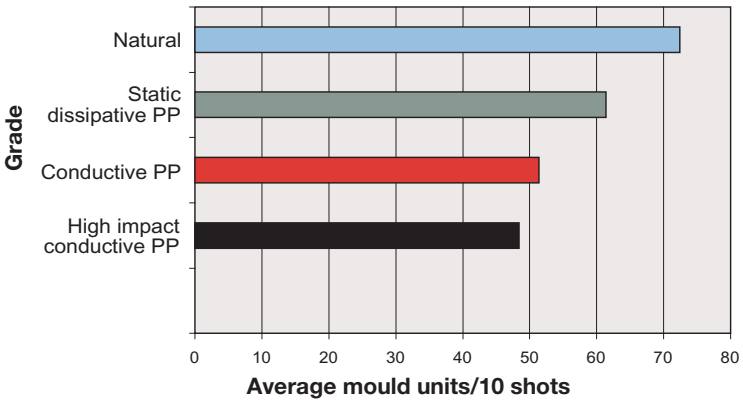
Processing parameter	Settings versus natural polymer
Barrel temperatures	10-20°C higher
Melt temperatures	10-20°C higher
Injection pressure	Lower
Back pressure	Lower
Injection speed	Lower
Cycle time	Should be optimised when other conditions have been set and required conductivity achieved

Note that cycle times will probably be similar to those for natural polymers as the higher processing temperatures together with faster cooling characteristics will normally balance each other out.

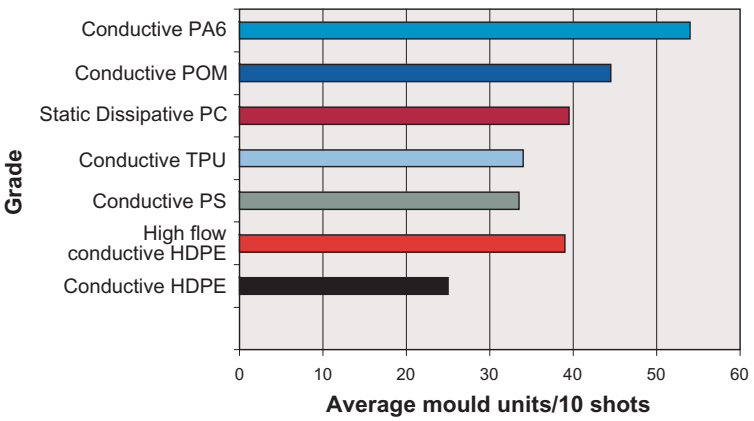
Polymer base	Recommended mould temperature (°C)
Polyacetal	60
Polycarbonate	80-100
Polyethylene	40-50
Polypropylene	30-40
Polystyrene	30
Polyurethane	30

The diagrams below compare i) the flow behaviour of 3 injection moulding CABELEC grades based on PP at their recommended melt temperature with a natural PP at its recommended melt temperature and ii) the flow behaviour of other CABELEC injection moulding grades based on different polymers:

i) Comparison of flow of PP grades versus natural PP



ii) Comparison of flow of CABELEC grades



Troubleshooting guide

Problem	Potential cause	Recommendations
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 mould design	Review mould design
Cavity not filled	Viscosity too high Sprues, runners or gates too narrow Shot weight too low Melt temperature too low Mould 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 mould temperature Increase injection time
Part sticking in mould	Low shrinkage	Reduce injection speed and injection and holding pressure
Weld lines	Flow path too short	Increase barrel temperature and mould temperature
Poor surface finish	Moisture Gas entrapment Contamination on mould surface	Dry CABELEC compound according to guidelines in product data sheet Vent mould Clean mould surface
Silver streaking	Mould temperature too low Screw speed too high Moisture Melt temperature too low	Increase mould 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 mould faces Mould not shutting correctly	Reduce injection pressure Increase clamp pressure Clean mould faces Check mould faces for proper fit
Gas Burns	Insufficient venting of mould 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 if necessary
Oversized part	Mould temperature too low Cycle time too long Injection speed too high Injection and holding pressure too high	Increase mould 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 Mould temperature too high	Increase holding time Increase melt temperature Increase size of gate Decrease mould temperature
Sink marks	Holding time and pressure too low Mould temperature too high Gate too narrow Gate incorrectly positioned	Increase holding time and pressure Reduce mould temperature Increase size of gate Locate gates near heavy cross sections
Warping	Moulded in stress Uneven mould temperature Ejected part not cooled enough Ejectors not designed correctly	Raise melt temperature, reduce injection speed, relocate gate if necessary Check mould temperature Increase cooling time, reduce mould temperature Redesign ejectors
Voids	Moisture Mould temperature too low	Dry CABELEC compound according to guidelines in product data sheet Increase mould temperature

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Cabot (headquarters)
Interleuvenlaan 15 I
B - 3001 Leuven
BELGIUM
Tel.: (32) 016 39 24 00
Fax: (32) 016 39 24 44

Cabot Plastics Belgium S.A. (plant & sales office)
Rue Prévôchamps 78
B - 4860 Pepinster
BELGIUM
Tel.: (32) 087 39 27 11
Fax: (32) 087 46 98 69

Cabot Plastics Deutschland (sales office)
Tel.: (0800) 182 40 86
Fax: (0800) 182 40 87

Cabot Plastics Ltd (plant and sales office)
Gate Street
Dukinfield SK16 4RU
ENGLAND
Tel.: (44) 161 934 4500
Fax: (44) 161 934 4501

Cabot Italiana S.p.A. (plant)
Plastics Division
Zona Industriale 4
I - 38055 Grigno (TN)
ITALIA
Tel.: (39) 0461 775 211
Fax: (39) 0461 765 146

Cabot Latin America Division (sales office)
Av. Joao Castaldi 88
04517-900 Sao Paulo, SP
BRAZIL
Tel.: (55) 11 5091 8300
Fax: (55) 11 5542 6037
Tel.: 0800 - 195959 (Customer service)

Cabot Plastics Hong Kong Ltd (plant & sales office)
18 Dai Kwai Street
Tai Po Industrial Estate/Tai Po (NT)
HONG KONG SAR
PRC
Tel.: (852) - 2666-2666
Fax: (852) - 2666-0807

Shanghai Cabot Chemical Company Ltd.
No. 558 Shuang Bai Lu
Wujing, Shanghai
CHINA 201108
Tel.: (86) 21-6434 7766
Fax: (86) 21-6434 5532

www.cabot-corp.com/plastics

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