

(12) STANDARD PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. **AU 2006265360 B2**

(54) Title
Outer sheath layer for power or communication cable

(51) International Patent Classification(s)
H01B 3/44 (2006.01) **H01B 3/30** (2006.01)
C08F 10/02 (2006.01) **H01B 9/00** (2006.01)
C08L 23/04 (2006.01) **H01B 11/00** (2006.01)

(21) Application No: **2006265360** (22) Date of Filing: **2006.06.28**

(87) WIPO No: **WO07/003323**

(30) Priority Data

(31) Number (32) Date (33) Country
05014217.3 **2005.06.30** **EP**

(43) Publication Date: **2007.01.11**

(44) Accepted Journal Date: **2010.06.03**

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(56) Related Art
WO 2004/101674
US 5718974
US 2005/0054799

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
11 January 2007 (11.01.2007)

PCT

(10) International Publication Number
WO 2007/003323 A1

(51) International Patent Classification:

H01B 3/44 (2006.01) **C08L 23/04** (2006.01)
H01B 9/00 (2006.01) **C08F 10/02** (2006.01)
H01B 11/00 (2006.01)

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(21) International Application Number:

PCT/EP2006/006267

(22) International Filing Date: 28 June 2006 (28.06.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

05014217.3 30 June 2005 (30.06.2005) EP

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: OUTER SHEATH LAYER FOR POWER OR COMMUNICATION CABLE

(57) Abstract: The present invention relates to a power or communications cable comprising an outer sheath layer made of a polyethylene composition comprising a base resin which comprises (A) a first ethylene homo- or copolymer fraction, and (B) a second ethylene homo- or copolymer fraction, wherein fraction (A) has a lower molecular weight than fraction (B), and the base resin has a molecular weight distribution M_w/M_n of more than 14.



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Outer Sheath Layer for Power or Communication Cable

The present invention concerns a power or communication cable comprising an outer sheath layer made of a polyethylene composition
5 which comprises a base resin comprising two ethylene homo- or copolymer fractions. Furthermore, the present invention relates to the use of such a composition for the production of the outer sheath layer of a cable.

Cables, such as power or communication cables, usually comprise an inner core which comprises a conducting element, such as a metal wire or a glass
10 fibre, and one or more outer layers for shielding and protecting purposes. The outermost of these layers having mainly protective purpose is usually referred to as outer sheath or outer jacket.

It is known to produce outermost protective sheath layers from polymer compositions comprising mainly polyolefins, in particular polyethylenes.
15 The diverse application fields for the various kinds of cables make it necessary that the outer jacket meets a number of requirements which at least partly are contradictory to each other.

Among important properties of a cable jacket and a material used for production of a cable jacket are good processability, including good
20 extrusion properties at a broad processing temperature window, and good mechanical properties, such as good resistance to environmental stress cracking ESCR, high mechanical strength, high surface finish and low shrinkage of the final cable jacket.

It is accordingly an object of the present invention to provide a cable jacket
25 made from a polyethylene composition having simultaneously the above-

mentioned properties, with a high flexibility combined with all above mentioned properties. In particular, the composition used for the jacket should show an improved processability so that a high production rate can be achieved, while yielding a cable jacket with good surface properties.

5

The present invention is based on the finding that such a jacket can be provided if a polyethylene composition is used for its production which has a very broad molecular weight distribution of higher than 14.

10

According to the present invention there is provided a power or communications cable comprising an outer sheath layer made of a polyethylene composition comprising a base resin which comprises

(A) a first ethylene homo-or copolymer fraction.

(B) a second ethylene homo-or copolymer fraction, and

15

(C) a third ethylene homo-or copolymer fraction in an amount of up to 20 wt% of total base resin,

wherein fraction (A) has a lower molecular weight than fraction (B), and the base resin has a molecular weight distribution M_w/M_n of more than 14, and fraction (C) has an MFR₂ of 0.1 g/10 min or lower.

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According to the present invention there is provided a polyethylene composition comprising a base resin which comprises

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(C) a third ethylene homo-or copolymer fraction in an amount of up to 20 wt% of the total base resin,

wherein fraction (A) has a lower molecular weight than fraction (B), and the base resin has a molecular weight distribution M_w/M_n of more than 14, and fraction (C) has a MFR₂ of 0.1g/10 min or lower for the production of an outer sheath layer of a power or communication cable.

30

The outermost sheath layer of the cable of the invention can be processed more easily as compared to prior art materials while retaining at the same time good mechanical properties, in particular good surface appearance.

35

The term "molecular weight" as used herein denotes the weight average molecular molecular weight M_w . The melt flow rate MFR of a polymer may serve as a measure

2a

for the weight average molecular weight.

The term “base resin” means the entirety of polymeric components in the polyethylene composition used for the outer sheath layer of the cable according to the invention,
5 usually making up at least 90 wt% of the total composition.

Usually, a polyethylene composition comprising at least two polyethylene fractions, which have been produced under different polymerisation conditions resulting in different (weight average) molecular weights for the fractions, is referred to as "multimodal". The prefix "multi" relates to the number of different polymer fractions the composition is consisting of. Thus, for example, a composition consisting of two fractions only is called "bimodal".

The form of the molecular weight distribution curve, i.e. the appearance of the graph of the polymer weight fraction as function of its molecular weight, of such a multimodal polyethylene will show two or more maxima or at least be distinctly broadened in comparison with the curves for the individual fractions.

For example, if a polymer is produced in a sequential multistage process, utilising reactors coupled in series and using different conditions in each reactor, or when a polymer is produced in a process comprising a single stage in which two or more different catalysts are used, the polymer fractions produced in the different reactors, or by the different catalysts, respectively, will each have their own molecular weight distribution and weight average molecular weight. When the molecular weight distribution curve of such a polymer is recorded, the individual curves from these fractions are superimposed into the molecular weight distribution curve for the total resulting polymer product, usually yielding a curve with two or more distinct maxima.

In a preferred embodiment, the base resin has a molecular weight distribution M_w/M_n of 23 or more, more preferably 25 or more, even more preferably 30 or more.

The base resin preferably has a MFR_2 of 0.05 to 5 g/10min, more preferably of 0.1 to 4 g/10min, still more preferably of 0.2 to 3.5 g/10min and most preferably of 0.5 to 1.5 g/10min.

Furthermore, the base resin preferably has a MFR_{21} of 50 to 150 g/10min, more preferably of 70 to 130 g/10min. In a preferred embodiment, the base resin has a MFR_{21} of at least 90 g/10 min.

The density of the base resin preferably is 0.915 to 0.960 g/cm³, more preferably is 0.918 to 0.950 g/cm³, still more preferably is 0.918 to 0.935 g/cm³, and most preferably is 0.918 to 0.928 g/cm³.

10 The base resin preferably has a flow rate ratio FRR of 50 to 150, more preferably of 80 to 130.

Fraction (A) of the base resin preferably has a MFR_2 of 50 to 5000 g/10min, more preferably of 100 to 1000 g/10min, and most preferably of 200 to 700 g/10min.

15 Further, fraction (A) preferably has a density of 0.930 to 0.975 g/cm³, more preferably of 0.935 to 0.955 g/cm³.

Still further, fraction (A) preferably is an ethylene copolymer with at least one further alpha-olefin.

Preferably, the alpha-olefin comonomer of fraction (B) is having from 3 to 20 carbon atoms, more preferably 4 to 10 carbon atoms, and most preferably is selected from 1-butene, 1-hexene, 4-methyl-1-pentene, 1-octene and 1-decadene.

Further preferred, the weight average molecular weight of fraction (A) is from 5,000 g/mol to 100,000 g/mol, more preferably is from 7,000 to 90,000 g/mol, and most preferably is from 10,000 to 80,000 g/mol.

- 5 Fraction (B) of the base resin preferably has a MFR₂ of 0.01 to 1g/10min, more preferably of 0.05 to 0.3 g/10min.

Further, fraction (B) preferably has a density of 0.880 to 0.930 g/cm³, more preferably has a density of 0.890 to 0.920 g/cm³.

10

Still further, fraction (B) preferably is a copolymer of ethylene with at least one further alpha-olefin.

- 15 Preferably, the alpha-olefin comonomer of fraction (B) is having from 3 to 12 carbon atoms, more preferably 4 to 8 carbon atoms, and most preferably is selected from 1-butene, 1-hexene, 4-methyl-1-pentene and 1-octene.

- 20 Preferably, the amount of fraction (C) is up to 15 wt%, more preferred up to 10 wt% of the total base resin. In a preferred embodiment, fraction (C) is present in the base resin in an amount of 1 wt% to 5 wt%.

Further, preferably fraction (C) is present in the base resin in an amount of at least 2 wt%, more preferably of at least 3wt%.

- 25 Preferably, fraction (C) has a MFR₂₁ of less than 1g/10 min.

Fraction (C) preferably is an ethylene homopolymer.

Fraction (C) is preferably made in a previous step from (A) and (B) and fraction (C) has a higher MW than fraction (B).

The weight ratio of fractions (A):(B) in the base resin preferably is 30:70 to 70:30, more preferably 40:60 to 60:40, even more preferably 45:55 to
5 55:45.

The base resin preferably has a density of lower than 960 kg/m^3 .

The weight average molecular weight of the base resin preferably is from 100,000 g/mol to 2,000,000 g/mol.

In a preferred embodiment, the base resin consists of fraction (A), (B) and
10 (C).

In addition to the base resin, usual additives for utilization with polyolefins, such as pigments (for example carbon black), stabilizers (antioxidant agents), antacids and/or anti-UVs, antistatic agents and utilization agents (such as processing aid agents) may be present in the
15 polyethylene composition. The additives can be added as a polyolefin masterbatch. Preferably, the amount of these additives is 10 wt% or below, further preferred 8 wt% or below, of the total composition.

The polyethylene composition of the cable according to the invention preferably has a shear thinning index $\text{SHI}_{(2.7/210)}$ of at least 5, more
20 preferably at least 10, still more preferably at least 20 and most preferably at least 40.

Furthermore, the polyethylene composition preferably has a shear thinning index $\text{SHI}_{(2.7/210)}$ of 300 or less, more preferably 290 or less, still more preferably 220 or less and most preferably 200 or less.

The SHI is the ratio of the viscosity of the polyethylene composition at different shear stresses. In the present invention, the shear stresses at 2.7 kPa and 210 kPa are used for calculating the $SHI_{2.7/210}$ which may serve as a measure of the broadness of the molecular weight distribution.

- 5 Furthermore, the polyethylene composition preferably has a viscosity at a shear stress of 2.7 kPa $\eta_{(2.7)}$ of 10,000 to 500,000 Pas, more preferably of 50,000 to 400,000 Pas, and most preferably of 75,000 to 350,000 Pas.

The base resin of the polymer composition used for making the outermost sheath layer of the cable of the invention may be produced by any process
10 known in the art.

It is preferred, however, that the base resin is a so-called in-situ blend of its constituents. By "in-situ blend", a multimodal polymer is meant which fractions are produced either simultaneously in one reaction stage (e.g. by using two or more different catalysts), and/or are produced in a multistage
15 process. A multistage process is defined to be a polymerisation process in which a polymer comprising two or more fractions is produced by producing each or at least two polymer fraction(s) in a separate reaction stage, usually with different reaction conditions in each stage, in the presence of the reaction product of the previous stage which comprises a
20 polymerisation catalyst. The polymer can be recirculated to any stage or reactor.

Where herein preferred features of fractions (A) and/or (B) of the composition of the present invention are given, these values are generally valid for the cases in which they can be directly measured on the respective
25 fraction, e.g. when the fraction is separately produced or produced in the first stage of a multistage process.

However, the base resin may also be and preferably is produced in a multistage process wherein e.g. fractions (A) and (B) are produced in subsequent stages. In such a case, the properties of the fractions produced in the second and third step (or further steps) of the multistage process can
5 either be inferred from polymers, which are separately produced in a single stage by applying identical polymerisation conditions (e.g. identical temperature, partial pressures of the reactants/diluents, suspension medium, reaction time) with regard to the stage of the multistage process in which the fraction is produced, and by using a catalyst on which no previously
10 produced polymer is present. Alternatively, the properties of the fractions produced in a higher stage of the multistage process may also be calculated, e.g. in accordance with B. Hagström, Conference on Polymer Processing (The Polymer Processing Society), Extended Abstracts and Final Programme, Gothenburg, August 19 to 21, 1997, 4:13.

15 Thus, although not directly measurable on the multistage process products, the properties of the fractions produced in higher stages of such a multistage process can be determined by applying either or both of the above methods. The skilled person will be able to select the appropriate method.

20 The base resin of the cable according to the invention preferably is produced so that at least one of fractions (A) and (B), preferably (B), is produced in a gas-phase reaction.

Further preferred, one of the fractions (A) and (B) of the polyethylene composition, preferably fraction (A), is produced in a slurry reaction,
25 preferably in a loop reactor, and one of the fractions (A) and (B), preferably fraction (B), is produced in a gas-phase reaction.

It is furthermore preferred that fraction (A) and (B) of the polyethylene composition are produced in different stages of a multistage process.

Preferably, the multistage process comprises at least one gas phase stage in which, preferably, fraction (B) is produced.

- 5 Further preferred, fraction (B) is produced in a subsequent stage in the presence of fraction (A) which has been produced in a previous stage.

It is previously known to produce multimodal, in particular bimodal, olefin polymers, such as multimodal polyethylene, in a multistage process comprising two or more reactors connected in series. As an example of this
10 prior art, mention may be made of EP 517 868, which is hereby incorporated by way of reference in its entirety, including all its preferred embodiments as described therein, as a preferred multistage process for the production of the polyethylene composition of the cable according to the invention.

- 15 Preferably, the main polymerisation stages of the multistage process are such as described in EP 517 868, i.e. the production of fractions (A) and (B) is carried out as a combination of slurry polymerisation for fraction (A)/gas-phase polymerisation for fraction (B). The slurry polymerisation is preferably performed in a so-called loop reactor. Further preferred, the
20 slurry polymerisation stage precedes the gas phase stage.

In a preferred embodiment, fraction (C) is also produced in the multistage process in which fractions (A) and (B) are produced. Preferably, fraction (C) is produced in a so-called prepolymerisation step, preceding the production of further fractions of the base resin. As mentioned, the
25 prepolymer is preferably an ethylene homopolymer (HDPE).

Preferably, in the prepolymerisation step, all of the catalyst is charged into a loop reactor and the prepolymerisation is performed as a slurry polymerisation. Such a prepolymerisation leads to less fine particles being produced in the following reactors and to a more homogeneous product
5 being obtained in the end.

In the production of the base resin, Ziegler-Natta (ZN) or metallocene catalysts are preferably used, more preferably Ziegler-Natta catalysts.

The catalyst may be supported, e.g. with conventional supports including silica, Al-containing supports and magnesium dichloride based supports.
10 Preferably the catalyst is a ZN catalyst, more preferably the catalyst is non-silica supported ZN catalyst, and most preferably MgCl_2 -based ZN catalyst.

The Ziegler-Natta catalyst further preferably comprises a group 4 (group numbering according to new IUPAC system) metal compound, preferably titanium, magnesium dichloride and aluminium.

15 The catalyst may be commercially available or be produced in accordance or analogously to the literature. For the preparation of the preferable catalyst usable in the invention reference is made to WO2004055068 and WO2004055069 of Borealis and EP 0 810 235. The content of these documents in its entirety is incorporated herein by reference, in particular
20 concerning the general and all preferred embodiments of the catalysts described therein as well as the methods for the production of the catalysts.

Preferably, the polymerisation conditions in the preferred multistage method are so chosen that, owing to a high content of chain-transfer agent (hydrogen gas), the comparatively low-molecular polymer is produced in a
25 stage preceding the stage in which the high-molecular polymer is produced. The order of these stages may, however, be reversed.

In the preferred embodiment of the polymerisation of fraction (A) in a loop reactor followed by production of fraction (B) in a gas-phase reactor, the polymerisation temperature in the loop reactor preferably is 85 to 115 °C, more preferably is 90 to 105°C, and most preferably is 92 to 100°C, and the
5 temperature in the gas-phase reactor preferably is 70 to 105 °C, more preferably is 75 to 100°C, and most preferably is 82 to 97°C.

A chain-transfer agent, preferably hydrogen, is added as required to the reactors, and preferably 200 to 800 moles of H₂/kmoles of ethylene are added to the reactor, when the LMW fraction is produced in this reactor,
10 and 0 to 50 moles of H₂/kmoles of ethylene are added to the gas phase reactor when this reactor is producing the HMW fraction.

If a prepolymerisation step is used in which fraction (C) is produced it is preferred that no hydrogen at all is introduced into the reactor during this step. We need to open up for allowing small addition of hydrogen.

- 15 The composition for the outer sheath layer of the cable of the invention preferably is produced in a process comprising a compounding step, wherein the composition of the base resin, i.e. the blend, which is typically obtained as a base resin powder from the reactor, is extruded in an extruder and then pelletised to polymer pellets in a manner known in the art.
- 20 Optionally, additives or other polymer components can be added to the composition during the compounding step in the amount as described above. Preferably, the composition of the invention obtained from the reactor is compounded in the extruder together with additives in a manner known in the art.

The extruder may be e.g. any conventionally used extruder. As an example of an extruder for the present compounding step may be those as supplied by Japan steel works, Kobe steel or Farrel-Pomini, e.g. JSW 460P.

The cables of the invention in addition to the outermost sheath layer
5 comprise at least one or more power or information conducting elements. The cable comprising the outer sheath layer may be produced...

As indicated in the foregoing, the cable sheathing composition can be used for producing outer sheath layers for cables, including power cables as well as communication cables. Amongst power cables, mention may be made of
10 high-voltage cables, medium voltage cables, and low voltage cables. Amongst communication cables, mention may be made of pair cables, coaxial cables and optical cables.

Examples

15

Measuring methods

a) Molecular weight/molecular weight distribution

The weight average molecular weight M_w and the molecular weight distribution ($MWD = M_w/M_n$ wherein M_n is the number average molecular weight and M_w is the weight average molecular weight) is measured by a
20 method based on ISO 16014-4:2003. A waters 150CV plus instrument was used with column 3 x HT&E styragel from Waters (divinylbenzene) and trichlorobenzene (TCB) as solvent at 140 °C. The column set was calibrated using universal calibration with narrow MWD PS standards (the
25 Mark Howings constant $K: 9.54 \cdot 10^{-5}$ and $a: 0.725$ for PS, and $K: 3.92 \cdot 10^{-4}$

and a : 0.725 for PE). The ratio of M_w and M_n is a measure of the broadness of the distribution, since each is influenced by the opposite end of the "population".

b) Density

5 Density is measured according to ISO 1872, Annex A.

c) Melt Flow Rate/Flow Rate Ratio

The melt flow rate (MFR) is determined according to ISO 1133 and is indicated in g/10 min. The MFR is an indication of the flowability, and hence the processability, of the polymer. The higher the melt flow rate, the
10 lower the viscosity of the polymer. The MFR is determined at 190°C and may be determined at different loadings such as 2.16 kg (MFR_2), 5 kg (MFR_5) or 21.6 kg (MFR_{21}).

The quantity FRR (flow rate ratio) is an indication of molecular weight distribution and denotes the ratio of flow rates at different loadings. Thus,
15 $FRR_{21/2}$ denotes the value of MFR_{21}/MFR_2 .

d) Rheological parameters

Rheological parameters such as Shear Thinning Index SHI and Viscosity are determined by using a rheometer, preferably a Rheometrics Phisica MCR 300 Rheometer. The definition and measurement conditions are
20 described in detail on page 8 line 29 to page 11, line 25 of WO 00/22040.

e) Environmental stress cracking resistance (ESCR)

ESCR was evaluated according to CTL: ISO 6259, with a notch applied according to ASTM F1473, using CTL with different constant stress of 2, 3 and 4 MPa. A 10% Igepal solution was used as medium.

- 5 f) Cable samples for the evaluation are extruded as follows.

Conductor	3.0 mm Solid Al conductor
Wall thickness	1.0 mm
Temperature, die	+210°C
Distance between die and waterbath	35cm
Temperature, water bath	+23°C
Line velocity	75m/min
Die type	Semi-tube
Nipple	3.65mm
Die	5,9mm
Screw design	Elise

g) Shrinkage

- 10 The shrinkage in percent is measured after 24h in constant temperature (+23°C) as well as after 24h at a temperature of +100°C . Cable samples measuring approximately 40cm are measured. Conveniently, the samples is so marked that the measurement after the conditioning can be carried out at the same point on the cable sample.

Should the sample be found to shrink during measurement, marks of about 40cm

first have to be made. Then the length is cut and remeasured. Double samples are taken of each cable that is to be analysed. The samples are placed in the room with constant temperature for 24h, whereupon they are measured, and shrinkage value in percent are calculated. All the samples are then placed on a talcum bed
5 at 100°C for 24h. The samples are measured, and the total shrinkage in percent is calculated on the basis of the initial length.

h) Filler absorption

Filler absorption was measured according to BTM22511 on plaques, quenched in cool water.

10 i) Mechanical properties

Elongation at break and tensile strength at break were measured according to 22542/ISO 527-2/1A,B, either on plaques or on cables having a jacket of 1 mm in thickness applied on a 3 mm in diameter aluminium conductor.

j) Heat deformation

15 This was tested according to EN 60811-3-1:1995. This was tested on cables 3mm core and 1mm jacketing layer extruded directly on the conductor. This property is directly proportional to the density. In this test we have used cool waterbath during extrusion, therefore reproducing the worst case. When the molten plastics meet cold water the density is lower than if the crystallization takes place during
20 slow cooling, see table for results. The indentation at 115°C after 4h is recorded and reported as how many % the egg is penetrating the sample thickness.

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Tested CompositionsExamples 1-5

Two comparative polyethylene compositions (CompEx 9 and CompEx 10) and
 5 three comparative polyethylene compositions have been prepared (CompEx 1-3).
 All compositions are bimodal. Further information about each composition is
 given below:

Table 1: Properties of CompEx 9, 10 and CompEx 1-2

	CompEx 9	CompEx. 10	CompEx 1	CompEx 2
Density (kg/cm ³)	921.8	924.4	923	923
MFR2 (g/10 min)	0.87	0.81	0.4	0.2
MFR21 (g/10 min)	87	96	40	22
FRR21/2	100	118	100	110
Loop				
Temperature (°C)	85	85		
Pressure (bar)	60	60		
H2/C2 ratio (mol/kmol)	282	275	330	350
C4/C2 ratio (mol/kmol)	147	142	670	630
MFR2 (g/10 min)	520	520	300	300
Density (kg/cm ³)	952	951	951	945
Split	50	54	43	42
Gasphase				
Temperature (°C)	80	80		
Pressure (bar)	20	20		
H2/C2 ratio (mol/kmol)	8	8	10	3
C4/C2 ratio (mol/kmol)	747	695	650	600
MFR2 (g/10 min)	0,85	0,7-1		
Density (kg/cm ³)	892	893	901	907
Split	50	46	57	58

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As additives, 2400 ppm Irganox B225 and 1500 ppm calcium stearate have been used. The catalyst used in CompEx 9, 10 and CompEx 1-2 is a Ziegler-Natta type catalyst which corresponds to the one used in EP 6887794, Example 3.

5

Table 2: Molecular weight and molecular weight distribution of CompEx 9, 10

	CompEx 9	CompEx 10
Mw	149000	139000
Mn	9040	8070
Mz	845000	796000
MWD	16.5	17.3

10 In CompEx 9, 10, the melt flow rate $\text{MFR}_{21.6\text{kg}/190^\circ\text{C}}$ is significantly higher than in the comparative examples. Furthermore, as indicated by FRR21/2 and MWD values, the inventive examples have a broad molecular weight distribution.

15 CompEx 3 is a linear low density polyethylene (LLDPE) including 15 wt% low density polyethylene to improve processability. Properties of the blend are given in Table 3:

Table 3: Properties of CompEx 3

	Comp.Ex. 3
Density (g/cm^3)	0.920
MFR2 ($\text{g}/10 \text{ min}$)	0.8
MFR21 ($\text{g}/10 \text{ min}$)	79
FRR _{21/2}	65

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In the following, relevant processing properties and mechanical properties of these compositions will be provided and discussed.

5

Processability

As already discussed above, the processability of a jacketing material includes several parameters e.g. surface finish, output, melt pressure, and extruder motor power. It is important that the processing window is wide since there are many
10 different applications for a jacketing material.

To evaluate the processability, the compositions were extruded at a cable line. 1mm thick jacket were applied on a 3mm in diameter aluminum conductor. To stress the material in terms of shrinkage performance the temperature setting was not optimal. The conductor was not preheated, the melt temperature was 210°C
15 and the cooling bath temperature was 23°C. The line speed was 75m/min.

Surface finish

Surface finish was evaluated by visual and hands on inspection.

Previous experience is that the lower the MFR the better is the surface finish.
20 However, all cables produced showed a very smooth surface which is quite surprising considering the high MFR21 values chosen for CompEx 9, 10.

Output and melt pressure

In Table 4, data from the cable line extrusion test are shown.

25

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Table 4: Cable line extrusion test

	Comp Ex 9	Comp Ex 10	Comp Ex 2	Comp Ex 1	Comp Ex 3
Filter pressure (Bar)	243	235	332	300	255
RPM	61	61	65	59	58
Extruder power (amps)	55	55	67	65	62

- 5 The results of Table 4 clearly indicate that the compositions can be extruded at lower pressure and extruder power.

The effect of $MFR_{21.6kg/190^{\circ}C}$ on extruder pressure is also shown in Fig. 1. Due to the lower MFR₂₁, CompEx 1-2 need a much higher extruder pressure to have the same output. By blending LDPE and LLDPE (i.e. CompEx 3), it is possible to

10 have an extruder pressure comparable the one of CompEx 9, 10. However, adding LDPE adversely affects mechanical properties, heat deformation and shrinkage behaviour, as will be shown below.

15 Environmental stress cracking resistance (ESCR)

The environmental stress cracking was evaluated using CTL with different constant stress. A 10% igepal solution was used as medium. The results are shown in table 5.

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Table 5: ESCR results

	CompEx 9	CompEx 10	CompEx 1	CompEx 2	CompEx 3
CTL 2MPa (h)					
CTL 3MPa (h)	>3500	>3500	>3500	>3500	55.25
CTL 4MPa (h)	>3500	>3500	>3500	>3500	30,35
ESCR bell test (F0h)	>2000	>2000	>2000		>2000

Mechanical properties

5 Elongation at break and tensile strength are summarized in Table 6. The results demonstrate that the inventive examples have good mechanical properties. In other words, processability has been improved while keeping mechanical properties on a high level.

Table 6: Data about mechanical properties

	CompEx 9	CompEx 10	CompEx 2	CompEx 1	CompEx 3
Elongation at break (%)	711	703	661	804	829
Tensile strength at break (MPa)	26.1	25.8	30.5	31.8	22.0

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Shrinkage

Shrinkage values are listed in Table 7.

Table 7: Shrinkage behaviour

	CompEx 9	CompEx 10	CompEx 2	CompEx 1	CompEx 3
Shrinkage 24h 23°C (%)	0.04	0.04	0.05	0.00	0.24
Shrinkage 24h 100°C (%)	0.08	0.13	0.19	0.18	0.92

5

The data of Table 7 indicate that the compositions show low shrinkage. In particular, it is evident that the improvement in processability of CompEx 3 (e.g. low extrusion pressure) adversely affects shrinkage behaviour.

10 Compatibility with filling compounds

The main application for LD and LLD jackets is in telecommunication cables. In many telecables, copper or fiber optical, filling compounds are used to protect them from water intrusion. A petroleum jelly based, Insojell 3332, is commonly used in copper cables. This filling compound is normally the filling compound that gives the highest absorption.

15

Two tests are performed, weight increase and the influence on the mechanical properties.

Dumbbells 2 mm thick from pressed plaques were put in Insojell 3332 for 7 days.

The samples were put on aluminum rods to enable free access for the petroleum

20 jelly from all sides. The ageing was done at 60°C. For the results see table 9.

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Table 9: Influence of petroleum jelly

	CompEx 9	CompEx 10	CompEx 2	CompEx 1	CompEx 3
Weight increase (%)	14.5	12.2	10.5	9.0	7.9
Tensile strength at break (MPa)	20.7	21.4	25.4	25.7	16.4
Change in tensile strength (%)	-8.0	5	-23.3	-20.5	-11.4
Elongation at break (%)	717	778	639	736	756
Change in elongation (%)	-19.2	-14.8	-22.0	-13.9	-10.7

5

Examples 6-13

In these examples, three polyethylene compositions according to the present invention (Ex 3-5) and five reference materials (CompEx 4-8) have been prepared.

- 10 The inventive examples were prepared in a sequential multistage process including a prepolymerization step, followed by polymerization in a loop reactor and subsequently in a gas phase reactor. Thus, the final composition included three polymer fractions.

As a catalyst for the examples 3-5, a commercial Lynx 200™ catalyst as
15 manufactured and supplied by Engelhard Corporation has been used

Just like the inventive examples, CompEx 4-5 have been prepared in a sequential multistage process. However, in contrast to Ex 3-5, no prepolymerization step was included. Thus, CompEx 4-5 are bimodal.

CompEx 4 is based on CompEx 1. However, low density polyethylene was
5 added.

CompEx 5 corresponds to CompEx 1.

CompEx 6-7 are both based on linear low density polyethylene to which low density polyethylene has been added to improve processability.

CompEx 8 has been prepared in a two-step process, the first step being carried
10 out in a loop reactor, followed by a gas phase polymerization step.

Further information about these compositions is provided in Table 10.

15

20

Table 10: Process conditions and properties for Ex 3-5

sample		Ex 3	Ex 4	Ex 5
PREPOLYMERISATION REACTOR				
temperature	°C	60	60	60
pressure	bar	61	60	61
catalyst feed	g/h	1.4	1.4	2.3
cocatalyst feed	g/h	5.0	5.0	5.0
antistatic feed	ppm	7	7	7
C ₂ feed	kg/h	1.9	1.7	2.0
H ₂ feed	g/h		0,6	
C ₄ feed	g/h			
C ₆ feed	g/h			
C ₃ feed	kg/h	36.8	35.7	38.7
split	wt-%	2.7	2.5	3.0
run stability		good	good	good
MFR2	g/(10 min)			
density	kg/cum			
ash content	ppm			
LOOP REACTOR				
temperature	°C	80	80	80
pressure	bar	56	56	56
catalyst feed	g/h	1.4	1.4	2.3
cocatalyst feed	g/h			
C ₂ feed	kg/h	32.9	33.0	31.7
H ₂ feed	g/h			
C ₄ feed	g/h			
C ₃ feed	kg/h	80.2	93.7	88.7
C ₂ concentration	mol%	3.9	4.5	4.3
H ₂ /C ₂ ratio	mol/kmol	399	360	390
C ₄ /C ₂ ratio	mol/kmol	469	388	421
C ₆ /C ₂ ratio	mol/kmol			
C ₄ /C ₂ feed ratio	g/kg			
ethane concentration	mol%	0.23	0.17	0.19
production rate	kg/h	32	31	30
productivity	kg/g	23	22	13
split	wt-%	50.9	51.6	51.5
run stability		good	fair	good
MFR2	g/(10 min)	350	300	350
density	kg/cum	944	947	946
bulk density	kg/cum	367	374	390
ash content	ppm	100	150	
US200	wt-%	7.2	13.4	10.5
pan	wt-%	10.8	14.0	11.2

finer (<106 µm)	wt-%	18.0	27.4	21.7
APS	mm	0.22	0.18	0.21
comonomer		1-butene	1-butene	1-butene
GAS PHASE REACTOR				
temperature	°C	80	80	80
pressure	bar	20	20	20
C ₂ feed	kg/h	35	38	34
H ₂ feed	g/h	10.2	11.0	10.1
C ₄ feed	kg/h	9.6	12.2	10.8
C ₆ feed	kg/h			
C ₂ concentration	mol%	11	12	11
C ₂ partial pressure	bar	2.2	2.4	2.2
H ₂ /C ₂ ratio	mol/kmol	34	29	31
C ₄ /C ₂ ratio	mol/kmol	403	455	450
C ₆ /C ₂ ratio	mol/kmol			
C ₄ /C ₆ feed ratio	g/kg	270	324	321
ethane concentration	mol%	0.03	0.03	0.03
production rate	kg/h	30.5	29.3	28.8
productivity (overall)	kg/g	45	42	25
split	wt-%	49.1	48.4	48.5
run stability		fair	good	good
MFR2	g/(10 min)	0,8	0,9	1,0
MFR21	g/(10 min)	87	94	106
FRR21/2	-	104	106	106
density	kg/cum	926	927	925
calculated density				
(HMW fraction)	kg/cum	907	906	903
bulk density	kg/cum	404	395	397
US200	wt-%	3,5		5,5
pan	wt-%	2,3		3,4
finer (<106 µm)	wt-%	5,8		8,9
APS	mm	0,3		0,3
comonomer		1-butene	1-butene	1-butene
EXTRUDER				
feed	kg/hr	221	221	221
screw speed	rpm	400	400	400
throttle valve position	degrees	12	12	12
SEI	kWh/t	260	271	260
melt temperature	°C	215,4	220,4	216,6
pellet quantity	kg	358	400	550
MFR2	g/(10 min)	0,8	0,9	1,0
MFR5	g/(10 min)	3,40	3,90	4,50
MFR21	g/(10 min)	90,0	102,0	111,0
FRR21/2	-	114	115	111

MWD	-	31,6	32,0	32,3
density	kg/cum	926,3	928,3	926,8
ash content	ppm	210	230	280
irganox B225	ppm	2640	2650	2690
irganox B561	ppm			
irganox 1076	ppm			
168/XR	ppm			
carbon black	wt-%			
Cast	ppm	1580	1580	1590
CaZnst	ppm			
Znst	ppm			
YI/3mm	-		-8,0	-8,3
Gel.2-	n/sqm			
Gel.4-	n/sqm			
Gel.7-	n/sqm			
WS dispersion	-			
CB disperion	-			

Table 11: Properties of reference materials

	CompEx 4	CompEx 5	CompEx 6	CompEx 7	CompEx 8
Density (kg/cm ³)	925	923	931	920	921.5
MFR2 (g/10 min)	0.4	0.4	0.7	0.8	0.7
MFR21 (g/10 min)		40	79	79	46
FRR21/2		100	65	65	68
Loop					
Temperature					85
Pressure					57
H2/C2 ratio		330			202
C4/C2 ratio		670			609
MFR2 (g/10 min)		300			290
Density (kg/cm ³)		951			950
Split		43			43,5
Gasphase					
Temperature					80
Pressure					20
H2/C2 ratio		10			4,4
C4/C2 ratio		650			619
MFR2 (g/10 min)					0.7
Density (kg/cm ³)		901			897
Split		57			56,5

Comparative example 4 is the same as comparative example 5 but with 15%LDPE compounded.

In Table 12, molecular weight and molecular weight distribution of Ex 3-5 and CompEx 5 and 8 are summarized. From Table 12, it is evident that the presence of a third fraction in the inventive compositions significantly broadens the molecular weight distribution, if compared to the reference materials.

Table 12: Molecular weight and molecular weight distribution

	Ex 3	Ex 4	Ex 5	CompEx 8	CompEx 5
Mw	136000	143000	136000	143000	185000
Mn	4330	4480	4220	10100	15000
Mz	808000	940000	901000	612000	
MWD	31.6	32	32.3	14.2	12.3

10

In Table 13, the shear thinning index SHI(2.7/210) of Ex 3-5 and CompEx 8 is given.

Table 13: Shear thinning index

Product	SHI(2.7/210)
Ex 3	65
Ex 4	60
Ex 5	58
CompEx 4	41
CompEx 5	35
CompEx 6	50
CompEx 8	25

15

As shown in Table 13, the inventive compositions have high shear thinning index, significantly exceeding the value of the reference material. As already discussed above, high SHI values indicate a broad molecular weight distribution.

The compositions have been subjected to tests for processability and mechanical properties. The results are shown and discussed below.

5 Surface finish

Surface finish was evaluated by visual and hands on inspection. Two different phenomena were observed, first the surface finish as such but also the shape of the insulation. At higher line speed a wave shape occurred at some of the materials. The former are due to the melt strength and the second is more due to extruder pumping and could possibly be corrected by increased melt temperature. However it indicates a more narrow processing window. Previous experience is that the lower the MFR the better is the surface finish. Although the inventive compositions have much higher MFR, they provide excellent results at these line speeds.

15 Table 14: Evaluation of surface properties

	Line speed	Ex 3	Ex 4	Ex.5 A2047	CompEx 8	CompEx 6	CompEx 5	CompEx 4
Surface smoothness	15	3	3	4	4	3	3	4
0-4 (4 is best)	35	4	4	4	4	4	4	4
	70	4	4	4	4	4	4	4
	140	4	4	4	4	4	4	4
Waviness	15	4	4	4	4	4	4	4
1-4 (4 is best)	35	4	4	4	4	4	4	4
	70	4	4	4	4	4	4	4
	140	4	4	4	3	3	2	2
Over all performance compared to CompEx 6		=/+	=/+	+/+	+/=		=/-	+/-

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Melt pressure

Just like CompEx 9, 10, the inventive examples 3-5 have low melt pressure at a specific line speed. With CompEx 6-7 (i.e. blends of LLDPE and LDPE), a low melt tension can be obtained as well. However, as will be shown below, in these materials low-melt tension adversely affects tensile strength, heat deformation and shrinkage behaviour.

In CompEx 4, 5 and 8, melt tension is significantly higher.

10 Melt tension as a function of line speed is shown in Fig. 2.

Mechanical properties

Mechanical properties are summarized in Tables 15 and 16.

15 Table 15: Mechanical properties measured on plaques

Plaques	Ex 3	Ex 4	Ex 5	CompEx 8	CompEx 4	CompEx 5	CompEx 6
Elongation at break (%)	904	907	937	837	808	824.9	810
Tensile strength at break (MPa)	26.3	28.7	28.5	33.1	31.7	32.5	19.5

The data of Table 15 show that the inventive examples have good mechanical properties. In particular, when comparing Ex 3-5 with CompEx 6 it is evident

that only the inventive examples have an improved balance between processability (e.g. low melt pressure) and mechanical properties.

5 Table 16: Mechanical properties measured on cables

Cables	Ex 3	Ex 4	Ex 5	CompEx 8	CompEx 4	CompEx 5	CompEx 6
Elongation at break (%)	597	631	620	576	500	551	527
Tensile strength at break (MPa)	17.1	17.6	17.3	18.8	17.9	17	17.6

Shrinkage

- 10 24 h shrinkage was measured at 23°C and 100°C. The results are summarized in Table 17. The inventive examples show good shrinkage performance.

Table 17: Shrinkage behaviour

	Ex 3	Ex 4	Ex 5	CompEx 4	CompEx 5	CompEx 6	CompEx 8
Shrinkage 24h 23°C (%)	0.15	0.0	0.0	0.0	0.00	0.0	0.0
Shrinkage 24h 100°C (%)	0.34	0.08	0.15	0.45	0.07	0.4	0.01

Compatibility with filling compounds

Two compatibility tests were performed: weight increase and the influence on the mechanical properties.

- 5 Dumbbells 2 mm thick from pressed plaques were put in Insojell 3332 for 7 days. The samples were put on aluminum rods to enable free access for the petroleum jelly from all sides. The ageing was done at 70°C. The results are shown in Table 18.

10 Table 18: Results from compatibility tests

Jelly absorption	Ex 3	Ex 4	Ex 5	CompEx 8	CompEx 4	CompEx 5	CompEx 6
Change in Elongation at break (%)	-5.6	-2.9	-3.7	-12.2	-9	-8.8	-0.8
Stress at break (%)	-11.4	-10.3	-17.5	-19.0	-15.6	-13.6	-9.1
Absorption weight increase (%)	5.61	5.48	5.84	8.24	7.14	7.26	6.79

- The materials prepared in a sequential multistage process (i.e. Ex 3-5 and CompEx 4, 5 and 8) have a more pronounced change in mechanical properties than the blend of LLDPE/LDPE. With regard to absorption weight increase, the
- 15 inventive examples have the lowest values. Thus, considering both effects (i.e. change in mechanical properties as well as change in weight), the inventive materials offer the best compromise.

Heat deformation values are provided in Table 19.

Table 19: Heat deformation

	Ex 3	Ex 4	Ex 5	Comp 8	Comp 4	Comp 5	Comp 6
Heat deformation 4h at 115° (%)	14.9	13.1	10.6	10.9	15.4	14.6	65

Crystallization temperature

In Table 20, crystallization temperatures of Ex 3-5 and CompEx 5 are listed.

Table 20: Crystallization temperature

	Ex 1	Ex 2	Ex 3	CompEx 5
Crystallization temperature (°C)	112.7	112.9	113.3	111.6

The increase in crystallization temperature is beneficial for processing, e.g. for film applications, since the high molecular weight fraction (iii) acts as a nucleator increasing the crystallization. This is advantageous for the cooling properties after processing the article.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A power or communications cable comprising an outer sheath layer made of a polyethylene composition comprising a base resin which comprises
 - (A) a first ethylene homo-or copolymer fraction.
 - (B) a second ethylene homo-or copolymer fraction, and
 - (C) a third ethylene homo-or copolymer fraction in an amount of up to 20 wt% of total base resin,wherein fraction (A) has a lower molecular weight than fraction (B), and the base resin has a molecular weight distribution M_w/M_n of more than 14, and fraction (C) has an MFR₂ of 0.1 g/10 min or lower.
2. Cable according to claim 1 wherein the base resin has a molecular weight distribution M_w/M_n of 23 or more.
3. Cable according to claim 1 or 2 wherein the base resin has a MFR₂₁ of at least 90g/10min.
4. Cable according to any one of claims 1 to 3 wherein the base resin has a MFR₂ of 0.05 to 5g/10min.
5. Cable according to claim 4 wherein the base resin has a MFR₂ of 0.5 to 1.2g/10min.
6. Cable according to any one of claims 1 to 5 wherein the base resin has a density of 0.915 to 0.960 g/cm³.
7. Cable according to claim 6 wherein the base resin has a density of 0.918 to 0.928 g/cm³.
8. Cable according to any one of claims 1 to 7 wherein the base resin has a flow rate ratio FRR of 50 to 150.
9. Cable according to claim 8 wherein the base resin has a flow rate ratio FRR of 80 to 130.
10. Cable according to any one of claims 1 to 9 wherein fraction (A) has a MFR₂

of 50 to 5000g/10min.

11. Cable according to any one of claims 1 to 10, wherein fraction (A) has a density of 0.930 to 0.975g/cm³.

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12. Cable according to any one of claims 1 to 11, wherein fraction (A) is an ethylene copolymer with at least one further alpha-olefin.

10

13. Cable according to any one of claims 1 to 12 wherein fraction (B) has a MFR₂ of 0.01 to 1g/10min.

14. Cable according to any one of claims 1 to 13 wherein fraction (B) has a density of 0.880 to 0.930 g/cm³.

15

15. Cable according to any one of claims 1 to 14 wherein fraction (B) is a copolymer of ethylene with at least one further alpha-olefin.

16. Cable according to any one of claims 1 to 15 wherein fraction (C) is present in the base resin in an amount of 1 wt% to 5 wt%.

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17. Cable according to any one of claims 1 to 16, wherein fraction (C) has a MFR₂₁ of less than 1g/10min.

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18. Cable according to any one of claims 1 to 17 wherein the weight ratio of fractions (A):(B) in the base resin is 40:60 to 60:40.

19. Cable according to any one of claims 1 to 18 wherein the composition has a SHI_(2.7/210) of 5 to 300.

30

20. Cable according to any one of claims 1 to 19 wherein the base resin is an in-situ blend.

21. A polyethylene composition comprising a base resin which comprises (A) a first ethylene homo-or copolymer fraction,

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(B) a second ethylene homo-or copolymer fraction, and

(C) a third ethylene homo-or copolymer fraction in an amount of up to 20 wt% of the total base resin,

wherein fraction (A) has a lower molecular weight than fraction (B), and the base resin has a molecular weight distribution M_w/M_n of more than 14, and fraction (C) has a MFR₂ of 0.1g/10 min or lower for the production of an outer sheath layer of a power or communication cable.

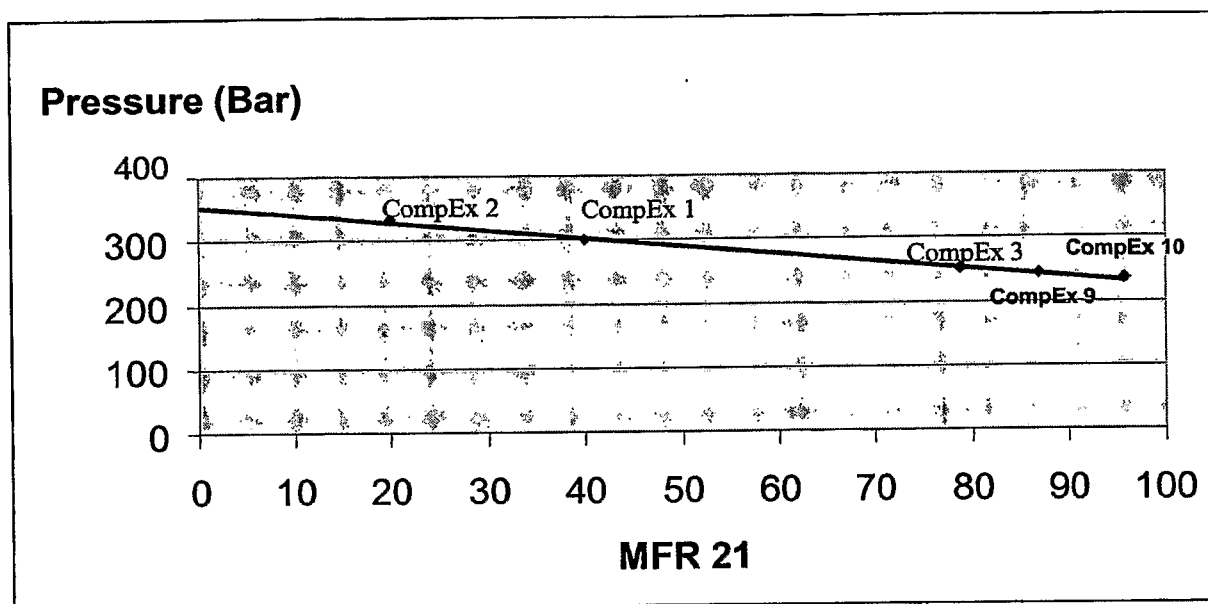
22. A power or communications cable substantially as herein described with reference to the accompanying drawings.
- 10 23. A polyethylene composition substantially as herein described with reference to the accompanying drawings.
24. A power or communications cable substantially as herein described with reference to the accompanying examples except for the comparative examples.
- 15 25. A polyethylene composition substantially as herein described with reference to the accompanying examples except for the comparative examples.

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Figures

Fig.1: Extruder pressure as a function of MFR 21



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