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(54) Title: ADDITIVES FOR IMPROVING THE COLD PROPERTIES OF FUEL OILS

(57) Abrégé/Abstract:

The invention provides additive mixtures comprising A) at least one terpolymer of ethylene, propene and at least one ethylenically unsaturated ester, which i) contains from 6.0 to 12.0 mol% of structural units derived from at least one ethylenically unsaturated ester having a C<sub>1</sub>- to C<sub>3</sub>-alkyl radical, ii) contains from 0.5 to 4.0 methyl groups derived from propene per 100 aliphatic carbon atoms, iii) has fewer than 8.0 methyl groups stemming from chain ends per 100 CH<sub>2</sub> groups, and B) from 0.5 to 20 parts by weight, based on A), of at least one further component which is effective as a cold additive for mineral oils and is selected from B1) copolymers of ethylene and ethylenically unsaturated compounds whose content of ethylenically unsaturated compounds is at least 2 mol% higher than the content of ethylenically unsaturated esters in the terpolymer defined under A), B2) comb polymers, and B3) mixtures of B1) and B2), and also their use as a cold additive for middle distillates.



Abstract

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Additives for improving the cold properties of fuel oils

5 The invention provides additive mixtures comprising

A) at least one terpolymer of ethylene, propene and at least one ethylenically unsaturated ester, which

10 i) contains from 6.0 to 12.0 mol% of structural units derived from at least one ethylenically unsaturated ester having a C<sub>1</sub>- to C<sub>3</sub>-alkyl radical,

ii) contains from 0.5 to 4.0 methyl groups derived from propene per 100 aliphatic carbon atoms,

15

iii) has fewer than 8.0 methyl groups stemming from chain ends per 100 CH<sub>2</sub> groups, and

20 B) from 0.5 to 20 parts by weight, based on A), of at least one further component which is effective as a cold additive for mineral oils and is selected from

25 B1) copolymers of ethylene and ethylenically unsaturated compounds whose content of ethylenically unsaturated compounds is at least 2 mol% higher than the content of ethylenically unsaturated esters in the terpolymer defined under A),

B2) comb polymers, and

B3) mixtures of B1) and B2),

30

and also their use as a cold additive for middle distillates.

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Dr. KM/sch

## Description

## 5 Additives for improving the cold properties of fuel oils

The present invention relates to additive mixtures comprising ethylene-propene-vinyl ester terpolymers in addition to a further cold additive, which have improved handling and improved performance properties as cold additives for fuel oils.

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Crude oils and middle distillates, such as gas oil, diesel oil or heating oil, obtained by distillation of crude oils contain, depending on the origin of the crude oils, different amounts of n-paraffins which crystallize out as platelet-shaped crystals when the temperature is reduced and sometimes agglomerate with inclusion of oil. This

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crystallization and agglomeration causes a deterioration in the flow properties of the oils or distillates, which may result in disruption in the course of extraction, transport, storage and/or use of the mineral oils and mineral oil distillates. When mineral oils are transported through pipelines, the crystallization phenomenon can, especially in winter, lead to deposits on the pipe walls and, in individual cases, for example in the

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event of stoppage of a pipeline, even to its complete blockage. In the storage and further processing of the mineral oils, it may also be necessary in winter to store the mineral oils in heated tanks in order to ensure their flowability. In the case of mineral oil distillates, the consequence of crystallization may be blockages of the filters in diesel engines and boilers, which prevents reliable metering of the fuels and, under

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some circumstances, results in complete interruption of the fuel or heating medium supply.

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In addition to the classical methods of eliminating the crystallized paraffins (thermally, mechanically or with solvents), which merely involve the removal of the precipitates which have already formed, chemical additives, known as flow improvers, are increasingly being used. These additives often comprise two components: firstly constituents which act as additional crystal seeds, crystallize out with the paraffins and bring about a larger number of smaller paraffin crystals with modified crystal form (nucleates), and secondly constituents which restrict the growth of the crystals once

they have formed (arrestors). The modified paraffin crystals have a lesser tendency to agglomerate, so that the oils admixed with these additives can still be pumped and processed at temperatures which are often more than 20°C lower than in the case of nonadditized oils.

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In view of decreasing world oil reserves, ever heavier and hence paraffin-richer crude oils are being extracted and processed, which consequently also lead to paraffin-richer fuel oils. In addition, the hydrogenating desulfurization of fuel oils, which is increasing for environmental reasons, causes altered processing of the crude oils, 10 which leads in some cases to an increased proportion of cold-critical paraffins in the fuel oil. In such oils, solubility and effectiveness of the known prior art additives are often unsatisfactory. Moreover, the low tolerances of modern engine technology, which are required for compliance with emission values, require very clean fuel oils. However, the known prior art additives, especially the additive components used as 15 crystal seed formers, often comprise small proportions of relatively insoluble constituents which recrystallize in some cases and can lead to problems in the injection systems and to deposits in the upstream fuel filters.

A known additive class which is used in many cases for the improvement of the cold 20 properties of mineral oils and middle distillates produced therefrom is that of copolymers of ethylene and vinyl esters, especially ethylene and vinyl acetate. The polymers are partly crystalline polymers whose mode of action is explained by cocrystallization of their poly(ethylene) sequences with the n-paraffins which precipitate out of the middle distillates in the course of cooling. This physical 25 interaction modifies shape, size and adhesion properties of the precipitating paraffin crystals to the effect that many small crystals form, which pass through the fuel filter and can be fed to the combustion chamber.

The ethylene copolymers used as crystal seed formers or nucleating agents in 30 particular must have a low solubility in the oil to fulfill their function, in order to crystallize out with or just before the paraffins when the oil is cooled. The crystal seed formers used are preferably ethylene copolymers with low comonomer content and hence long free poly(ethylene) sequences, which are capable to a particularly high degree of cocrystallization with the long-chain paraffins which precipitate out of the oil

first. In order, though, to be completely dissolved above the cloud point of the oil and not themselves be the cause of filter blockages, these ethylene-vinyl ester copolymers require, owing to their elevated intrinsic crystallinity, handling and dosage at elevated temperature or alternatively transport and processing in high dilution with 5 solvents. Otherwise, there is the risk that the additives remain undissolved, as a result of which they cannot display their full effect and may additionally themselves be the cause of filter coverage and filter blockage.

10 In addition, the injection units and pumps of current engine designs in particular require very clean fuels. Even small proportions of undissolved additive constituents are extremely undesired in this context. Removal of such secondary constituents from polymers by filtration is very difficult, if indeed possible at all.

15 It is also known that the intrinsic flowability of ethylene-vinyl ester copolymers and their dispersions can be improved by a high proportion of so-called short-chain branches, as can be established, for example, by polymerization at high temperatures and/or low pressures. These short-chain branches form through intramolecular chain transfer reactions ("back-biting mechanism") during the free-radical chain polymerization and consist essentially of butyl and ethyl radicals (see, 20 for example, Macromolecules 1997, 30, 246-256). However, these short-chain branches reduce the effectiveness of these polymers as cold additives significantly.

25 Structures comparable to the short-chain branches and associated effects are obtained by the incorporation of branched comonomers such as isobutylene (EP-A-0 099 646), 4-methylpentene (EP-A-0 807 642) or diisobutylene (EP-A-0 203 554) in EVA copolymers: Although an improvement in the flowability and the solubility of the polymers is observed with increasing incorporation of these monomers, their effectiveness as a cold additive also falls simultaneously.

30 US-3 961 916 discloses fuel oils which, for improvement in the cold flow properties, comprise two copolymers of ethylene and unsaturated esters, which function as nucleators or arrestors for paraffin crystallization.

EP-A-0 190 553 discloses terpolymers of ethylene, 20-40% by weight of vinyl acetate and propene, which have a degree of branching of from 8 to 25 CH<sub>3</sub>/100 CH<sub>2</sub> groups. These polymers, which can be considered as growth inhibitors, alone exhibit barely any effectiveness as cold flow improvers and are used to improve the solubility of 5 conventional EVA copolymers with comparable content of vinyl acetate.

US-4 178 950 discloses terpolymers of ethylene, from 10 to 45% by weight of vinyl acetate, from 0.01 to 5.0% by weight of propene or butene, and their use as pour point depressants for residue oils. Polymer mixtures are not disclosed.

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DE-A-2 037 673 discloses polymer mixture of ethylene-vinyl acetate copolymers of different molecular weight as cold flow improvers, which, as well as ethylene, may also contain propene as an olefin.

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EP-A-0 406 684 discloses polymer mixtures which comprise A) copolymers of ethylene, 25-35% by weight of vinyl acetate, optionally from 5 to 15% by weight of an olefin and a degree of branching of from 3 to 15 CH<sub>3</sub> groups, and B) a further ethylene-vinyl acetate copolymer and optionally C) a polyalkyl (meth)acrylate. The terpolymer of ethylene, vinyl acetate and diisobutylene demonstrated in the example 20 is used as a cold flow improver together with an EVA copolymer which has a low comonomer content and can be considered as a crystal seed former. Use of propene as a comonomer for nucleators is indicated neither in combination with arrestors nor in combination with comb polymers.

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Although it is possible to improve the intrinsic flowability of polymers of ethylene and unsaturated esters by virtue of short-chain branches or else relatively long-chain and especially branched olefin comonomers, this is often accompanied by a loss in activity as cold flow improvers, since the optimal range of the polyethylene sequence lengths for cocrystallization with paraffins is departed from, and even relatively small 30 amounts of the comonomers bring about such great disruption to the polyethylene sequences that effective cocrystallization with the paraffins of the oil and especially stimulation of paraffin crystallization (nucleation) is no longer possible. In addition, these nucleators often comprise very sparingly soluble fractions which recrystallize out of the oil and can lead to blockages of filters and injection systems.

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The incorporation of relatively large amounts of the known branched olefins such as isobutylene, 4-methylpentene or isobutylene into polymers of ethylene and unsaturated esters is additionally restricted by the fact that these olefins have such a

strong moderating effect on the polymerization that the requirement for initiators

5 reaches a level prohibitive for commercial applications, a sufficiently high molecular weight is not attained and/or that a conversion of commercial interest cannot be achieved in the polymerization. In addition, the resulting highly short chain-branched products do not exhibit sufficient effectiveness as nucleating agents for paraffin crystallization.

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The present invention relates to additives for improving the cold flowability of fuel oils, which are free-flowing and pumpable without any problem in highly concentrated form at very low temperatures, exhibit improved effectiveness over the prior art additives as cold flow improvers, and do not 15 contain any insoluble fractions which lead to valve and/or filter blockages.

It has now been found that additive concentrates which comprise terpolymers of ethylene, propene and unsaturated esters with few short chain branches as nucleating agents for paraffins exhibit very good handling and miscibility at low

20 temperatures and simultaneously superior effectiveness as cold additives. In addition, these additives comprise a lower level of sparingly soluble fractions than the known prior art ethylene copolymers.

The invention thus provides additive mixtures comprising

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A) at least one terpolymer of ethylene, propene and at least one ethylenically unsaturated ester, which

- i) contains from 6.0 to 12.0 mol% of structural units derived from at least one ethylenically unsaturated ester having a C<sub>1</sub>- to C<sub>3</sub>-alkyl radical,
- ii) contains from 0.5 to 4.0 methyl groups derived from propene per 100 aliphatic carbon atoms,

30

iii) has fewer than 8.0 methyl groups stemming from chain ends per 100 CH<sub>2</sub> groups, and

B) from 0.5 to 20 parts by weight, based on A), of at least one further component  
5 which is effective as a cold additive for mineral oils and is selected from

B1) copolymers of ethylene and ethylenically unsaturated compounds whose content of ethylenically unsaturated compounds is at least 2 mol% higher than the content of ethylenically unsaturated esters in the terpolymer  
10 defined under A),

B2) comb polymers, and

B3) mixtures of B1) and B2).

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The invention further provides for the use of additive mixtures of A) and B) for improving the cold flowability of fuel oils.

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The invention further provides a process for improving the cold flowability of fuel oils by adding an additive mixture of A) and B) to the fuel oil.

The invention further provides fuel oils with improved cold flowability, comprising an additive mixture of A) and B).

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Unsaturated esters suitable in accordance with the invention for component A) are in particular vinyl esters of carboxylic acids having from 1 to 4 carbon atoms and esters of acrylic and methacrylic acid with fatty alcohols having from 1 to 3 carbon atoms.

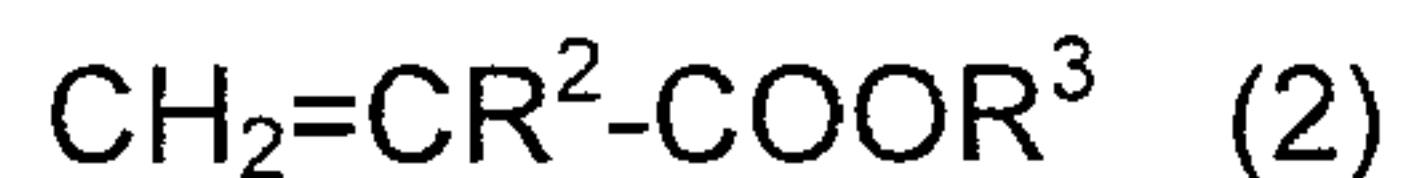
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Particularly preferred ethylenically unsaturated esters are vinyl esters of carboxylic acids having from 2 to 12 carbon atoms. They are preferably those of the formula 1



in which R<sup>1</sup> is C<sub>1</sub>- to C<sub>3</sub>-alkyl and preferably C<sub>2</sub>- to C<sub>3</sub>-alkyl. Examples of suitable vinyl esters are vinyl acetate, vinyl propionate, vinyl butyrate and vinyl isobutyrate. Vinyl acetate is especially preferred.

5 Further preferred ethylenically unsaturated esters are esters of acrylic and methacrylic acid with fatty alcohols having from 1 to 12 carbon atoms. They are preferably those of the formula 2



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in which R<sup>2</sup> is hydrogen or methyl and R<sup>3</sup> is C<sub>1</sub>- to C<sub>3</sub>-alkyl and preferably C<sub>1</sub>- or C<sub>2</sub>-alkyl. Suitable esters of acrylic and methacrylic acid include, for example, methyl (meth)acrylate, ethyl (meth)acrylate, n- and isopropyl (meth)acrylate and mixtures of these comonomers. Methyl acrylate and ethyl acrylate are particularly preferred.

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The content in the terpolymer A) of unsaturated ester is preferably between 7.0 and 11.5 mol% and in particular between 8.0 and 11.0 mol%, for example between 8.5 and 10.5 mol%. In the case of the vinyl acetate which is particularly preferred as the ethylenically unsaturated ester, the content is preferably between 12.0 and 29.0% by weight and in particular between 18 and 28% by weight, for example between 20.0 and 27.0% by weight. The comonomer content is determined by means of pyrolysis of the polymer and subsequent titration of the eliminated carboxylic acid.

The terpolymers A may additionally contain minor amounts of, for example, up to 4 mol%, preferably up to 2.5 mol%, for example from 0.1 to 2.0 mol%, of structural units which derive from unsaturated esters with relatively long alkyl chains. Unsaturated esters suitable for this purpose are vinyl esters of the formula (1) and/or (meth)acrylic esters of the formula (2) in which R<sup>2</sup> and R<sup>3</sup> are each independently an alkyl radical having from 4 to 20 carbon atoms. These alkyl radicals may be linear or branched. They are preferably branched.

The content in the terpolymer A) of methyl groups which derive from propene is preferably between 0.7 and 3.5 and in particular between 1.0 and 3.0, for example between 1.1 and 2.5, methyl groups per 100 aliphatic carbon atoms.

The number of methyl groups derived from propene per 100 aliphatic carbon atoms in the terpolymer A) (propene-CH<sub>3</sub>) is determined by means of <sup>13</sup>C NMR spectroscopy. For instance, terpolymers of ethylene, vinyl ester and propene exhibit characteristic signals of methyl groups bonded to the polymer backbone between 5 about 19.3 and 20.2 ppm, which have a positive sign in the DEPT experiment. The integral of this signal of the methyl side groups of the polymer backbone which are derived from propene is determined relative to that of all aliphatic carbon atoms of the polymer backbone between about 22 and 44 ppm. Any signals which stem from the alkyl radicals of the unsaturated esters and overlap with the signals of the 10 polymer backbone are subtracted from the total integral of the aliphatic carbon atoms on the basis of the signal of the methine group adjacent to the carbonyl group of the unsaturated ester. Such measurements can be performed, for example, with NMR spectrometers at a measurement frequency of 125 MHz at 30°C in solvents such as CDCl<sub>3</sub> or C<sub>2</sub>D<sub>2</sub>Cl<sub>4</sub>.

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The number of methyl groups stemming from chain ends in the terpolymers A) is preferably between 2.0 and 7.0 CH<sub>3</sub>/100 CH<sub>2</sub> groups and in particular between 2.5 and 6.5 CH<sub>3</sub>/100 CH<sub>2</sub> groups, for example between 3.0 and 6.0 CH<sub>3</sub>/100 CH<sub>2</sub> groups. 20 The number of methyl groups stemming from chain ends is understood to mean all of those methyl groups of the terpolymer A) which do not stem from the unsaturated esters used as comonomers. This is consequently understood to mean both the methyl groups present on the main chain ends including the methyl groups derived from structural units of the moderator and the methyl groups stemming from short-chain branches. 25

The number of methyl groups stemming from chain ends is determined by means of <sup>1</sup>H NMR spectroscopy by determining the integral of the signals of the methyl protons which appear in the <sup>1</sup>H NMR spectrum typically at a chemical shift between about 0.7 30 and 0.9 ppm (relative to TMS) relative to the integral of the signals of the methylene protons which appear at from 0.9 to 1.9 ppm. The methyl and methylene groups stemming from alkyl radicals of the comonomers, for example the acetyl group of vinyl acetate, are not included or are eliminated from the calculation. The signals caused by structural units of the moderators are accordingly attributable to the methyl

or methylene protons. The number of methyl groups stemming from propene, which has been determined by means of  $^{13}\text{C}$  NMR spectroscopy, is subtracted from the resulting value in order to obtain the number of methyl groups stemming from chain ends. Suitable  $^1\text{H}$  NMR spectra can be recorded, for example, at a measurement 5 frequency of 500 MHz at 30°C in solvents such as  $\text{CDCl}_3$  or  $\text{C}_2\text{D}_2\text{Cl}_4$ .

The sum G of molar content of unsaturated ester i) and the number of methyl groups derived from propene per 100 aliphatic carbon atoms of the polymer ii)

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$$G = [\text{mol\% of unsaturated ester}] + [\text{propene-CH}_3]$$

is preferably between 8.0 and 14.0 and especially between 9.5 and 13.0, for example between 10.0 and 12.5. The two summands should be added as dimensionless numbers.

15 The weight-average molecular weight  $M_w$  of the terpolymers A), which is determined by means of gel permeation chromatography against poly(styrene) standards is preferably between 2500 and 50 000 g/mol, preferably between 4000 and 30 000 g/mol, for example between 5000 and 25 000 g/mol. The melt viscosity of the 20 terpolymers A) determined at 140°C is between 100 and 5000 mPas, preferably between 150 and 2500 mPas and in particular between 200 and 2000 mPas.

For all analyses, the polymer is freed beforehand of residual monomers and any solvent fractions at 140°C under reduced pressure (100 mbar) for two hours.

25 The ethylene polymers A) and also B1) are independently preparable by customary copolymerization processes, for example suspension polymerization, solvent polymerization, gas phase polymerization or high-pressure bulk polymerization. Preference is given to performing high-pressure bulk polymerization at pressures 30 above 100 MPa, preferably between 100 and 300 MPa, for example between 150 and 275 MPa, and temperatures of from 100 to 340°C, preferably from 150 to 310°C, for example between 200 and 280°C. Suitable selection of the reaction conditions and of the amounts of monomers used allows the propene content and also the extent of the short-chain branches/chain ends to be established. Thus, low reaction

temperatures and/or high pressures in particular lead to low proportions of short-chain branches and hence to a low number of chain ends.

The reaction of the monomers is induced by free-radical-forming initiators (free-5 radical chain starters). This substance class includes, for example, oxygen, hydroperoxides, peroxides and azo compounds, such as cumene hydroperoxide, t-butyl hydroperoxide, dilauroyl peroxide, dibenzoyl peroxide, bis(2-ethylhexyl) peroxodicarbonate, t-butyl perpivalate, t-butyl permaleate, t-butyl perbenzoate, dicumyl peroxide, t-butyl cumyl peroxide, di(t-butyl) peroxide, 2,2'-azobis(2-10 methylpropanonitrile), 2,2'-azobis(2-methylbutyronitrile). The initiators are used individually or as a mixture of two or more substances in amounts of from 0.01 to 10% by weight, preferably from 0.05 to 5% by weight, based on the monomer mixture.

15 The high-pressure bulk polymerization is performed in known high-pressure reactors, for example autoclaves or tubular reactors, batchwise or continuously; particularly useful reactors have been found to be continuous tubular reactors. Solvents such as aliphatic and/or aromatic hydrocarbons or hydrocarbon mixtures, benzene or toluene, may be present in the reaction mixture. Preference is given to the essentially solvent-20 free procedure. In a preferred embodiment of the polymerization, the mixture of the monomers, the initiator and, when used, the moderator is fed to a tubular reactor via the reactor inlet and via one or more side branches. The comonomers and also the moderators may be metered into the reactor either together with ethylene or separately via sidestreams. In this case, the monomer streams may have different 25 composition (EP-A-0 271 738 and EP-A-0 922 716).

It has been found to be advantageous to adjust the molecular weight of the polymers not solely via the moderating action of the propene but additionally to use moderators which essentially bring about only one chain transfer and are not incorporated into 30 the polymer chain in the manner of comonomers. Methyl groups can thus be incorporated selectively into the polymer backbone as disruption sites, and polymers with improved effectiveness as cold flow improvers are obtained. Preferred moderators are, for example, saturated and unsaturated hydrocarbons, for example propane, hexane, heptane and cyclohexane, and also alcohols, for example butanol,

and especially aldehydes, for example acetaldehyde, propionaldehyde, n-butyraldehyde and isobutyraldehyde and also ketones, for example acetone, methyl ethyl ketone, methyl propyl ketone, methyl isopropyl ketone, methyl butyl ketone, methyl isobutyl ketone and cyclohexanone. Hydrogen is also suitable as a  
5 moderator.

In a particularly preferred embodiment, the inventive polymers, in addition to vinyl ester and propene, contain from 0.3 to 5.0% by weight, preferably from 0.5 to 3.5% by weight, of structural units which derive from moderator containing at least one  
10 carbonyl group. The concentration of these structural elements derived from the moderator in the polymer can likewise be determined by means of  $^1\text{H}$  NMR spectroscopy. This can be effected, for example, by correlating the intensity of the signals stemming from the vinyl ester, whose proportion in the polymer is known, with the signals of the methylene or methine group adjacent to the carbonyl group of the  
15 moderators, which appears at from about 2.4 to 2.5 ppm.

Suitable components B1) are one or more copolymers of ethylene and olefinically unsaturated compounds whose total comonomer content is higher by at least 2 mol%, preferably 3 mol%, than that of component A. Suitable ethylene copolymers  
20 are in particular those which, as well as ethylene, contain from 9 to 21 mol%, in particular from 10 to 18 mol%, of comonomers. Comonomers may, as well as olefinically unsaturated esters, also be other olefinically unsaturated compounds. Total comonomer content is understood to mean the content of monomers apart from ethylene.

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The olefinically unsaturated compounds are preferably vinyl esters, acrylic esters, methacrylic esters, alkyl vinyl ethers and/or alkenes, and the compounds mentioned may be substituted by hydroxyl groups. One or more comonomers may be present in the polymer.

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The vinyl esters are preferably those of the formula 3



where  $R^4$  is  $C_1$ - to  $C_{30}$ -alkyl, preferably  $C_4$ - to  $C_{16}$ -alkyl, especially  $C_6$ - to  $C_{12}$ -alkyl. In a further embodiment, the alkyl groups mentioned may be substituted by one or more hydroxyl groups.

5 In a further preferred embodiment, these ethylene copolymers contain vinyl acetate and at least one further vinyl ester of the formula 3 where  $R^4$  is  $C_4$ - to  $C_{30}$ -alkyl, preferably  $C_4$ - to  $C_{16}$ -alkyl, especially  $C_6$ - to  $C_{12}$ -alkyl.

10 In a further preferred embodiment,  $R^4$  is a branched alkyl radical or a neoalkyl radical having from 7 to 11 carbon atoms, in particular having 8, 9 or 10 carbon atoms. Particularly preferred vinyl esters derive from secondary and especially tertiary carboxylic acids whose branch is in the alpha-position to the carbonyl group. Suitable vinyl esters include vinyl acetate, vinyl propionate, vinyl butyrate, vinyl isobutyrate, vinyl hexanoate, vinyl heptanoate, vinyl octanoate, vinyl pivalate, vinyl 15 2-ethylhexanoate, vinyl laurate, vinyl stearate and Versatic esters such as vinyl neononanoate, vinyl neodecanoate, vinyl neoundecanoate.

The acrylic esters are preferably those of the formula 4

20  $CH_2=CR^2-COOR^5 \quad (4)$

where  $R^2$  is hydrogen or methyl and  $R^5$  is  $C_1$ - to  $C_{30}$ -alkyl, preferably  $C_4$ - to  $C_{16}$ -alkyl, especially  $C_6$ - to  $C_{12}$ -alkyl. Suitable acrylic esters include, for example, methyl (meth)acrylate, ethyl (meth)acrylate, propyl (meth)acrylate, n- and isobutyl (meth)acrylate, hexyl, octyl, 2-ethylhexyl, decyl, dodecyl, tetradecyl, hexadecyl, octadecyl (meth)acrylate and mixtures of these comonomers. In a further embodiment, the alkyl groups mentioned may be substituted by one or more hydroxyl groups. An example of such an acrylic ester is hydroxyethyl methacrylate.

30 The alkyl vinyl ethers are preferably compounds of the formula 5

$CH_2=CH-OR^6 \quad (5)$

where  $R^6$  is  $C_1$ - to  $C_{30}$ -alkyl, preferably  $C_4$ - to  $C_{16}$ -alkyl, especially  $C_6$ - to  $C_{12}$ -alkyl.

Examples include methyl vinyl ether, ethyl vinyl ether, isobutyl vinyl ether. In a further embodiment, the alkyl groups mentioned may be substituted by one or more hydroxyl groups.

- 5 The alkenes are preferably monounsaturated hydrocarbons having from 3 to 30 carbon atoms, in particular from 4 to 16 carbon atoms and especially from 5 to 12 carbon atoms. Suitable alkenes include propene, butene, isobutylene, pentene, hexene, 4-methylpentene, octene, diisobutylene and norbornene and derivatives thereof such as methylnorbornene and vinylnorbornene. In a further embodiment, the
- 10 alkyl groups mentioned may be substituted by one or more hydroxyl groups.

Apart from ethylene, particularly preferred terpolymers of vinyl 2-ethylhexanoate, of vinyl neononanoate or of vinyl neodecanoate preferably contain from 3.5 to 20 mol%, in particular from 8 to 15 mol%, of vinyl acetate, and from 0.1 to 12 mol%, in

- 15 particular from 0.2 to 5 mol%, of the particular long-chain vinyl ester, the total comonomer content being between 9 and 21 mol%, preferably between 12 and 18 mol%. Further particularly preferred copolymers contain, in addition to ethylene and from 8 to 18 mol% of vinyl esters, also from 0.5 to 10 mol% of olefins such as propene, butene, isobutylene, hexene, 4-methylpentene, octene, diisobutylene
- 20 and/or norbornene.

These ethylene co- and terpolymers preferably have melt viscosities at 140°C of from 20 to 10 000 mPas, in particular from 30 to 5000 mPas, especially from 50 to 2000 mPas. The degrees of branching determined by means of  $^1\text{H}$  NMR

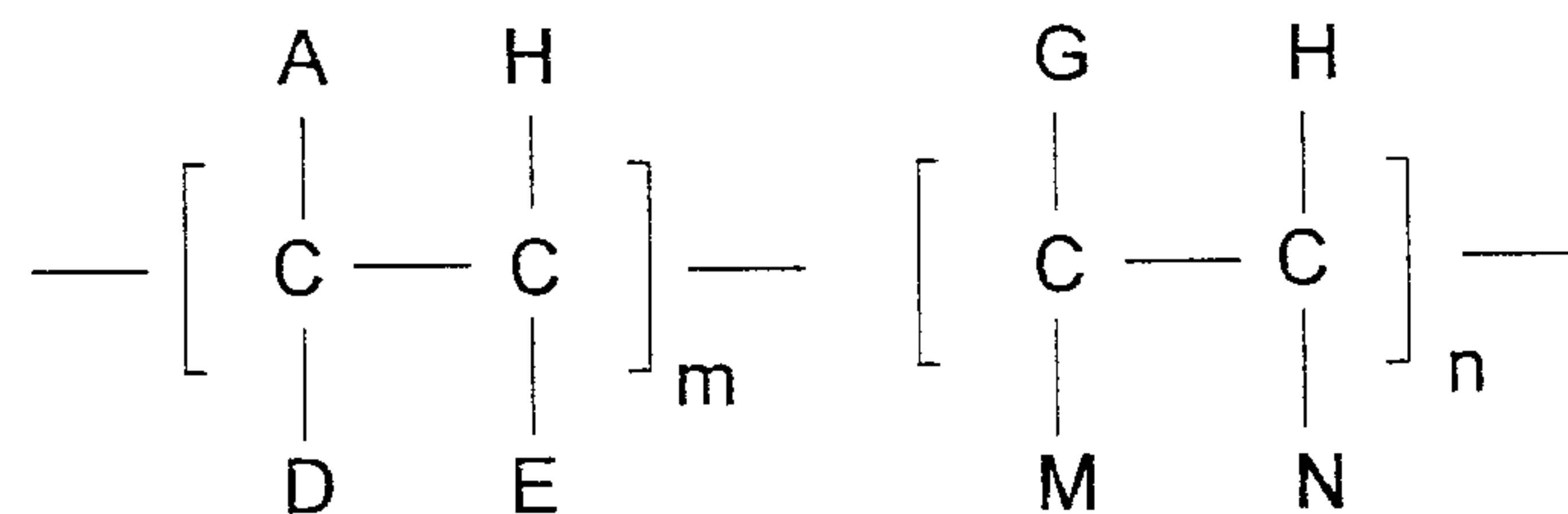
- 25 spectroscopy are preferably between 1 and 9  $\text{CH}_3/100 \text{CH}_2$  groups, in particular between 2 and 6  $\text{CH}_3/100 \text{CH}_2$  groups, which do not stem from the comonomers.

The mixing ratio between the terpolymers A) and ethylene copolymers B1) may, according to the application, vary within wide limits, the terpolymers A) as crystal

- 30 seed formers often constituting the smaller proportion. Such additive mixtures preferably contain from 2 to 70% by weight, preferably from 3 to 50% by weight and especially from 5 to 20% by weight of constituent A and from 30 to 98% by weight, preferably from 50 to 97% by weight and especially from 70 to 95% by weight of constituent B1.

Comb polymers as component B2) are generally characterized in that they contain a polymer backbone to which, at regular intervals, long-chain branches or side chains, for example hydrocarbon chains having from about 8 to 50 carbon atoms, are bonded. These side chains may be bonded to the polymer backbone directly via a C-5 C bond or else via an ether, ester, amide or imide bond.

Suitable comb polymers as component B2) may, for example, be described by the formula



10

In this formula,

- A is R', COOR', OCOR', R"-COOR', OR';
- D is H, CH<sub>3</sub>, A or R";
- E is H, A;
- 15 G is H, R", R"-COOR', an aryl radical or a heterocyclic radical;
- M is H, COOR", OCOR", OR", COOH;
- N is H, R", COOR", OCOR", an aryl radical;
- R' is a hydrocarbon chain having from 8 to 50 carbon atoms;
- R" is a hydrocarbon chain having from 1 to 10 carbon atoms;
- 20 m is from 0.4 to 1.0; and
- n is from 0 to 0.6.

R' is preferably a hydrocarbon radical having from 10 to 24 carbon atoms and in particular a hydrocarbon radical having from 12 to 18 carbon atoms. R' is preferably 25 linear or predominantly linear, i.e. R' contains at most one methyl or ethyl branch.

Suitable comb polymers are, for example, esterified copolymers of ethylenically unsaturated dicarboxylic acids such as maleic acid or fumaric acid or their reactive derivatives with other ethylenically unsaturated monomers such as olefins or vinyl esters. Particularly suitable olefins are  $\alpha$ -olefins having from 10 to 24 carbon atoms,

for example 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-octadecene and mixtures thereof. Suitable comonomers are also longer-chain olefins based on oligomerized C<sub>2</sub>-C<sub>6</sub>-olefins, for example poly(isobutylene) having a high proportion of terminal double bonds. Particularly preferred copolymers are those of maleic acid or

5 maleic anhydride and/or fumaric acid with hexadecene, octadecene and with mixtures of these olefins. In a further preferred embodiment, the copolymers contain up to 15 mol%, for example from 1 to 10 mol%, of poly(isobutylene) having a molecular weight M<sub>w</sub> between 300 and 5000 g/mol. Vinyl esters particularly suitable as comonomers derive from fatty acids having from 1 to 12 carbon atoms and in

10 particular from 2 to 8 carbon atoms, for example vinyl acetate, vinyl propionate, vinyl butyrate, vinyl 2-ethylhexanoate, vinyl neononanoate, vinyl neodecanoate and vinyl neoundecanoate. Mixtures of different vinyl esters are also suitable. Particular preference is given to copolymers of fumaric acid with vinyl acetate.

15 Typically, these copolymers are esterified to an extent of at least 50% with alcohols having from 10 to 24 carbon atoms, for example having from 12 to 18 carbon atoms. Suitable alcohols include n-decan-1-ol, n-dodecan-1-ol, n-tetradecan-1-ol, n-hexadecan-1-ol, n-octadecan-1-ol, n-eicosan-1-ol and mixtures thereof. Particular preference is given to n-tetradecan-1-ol, n-hexadecan-1-ol and mixtures thereof.

20 Likewise suitable as comb polymers B2) are polymers and copolymers of  $\alpha$ -olefins, and also esterified copolymers of styrene and maleic anhydride, and esterified copolymers of styrene and fumaric acid. Here too, preference is given to the abovementioned alcohols having from 10 to 24 carbon atoms for the esterification. In

25 addition, poly(alkyl acrylates), poly(alkyl methacrylates) and poly(alkyl vinyl ethers) which derive from alcohols having from 12 to 20 carbon atoms, and also poly(vinyl esters) which derive from fatty acids having from 12 to 20 carbon atoms, are suitable as comb polymers. Likewise suitable are copolymers based on the aforementioned alkyl acrylates, methacrylates, alkyl vinyl ethers and/or vinyl esters, for example

30 copolymers of alkyl acrylates and vinyl esters. Mixtures of two or more comb polymers are also suitable in accordance with the invention.

The comb polymers of components B2) preferably have molecular weights Mw between approx. 2000 and approx. 50 000 g/mol, preferably between 3000 and 20 000 g/mol.

5 The mixing ratio between component A) and comb polymer B2) is typically in the range from 10:1 to 1:3, preferably between 6:1 and 1:2, for example between 5:1 and 1:1. The mixing ratio between component B1) and comb polymer B2) is typically between 10:1 and 1:3, preferably between 6:1 and 1:2, for example between 5:1 and 1:1

10

For the purpose of better handling, the inventive additive mixtures are typically used in the form of concentrates in organic solvents. Suitable solvents or dispersants are, for example, relatively high-boiling aliphatic hydrocarbons, aromatic hydrocarbons, alcohols, esters, ethers and mixtures thereof. Solutions or dispersions of the

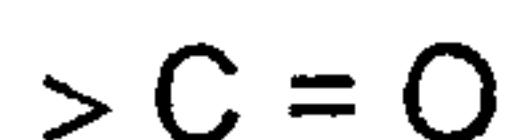
15 inventive additive mixtures preferably contain from 10 to 90% by weight, in particular from 20 to 80% by weight and especially from 40 to 75% by weight of solvent.

It has been found that, surprisingly, the solutions of the inventive additive mixtures have a lower intrinsic pour point than corresponding mixtures based on terpolymers 20 of ethylene, unsaturated esters and higher olefins according to the prior art. In addition, they exhibit improved effectiveness in relation to cold flow improvement of fuel oils and in particular improved solubility in fuel oils even at low temperatures. These additives can thus be used at low temperatures even without preceding heating of oil and/or additives without there being any filtration problems resulting 25 from undissolved or recrystallized fractions of the polymer A) in the additized oil. On the other hand, the inventive additives can be transported and processed at the same temperature with lower solvent content than corresponding prior art additives, which reduces transport and storage costs.

30 The inventive additive mixtures may be added to middle distillates for improving the cold flowability also in combination with further additives, for example oil-soluble polar nitrogen compounds, alkylphenol resins, polyoxyalkylene compounds and/or olefin copolymers.

Suitable oil-soluble polar nitrogen compounds are preferably reaction products of fatty amines with compounds which contain an acyl group. The preferred amines are compounds of the formula  $NR^7R^8R^9$  where  $R^7$ ,  $R^8$  and  $R^9$  may be the same or different, and at least one of these groups is  $C_8$ - $C_{36}$ -alkyl,  $C_6$ - $C_{36}$ -cycloalkyl or  $C_8$ - $C_{36}$ -alkenyl, in particular  $C_{12}$ - $C_{24}$ -alkyl,  $C_{12}$ - $C_{24}$ -alkenyl or cyclohexyl, and the remaining groups are either hydrogen,  $C_1$ - $C_{36}$ -alkyl,  $C_2$ - $C_{36}$ -alkenyl, cyclohexyl, or a group of the formulae  $-(A-O)_x-E$  or  $-(CH_2)_n-NYZ$ , where A is an ethyl or propyl group, x is a number from 1 to 50, E = H,  $C_1$ - $C_{30}$ -alkyl,  $C_5$ - $C_{12}$ -cycloalkyl or  $C_6$ - $C_{30}$ -aryl, and n = 2, 3 or 4, and Y and Z are each independently H,  $C_1$ - $C_{30}$ -alkyl or  $-(A-O)_x$ . The alkyl and alkenyl radicals may each be linear or branched and contain up to two double bonds. They are preferably linear and substantially saturated, i.e. they have iodine numbers of less than 75 g of  $I_2$ /g, preferably less than 60 g of  $I_2$ /g and in particular between 1 and 10 g of  $I_2$ /g. Particular preference is given to secondary fatty amines in which two of the  $R^7$ ,  $R^8$  and  $R^9$  groups are each  $C_8$ - $C_{36}$ -alkyl,  $C_6$ - $C_{36}$ -cycloalkyl,  $C_8$ - $C_{36}$ -alkenyl, in particular  $C_{12}$ - $C_{24}$ -alkyl,  $C_{12}$ - $C_{24}$ -alkenyl or cyclohexyl. Suitable fatty amines are, for example, octylamine, decylamine, dodecylamine, tetradecylamine, hexadecylamine, octadecylamine, eicosylamine, behenylamine, didecylamine, didodecylamine, ditetradecylamine, dihexadecylamine, dioctadecylamine, dieicosylamine, dibehenylamine and mixtures thereof. The amines especially contain chain cuts based on natural raw materials, for example coconut fatty amine, tallow fatty amine, hydrogenated tallow fatty amine, dicoconut fatty amine, ditallow fatty amine and di(hydrogenated tallow fatty amine). Particularly preferred amine derivatives are amine salts, imides and/or amides, for example amide-ammonium salts of secondary fatty amines, in particular of dicoconut fatty amine, ditallow fatty amine and distearylamine.

Acyl group is understood here to mean a functional group of the following formula:



30

Carbonyl compounds suitable for the reaction with amines are either monomeric or polymeric compounds having one or more carboxyl groups. Preference is given to those monomeric carbonyl compounds having 2, 3 or 4 carbonyl groups. They may also contain heteroatoms such as oxygen, sulfur and nitrogen. Suitable carboxylic

acids are, for example, maleic acid, fumaric acid, crotonic acid, itaconic acid, succinic acid, C<sub>1</sub>-C<sub>40</sub>-alkenylsuccinic acid, adipic acid, glutaric acid, sebacic acid and malonic acid, and also benzoic acid, phthalic acid, trimellitic acid and pyromellitic acid, nitrilotriacetic acid, ethylenediaminetetraacetic acid and their reactive derivatives, for example esters, anhydrides and acid halides. Useful polymeric carbonyl compounds have been found to be in particular copolymers of ethylenically unsaturated acids, for example acrylic acid, methacrylic acid, maleic acid, fumaric acid and itaconic acid; particular preference is given to copolymers of maleic anhydride. Suitable comonomers are those which impart oil solubility to the copolymer. Oil-soluble means here that the copolymer, after reaction with the fatty amine, dissolves without residue in the middle distillate to be additized in practically relevant dosages. Suitable comonomers are, for example, olefins, alkyl esters of acrylic acid and methacrylic acid, alkyl vinyl esters, alkyl vinyl ethers having from 2 to 75, preferably from 4 to 40 and in particular from 8 to 20, carbon atoms in the alkyl radical. In the case of olefins, the carbon number is based on the alkyl radical attached to the double bond. The molecular weights of the polymeric carbonyl compounds are preferably between 400 and 20 000 g/mol, more preferably between 500 and 10 000 g/mol, for example between 1000 and 5000 g/mol.

It has been found that particularly useful oil-soluble polar nitrogen compounds are those which are obtained by reaction of aliphatic or aromatic amines, preferably long-chain aliphatic amines, with aliphatic or aromatic mono-, di-, tri- or tetracarboxylic acids or their anhydrides (cf. US 4 211 534). Equally suitable as oil-soluble polar nitrogen compounds are amides and ammonium salts of aminoalkylenepoly-carboxylic acids such as nitrilotriacetic acid or ethylenediaminetetraacetic acid with secondary amines (cf. EP 0 398 101). Other oil-soluble polar nitrogen compounds are copolymers of maleic anhydride and  $\alpha,\beta$ -unsaturated compounds which may optionally be reacted with primary monoalkylamines and/or aliphatic alcohols (cf. EP-A-0 154 177, EP 0 777 712), the reaction products of alkenyl-spiro-bislactones with amines (cf. EP-A-0 413 279 B1) and, according to EP-A-0 606 055 A2, reaction products of terpolymers based on  $\alpha,\beta$ -unsaturated dicarboxylic anhydrides,  $\alpha,\beta$ -unsaturated compounds and polyoxyalkylene ethers of lower unsaturated alcohols.

The mixing ratio between the inventive additive mixtures and oil-soluble polar nitrogen compounds may vary depending upon the application. Such additive mixtures preferably contain, based on the active ingredients, from 0.1 to 10 parts by weight, preferably from 0.2 to 5 parts by weight, of at least one oil-soluble polar nitrogen compound per part by weight of the inventive additive mixture.

Suitable alkylphenol-aldehyde resins are in particular those alkylphenol-aldehyde resins which derive from alkylphenols having one or two alkyl radicals in the ortho- and/or para-position to the OH group. Particularly preferred starting materials are alkylphenols which bear, on the aromatic, at least two hydrogen atoms capable of condensation with aldehydes, and in particular monoalkylated phenols. The alkyl radical is more preferably in the para-position to the phenolic OH group. The alkyl radicals (for the alkylphenol resins, this is generally understood to mean hydrocarbon radicals as defined below) may be the same or different in the alkylphenol-aldehyde resins usable with the inventive additive mixtures. The alkyl radicals may be saturated or unsaturated. They may be linear or branched, preferably linear. They have 1-200, preferably 1-24, in particular 4-16, for example 6-12 carbon atoms; they are preferably n-, iso- and tert-butyl, n- and isopentyl, n- and isohexyl, n- and isoctyl, n- and isononyl, n- and isodecyl, n- and isododecyl, tetradecyl, hexadecyl, octadecyl, eicosyl, tripropenyl, tetrapropenyl, poly(propenyl) and poly(isobutenyl) radicals. In a preferred embodiment, the alkylphenol resins are prepared by using mixtures of alkylphenols with different alkyl radicals. For example, resins based firstly on butylphenol and secondly on octyl-, nonyl- and/or dodecylphenol in a molar ratio of from 1:10 to 10:1 have been found to be particularly useful.

25

Suitable alkylphenol resins may also contain or consist of structural units of further phenol analogs such as salicylic acid, hydroxybenzoic acid and derivatives thereof, such as esters, amides and salts.

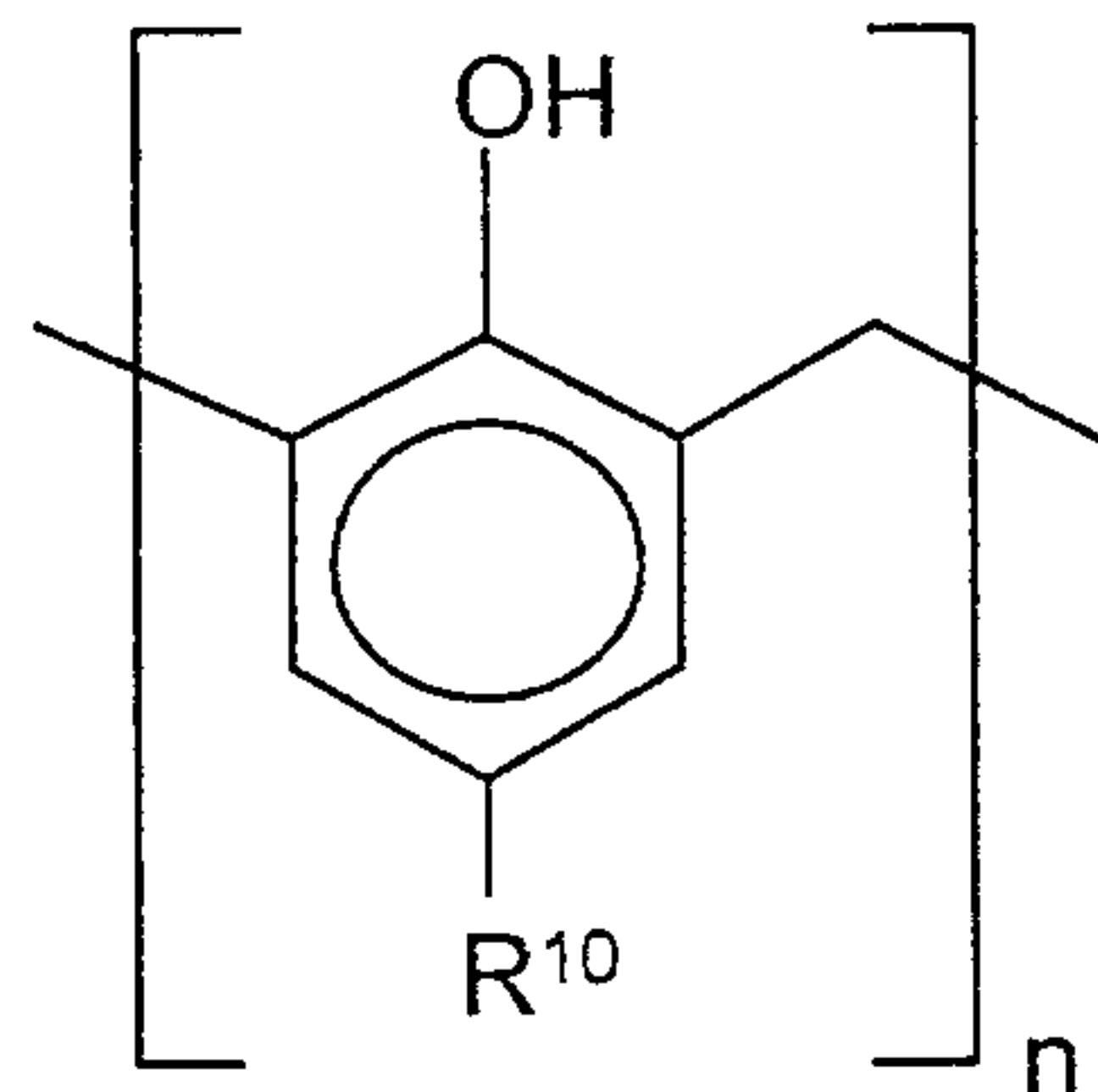
30 Suitable aldehydes for the alkylphenol-aldehyde resins are those having from 1 to 12 carbon atoms and preferably having from 1 to 4 carbon atoms, for example formaldehyde, acetaldehyde, propionaldehyde, butyraldehyde, 2-ethylhexanal, benzaldehyde, glyoxalic acid and their reactive equivalents such as para-formaldehyde and trioxane. Particular preference is given to formaldehyde in the

form of paraformaldehyde and especially formalin.

The molecular weight of the alkylphenol-aldehyde resins, measured by means of gel permeation chromatography against poly(styrene) standards in THF, is preferably

5 500-25 000 g/mol, more preferably 800-10 000 g/mol and especially 1000-5000 g/mol, for example 1500-3000 g/mol. A prerequisite here is that the alkylphenol-aldehyde resins are oil-soluble at least in concentrations relevant to use of from 0.001 to 1% by weight.

10 In a preferred embodiment of the invention, they are alkylphenol-formaldehyde resins which contain oligo- or polymers with a repeat structural unit of the formula



where R<sup>10</sup> is C<sub>1</sub>-C<sub>200</sub>-alkyl or -alkenyl, O-R<sup>11</sup> or O-C(O)-R<sup>11</sup>, R<sup>11</sup> is C<sub>1</sub>-C<sub>200</sub>-alkyl or 15 -alkenyl and n is from 2 to 100. R<sup>11</sup> is preferably C<sub>1</sub>-C<sub>20</sub>-alkyl or -alkenyl and in particular C<sub>4</sub>-C<sub>16</sub>-alkyl or -alkenyl, for example C<sub>6</sub>-C<sub>12</sub>-alkyl or -alkenyl. R<sup>10</sup> is more preferably C<sub>1</sub>-C<sub>20</sub>-alkyl or -alkenyl and in particular C<sub>4</sub>-C<sub>16</sub>-alkyl or -alkenyl, for example C<sub>6</sub>-C<sub>12</sub>-alkyl or -alkenyl. n is preferably from 2 to 50 and especially from 3 to 25, for example from 5 to 15.

20

For use in middle distillates such as diesel and heating oil, particular preference is given to alkylphenol-aldehyde resins with C<sub>2</sub>-C<sub>40</sub>-alkyl radicals of the alkylphenol, preferably with C<sub>4</sub>-C<sub>20</sub>-alkyl radicals, for example C<sub>6</sub>-C<sub>12</sub>-alkyl radicals. The alkyl radicals may be linear or branched, preferably linear. Particularly suitable 25 alkylphenol-aldehyde resins derive from linear alkyl radicals having 8 and 9 carbon atoms.

For use in heavy heating oils and especially in fuel oils comprising distillation

residues, particular preference is given to alkylphenol-aldehyde resins whose alkyl radicals bear from 4 to 50 carbon atoms, preferably from 10 to 30 carbon atoms. The degree of polymerization (n) here is preferably between 2 and 20, preferably between 3 and 10 alkylphenol units.

5

These alkylphenol-aldehyde resins are obtainable, for example by condensing the corresponding alkylphenols with formaldehyde, i.e. with from 0.5 to 1.5 mol, preferably from 0.8 to 1.2 mol of formaldehyde per mole of alkylphenol. The condensation can be effected without solvent, but is preferably effected in the 10 presence of a water-immiscible or only partly water-miscible inert organic solvent such as mineral oils, alcohols, ethers and the like. Particular preference is given to solvents which can form azeotropes with water. The solvents of this type used are in particular aromatics such as toluene, xylene, diethylbenzene and relatively high-boiling commercial solvent mixtures such as <sup>®</sup>Shellsol AB, and Solvent Naphtha. Also 15 suitable as solvents are fatty acids and derivatives thereof, for example esters with lower alcohols having from 1 to 5 carbon atoms, for example ethanol and especially methanol. The condensation is effected preferably between 70 and 200°C, for example between 90 and 160°C. It is typically catalyzed by from 0.05 to 5% by weight of bases or preferably by from 0.05 to 5% by weight of acids. As acidic 20 catalysts, in addition to carboxylic acids such as acetic acid and oxalic acid, in particular strong mineral acids such as hydrochloric acid, phosphoric acid and sulfuric acid, and also sulfonic acids, are useful catalysts. Particularly suitable catalysts are sulfonic acids which contain at least one sulfonic acid group and at least one saturated or unsaturated, linear, branched and/or cyclic hydrocarbon radical 25 having from 1 to 40 carbon atoms and preferably having from 3 to 24 carbon atoms. Particular preference is given to aromatic sulfonic acids, especially the alkylaromatic monosulfonic acids having one or more C<sub>1</sub>-C<sub>28</sub>-alkyl radicals and especially those having C<sub>3</sub>-C<sub>22</sub>-alkyl radicals. Suitable examples are methanesulfonic acid, butanesulfonic acid, benzenesulfonic acid, p-toluenesulfonic acid, xylenesulfonic 30 acid, 2-mesitylenesulfonic acid, 4-ethylbenzenesulfonic acid, isopropylbenzenesulfonic acid, 4-butylbenzenesulfonic acid, 4-octylbenzenesulfonic acid; dodecylbenzenesulfonic acid, didodecylbenzenesulfonic acid, naphthalenesulfonic acid. Mixtures of these sulfonic acids are also suitable. Typically, after the reaction has ended, they remain in the product as such or in neutralized form. For neutralization,

preference is given to using amines and/or aromatic bases, since they can remain in the product; salts which comprise metal ions and hence form ash are usually removed.

5 As a further constituent, suitable polyoxyalkylene compounds are, for example, esters, ethers and ether/esters of polyols which bear at least one alkyl radical having from 12 to 30 carbon atoms. When the alkyl groups stem from an acid, the remainder stems from a polyhydric alcohol; when the alkyl radicals come from a fatty alcohol, the remainder of the compound stems from a polyacid.

10

Suitable polyols are polyethylene glycols, polypropylene glycols, polybutylene glycols and their copolymers having a molecular weight of from approx. 100 to approx. 5000 g/mol, preferably from 200 to 2000 g/mol. Also suitable are alkoxylates of polyols, for example of glycerol, trimethylolpropane, pentaerythritol, neopentyl glycol, 15 and also the oligomers which are obtainable therefrom by condensation and have from 2 to 10 monomer units, for example polyglycerol. Preferred alkoxylates are those having from 1 to 100 mol, in particular from 5 to 50 mol, of ethylene oxide, propylene oxide and/or butylene oxide per mole of polyol. Esters are particularly preferred.

20

Fatty acids having from 12 to 26 carbon atoms are preferred for reaction with the polyols to form the ester additives, particular preference being given to using C<sub>18</sub>- to C<sub>24</sub> fatty acids, especially stearic acid and behenic acid. The esters may also be prepared by esterifying polyoxyalkylated alcohols. Preference is given to fully 25 esterified polyoxyalkylated polyols with molecular weights of from 150 to 2000, preferably from 200 to 600. PEG-600 dibehenate and glycerol-ethylene glycol tribehenate are particularly suitable.

Olefin copolymers suitable as a further constituent of the inventive additive may 30 derive directly from monoethylenically unsaturated monomers or be prepared indirectly by hydrogenating polymers which derive from polyunsaturated monomers such as isoprene or butadiene. Preferred copolymers contain, as well as ethylene, structural units which derive from  $\alpha$ -olefins having from 3 to 24 carbon atoms and have molecular weights of up to 120 000 g/mol.

Preferred  $\alpha$ -olefins are propene, butene, isobutene, n-hexene, isohexene, n-octene, iso-octene, n-decene, isodecene. The comonomer content of  $\alpha$ -olefins having from 3 to 24 carbon atoms is preferably between 15 and 50 mol%, more preferably between 20 and 35 mol% and especially between 30 and 45 mol%. These copolymers may

5 also contain small amounts, for example up to 10 mol%, of further comonomers, for example nonterminal olefins or nonconjugated olefins. Preference is given to ethylene-propene copolymers. The olefin copolymers can be prepared by known methods, for example by means of Ziegler or metallocene catalysts.

10 Further suitable olefin copolymers are block copolymers which contain blocks of olefinically unsaturated aromatic monomers A and blocks of hydrogenated polyolefins B. Particularly suitable block copolymers are those of the structure  $(AB)_nA$  and  $(AB)_m$ , where n is from 1 to 10 and m is from 2 to 10.

15 The mixing ratio between the inventive additive mixtures and alkylphenol resins, polyoxyalkylene compounds and/or olefin copolymers may vary according to the application. Such mixtures preferably contain, based on the active ingredients, in each case from 0.1 to 10 parts by weight, preferably from 0.2 to 5 parts by weight, of at least one alkylphenol resin, of a polyoxyalkylene compound and/or of an olefin

20 copolymer per part by weight of the inventive additive mixture.

The inventive additive mixtures may be used alone or else together with other additives, for example with other pour point depressants or dewaxing assistants, with antioxidants, cetane number improvers, dehazers, demulsifiers, detergents,

25 dispersants, defoamers, dyes, corrosion inhibitors, lubricity additives, sludge inhibitors, odorants and/or additives for lowering the cloud point.

The inventive additive mixtures are suitable for improving the cold flow properties of animal, vegetable, mineral and/or synthetic fuel oils. At the same time, these additive mixtures and their concentrated formulations in mineral oil-based solvents have low intrinsic pour points. This allows problem-free use of these additive mixtures at lower temperatures and/or in higher concentrations than is possible with prior art additives. The additive mixtures can also be dosed in oils owing to their good solubility without

there being any filter blockages by undissolved or recrystallized fractions of the additive mixtures.

They are particularly suitable for improving the properties of mineral oils and mineral oil distillates in the middle distillate range, for example jet fuel, kerosene, diesel and heating oil. Additive mixtures which comprise components A and B1 are suitable in particular for middle distillates with cloud points below +5°C, for example between -15°C and +3°C. They are especially suitable for those oils which have a high content of particularly cold-critical paraffins having a carbon chain length of 20 and more carbon atoms of more than 3.0 area% and in particular more than 4.0 area%.

Additive mixtures which comprise components A and B2 are suitable in particular for middle distillates with cloud points above -4°C, for example above -2°C. They are especially suitable for those oils which have a high content of particularly cold-critical paraffins having a carbon chain length of 20 and more carbon atoms of more than 3.5 area% and in particular more than 4.5 area%. The paraffin content is determined by gas chromatography separation of the oil with detection by an FID detector and calculation of the integral of the n-paraffins with a chain length of at least 20 carbon atoms in relation to the total integral of the oil. For the purpose of lowering the sulfur content, they have frequently been subjected to refining under hydrogenating conditions and contain preferably less than 350 ppm of sulfur and in particular less than 100 ppm of sulfur, for example less than 50 ppm or 10 ppm of sulfur.

The inventive fuel oils preferably contain from 5 to 5000 ppm, more preferably from 10 to 2000 ppm and especially from 50 to 1000 ppm of the inventive additive mixtures.

Middle distillates refer in particular to those mineral oils which are obtained by distilling crude oil and boil in the range from 120 to 450°C, for example kerosene, jet fuel, diesel and heating oil. The inventive additive mixtures are particularly advantageous in those middle distillates which have 90% distillation points to ASTM D86 above 340°C, in particular above 360°C and in special cases above 370°C. Middle distillates further comprise synthetic fuel oils which boil in the temperature range from about 120 to 450°C, and also mixtures of these synthetic and mineral middle distillates. Examples of synthetic middle distillates are especially fuels

produced by the Fischer-Tropsch process from coal, natural gas or else biomass. In this case, synthesis gas is first prepared and converted to normal paraffins via the Fischer-Tropsch process. The normal paraffins thus prepared can subsequently be modified, for example, by catalytic cracking, isomerization, hydrocracking or

5 hydroisomerization.

The inventive additive mixtures are also particularly effective in middle distillates which contain minor amounts, for example up to 30% by volume, of oils of animal and/or vegetable origin. Examples of suitable oils of animal and/or vegetable origin

10 are both triglycerides and esters derived therefrom with lower alcohols having from 1 to 5 carbon atoms, such as ethyl and especially methyl esters, which are obtainable, for example, from cotton, palm kernels, rape, soya, sunflower, tallow and the like.

### Examples

15

The following additives were used:

#### Preparation of ethylene copolymers A

20 Process A): in a continuous tubular reactor, ethylene, propene and vinyl acetate were copolymerized at 200 MPa and a peak temperature of 250°C with addition of a mixture of various free-radical chain starters and of the molecular weight regulator specified in table 1. The polymer formed was removed from the reaction mixture and then freed of residual monomers.

25

Process B): in a continuous high-pressure autoclave, ethylene, vinyl acetate and propene were copolymerized with addition of a 10% by weight solution of bis(2-ethylhexyl) peroxodicarbonate as an initiator and the molecular weight regulator specified in table 1. The polymer formed was removed from the reaction mixture and

30 then freed of residual monomers.

For comparison, a terpolymer of ethylene, vinyl acetate and propene according to EP 0 190 553, a terpolymer of ethylene, vinyl acetate and 4-methylpentene-1

according to EP 0 807 642, and a terpolymer of ethylene, vinyl acetate and isobutylene were employed.

The vinyl acetate content was determined by means of pyrolysis of the polymer  
5 which had been freed of residual monomers at 150°C/100 mbar. To this end, 100 mg  
of the polymer are dissociated thermally with 200 mg of pure polyethylene in a  
pyrolysis flask at 450°C in a closed system under reduced pressure for 5 minutes,  
and the dissociation gases are collected in a 250 ml round-bottom flask. The acetic  
acid dissociation product is reacted with an NaI/KIO<sub>3</sub> solution, and the iodine  
10 released is titrated with Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution.

The total number of methyl groups in the polymer which do not stem from vinyl esters  
is determined by means of <sup>1</sup>H NMR spectroscopy at a measurement frequency of  
500 MHz on 10 to 15% solutions in C<sub>2</sub>D<sub>2</sub>Cl<sub>4</sub> at 300 K. The integral of the  
15 methylprotons between 0.7 and 0.9 ppm is determined as a ratio relative to that of  
the methylene and methine protons between 0.9 and 1.9 ppm. A correction of the  
number of the methyl groups for the structural units which are derived from the  
moderator used and overlap with the signals of the main chain is effected on the  
basis of the methine proton of the moderator which appears separately (for example,  
20 methyl ethyl ketone exhibits multiplets at 2.4 and 2.5 ppm).

The content of methyl groups which derive from propene is determined by means of  
<sup>13</sup>C NMR spectroscopy at a measurement frequency of 125 MHz on likewise 10 to  
15% solutions in C<sub>2</sub>D<sub>2</sub>Cl<sub>4</sub> at 300 K. The integral of the methyl groups derived from  
25 propene between 19.3 and 20.2 ppm is determined as a ratio relative to that of the  
aliphatic hydrocarbons of the polymer backbone between 22 and 44 ppm.  
Advantageously, <sup>1</sup>H and <sup>13</sup>C NMR measurement is performed on the same sample.

The number of chain ends is determined by subtracting the number of methyl groups  
30 derived from propene, determined by means of <sup>13</sup>C NMR, from the total number of  
methyl groups, determined by means of <sup>1</sup>H NMR. The two values should be treated  
as dimensionless numbers.

Table 1: Characterization of the ethylene copolymers A used

Polymer	Polymerization process/moderator	Vinyl acetate in the polymer [mol%]	Propene-CH <sub>3</sub> per 100 aliph. CH <sub>2</sub>	Number of chain ends [CH <sub>3</sub> /100 CH <sub>2</sub> ]	Total G	V <sub>140</sub> [mPas]
P1	A / PA	8.9	2.1	4.3	10.3	314
P2	A / PA	9.3	1.5	4.7	10.8	357
P3	B / MEK	9.7	1.4	3.2	11.1	346
P4	B / MEK	10.1	1.8	3.4	11.9	316
P5	A / PA	9.6	1.3	4.0	10.9	286
P6	A / MEK	9.8	1.2	3.9	11.0	288
P7	A / PA	11.4	0.8	4.9	12.2	371
P8	A / PA	7.8	2.7	5.1	10.5	302
P9 (comp.)	B / propene	9.4	6.4	6.2	15.8	347
P10 (comp.)	B / PA	9.7	2.1 mol% of 4-MP-1	n.a.	n.a.	325
P11 (comp.)	B/PA	9.5	2.5 mol% of DIB	n.a.	n.a.	297

PA = propionaldehyde; MEK = methyl ethyl ketone; 4-MP-1 = 4-methylpentene-1; DIB = diisobutylene; n.a. = not applicable

Characterization of flow improver components (B) and further flow improver components (C):

B1-I) Terpolymer of ethylene, 14 mol% of vinyl acetate and 2 mol% of vinyl  
5 neodecanoate with a melt viscosity measured at 140 °C of 95 mPas.

B1-II) Copolymer of ethylene and 13.5 mol% of vinyl acetate with a melt viscosity  
measured at 140°C of 150 mPas.

10 B2-I) Alternating copolymer of maleic anhydride and octadecene, fully esterified with  
a mixture of equal parts of tetradecanol and hexadecanol.

15 C-I) Mixture of a reaction product of a copolymer of C<sub>16</sub>- $\alpha$ -olefin and maleic  
anhydride with 2 equivalents of di(hydrogenated tallow fat)amine and a  
nonylphenol-formaldehyde resin in a weight ratio of 2:1.

All additives A, B and C used were, unless stated otherwise, used as 50% by weight  
dilutions in relatively high-boiling, predominantly aliphatic solvents.

20 Table 2: Characterization of the test oils used

The test oils used were current oils from European refineries. The CFPP value was  
determined to EN 116 and the cloud point to ISO 3015. The paraffin content was  
determined by gas chromatography separation of the oil with detection by an FID  
25 detector and calculation of the integral of the n-paraffins with a chain length of at  
least 20 carbon atoms in relation to the total integral.

	Test oil 1	Test oil 2	Test oil 3	Test oil 4	Test oil 5	Test oil 6
Distillation						
IBP [°C]	163	160	174	167	153	187
20% [°C]	222	206	222	238	195	223
90% [°C]	343	339	354	341	354	337
FBP [°C]	366	363	371	359	375	360
Cloud Point [°C]	-3.9	-2.5	0.0	-3.9	+0.7	-5.1
CFPP [°C]	-6	-4	-3	-7	-3	-9
Sulfur [ppm]	19	25	8	5	66	8
Density @15°C [g/cm³]	0.835	0.829	0.858	0.845	0.858	0.834
Paraffin content ≥C <sub>20</sub> [area%]	5.7	5.9	7.6	5.2	7.0	7.9

#### Effectiveness of the additives as cold flow improvers

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The superior effectiveness of the inventive additives for mineral oils and mineral oil distillates is described with reference to the CFPP test (Cold Filter Plugging Test to EN 116).

10 Table 3: Testing as a cold flow improver in test oil 1

Example	Additive			CFPP [°C]		
	A	B	C	200 ppm	400 ppm	600 ppm
1	20 % P1	55 % B1-I	25 % C-I	-19	-22	-25
2	20 % P2	55 % B1-I	25 % C-I	-23	-28	-27
3	20 % P3	55 % B1-I	25 % C-I	-24	-22	-26
4	20 % P4	55 % B1-I	25 % C-I	-18	-22	-26
5	20 % P5	55 % B1-I	25 % C-I	-23	-26	-27
6	20 % P6	55 % B1-I	25 % C-I	-23	-29	-28
7	20 % P7	55 % B1-I	25 % C-I	-18	-21	-24

Example	Additive			CFPP [°C]		
	A	B	C	200 ppm	400 ppm	600 ppm
8	20 % P8	55 % B1-I	25 % C-I	-19	-22	-24
9 (comp.)	20 % P9	55 % B1-I	25 % C-I	-14	-16	-18
10 (comp.)	20 % P10	55 % B1-I	25 % C-I	-17	-20	-23
11 (comp.)	-	69 % B1-I	31 % C-I	-10	-12	-17

Table 4: Testing as a cold flow improver in test oil 2

Example	Additive			CFPP [°C]		
	A	B	C	200 ppm	400 ppm	600 ppm
12	20 % P1	55 % B1-I	25 % C-I	-15	-20	-20
13	20 % P2	55 % B1-I	25 % C-I	-17	-23	-23
14	20 % P3	55 % B1-I	25 % C-I	-18	-21	-22
15	20 % P4	55 % B1-I	25 % C-I	-16	-20	-22
16	20 % P5	55 % B1-I	25 % C-I	-16	-22	-25
17	20 % P6	55 % B1-I	25 % C-I	-18	-19	-22
18	20 % P7	55 % B1-I	25 % C-I	-14	-18	-19
19	20 % P8	55 % B1-I	25 % C-I	-15	-19	-20
20 (comp.)	20 % P9	55 % B1-I	25 % C-I	-9	-13	-14
21 (comp.)	20 % P11	55 % B1-I	25 % C-I	-14	-17	-18
22 (comp.)	-	69 % B1-I	31 % C-I	-8	-12	-16

Table 5: Testing as a cold flow improver in test oil 3

Example	Additive		CFPP [°C]		
	A	B	50 ppm	100 ppm	150 ppm
23	85 % P1	15 % B1-II	-5	-10	-12
24	85 % P2	15 % B1-II	-4	-8	-13
25	85 % P3	15 % B1-II	-4	-7	-14
26	85 % P4	15 % B1-II	-4	-9	-11
27	85 % P5	15 % B1-II	-5	-12	-15
28	85 % P6	15 % B1-II	-4	-8	-14
29 (comp.)	85 % P9	15 % B1-II	-3	-5	-7
30 (comp.)	85 % P10	15 % B1-II	-4	-6	-11
31 (comp.)	-	100 % B1-II	-4	-4	-5
32 (comp.)	100 % P1	-	0	-2	-4

5 Table 6: Testing as a cold flow improver in test oil 4

Example	Additive		CFPP [°C]		
	A	B	50 ppm	100 ppm	200 ppm
33	35 % P1	65 % B1-I	-10	-16	-20
34	35 % P2	65 % B1-I	-10	-17	-20
35	35 % P3	65 % B1-I	-11	-17	-20
36	35 % P5	65 % B1-I	-11	-17	-19
37	35 % P6	65 % B1-I	-10	-16	-18
38 (comp.)	35 % P9	65 % B1-I	-10	-13	-15
39 (comp.)	35 % P10	65 % B1-I	-11	-15	-18
40 (comp.)	-	100 % B1-I	-10	-9	-14
41 (comp.)	100 % P1	-	-8	-13	-16

Table 7: Testing as a cold flow improver in test oil 5

Example	Additive		CFPP [°C]	
	A	B	300 ppm	400 ppm
42	65 % P1	35 % B2-I	-7	-11
43	65 % P2	35 % B2-I	-7	-12
44	65 % P4	35 % B2-I	-6	-11
45	65 % P6	35 % B2-I	-6	-10
46 (comp.)	65 % P9	35 % B2-I	-4	-8
47 (comp.)	65 % P11	35 % B2-I	-4	-9

## Handling and filter blocking tendency of the polymers

5

To assess the cold flowability of concentrates of the inventive polymers, the polymers described in table 1 were dissolved at 35% strength by weight in a predominantly aliphatic solvent mixture with boiling range of 175 – 260°C and a flashpoint of 66°C.

10 To this end, polymer and solvent were heated to 80°C with stirring and, after homogenization, cooled to room temperature.

Subsequently, the pour point of the concentrate was determined to DIN ISO 3016.

Table 8: Intrinsic pour point of the polymer concentrates

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Example	Specimen	Pour Point
48	P1	+ 6°C
49	P2	+ 6°C
50	P3	0°C
51	P4	- 6°C
52	P5	+ 3°C
53	P6	0°C
54 (comp.)	P9	- 3°C
55 (comp.)	P10 (comp.)	+ 9°C
56 (comp.)	P11 (comp.)	+ 9°C

In addition, the filter blocking tendency of a test oil treated with inventive additives was determined to IP 387/97. In this test, 300 ml of an additized diesel fuel are filtered through a 1.6  $\mu\text{m}$  glass fiber filter at defined temperature and a pump output of 20 ml/min. The test is considered to have been passed when a volume of 300 ml 5 passes through the filter without the pressure (P) having attained or exceeded 105 kPa (filter blocking tendency  $\text{FBT} = (1+(P/105)^2)^{0.5} \leq 1.41$ ). It is considered not to have been passed when the pressure reaches 105 kPa before the total volume (V) of 300 ml has passed through the filter (filter blocking tendency  $\text{FBT} = (1+(300/V)^2)^{0.5} > 1.41$ ). For the assessment of the additives, it is also important that the filter blocking 10 tendency of the unadditized fuel is increased as little as possible by adding the additive.

For the performance of the test, 350 ml of the test oil 6 of temperature 20-22°C were admixed with 500 ppm of the additive of temperature 60°C (50% solution). After 15 manual shaking and storage at 60°C for 30 minutes, the additized oil was stored at 20°C for 16 hours. Subsequently, the additized oil was used for filtration without shaking again.

Table 9: Filter blocking tendency of the additized test oil 6 to IP 387/97

20

Example	Specimen	Filter blocking tendency
57	none	1.01
58	P1	1.02
59	P2	1.02
60	P3	1.11
61	P4	1.02
62	P5	1.03
63	P6	1.09
64	P7	1.25
65	P8	1.27
66 (comp.)	P9	1.05
67 (comp.)	P10	1.57
68 (comp.)	P11	1.76

The experiments show that the inventive additives, with regard to the improvement in the cold flowability and especially the lowering of the CFPP of middle distillates are superior to the prior art additives. At the same time, they are usable at relatively low temperatures. In particular, they are also usable in applications in which particularly

5 clean fuels with very low filter blocking tendency are required.

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CLAIMS:

1. An additive mixture, comprising:

(A) at least one terpolymer of ethylene, propene and at least one ethylenically unsaturated ester, which:

5 (i) contains from 6.0 to 12.0 mol% of structural units derived from at least one ethylenically unsaturated ester having a C<sub>1</sub>- to C<sub>3</sub>-alkyl radical,

(ii) contains from 0.5 to 4.0 methyl groups derived from propene per 100 aliphatic carbon atoms, and

(iii) has fewer than 8.0 methyl groups stemming from chain ends per 100 CH<sub>2</sub> groups;

10 and

(B) from 0.5 to 20 parts by weight, based on (A), of at least one further component which is effective as a cold additive for a mineral oil and is selected from the group consisting of:

(B1) a copolymer of ethylene and an ethylenically unsaturated compound, wherein  
15 the content of the ethylenically unsaturated compound is at least 2 mol% higher than the content of an ethylenically unsaturated ester in the terpolymer defined under (A),

(B2) a comb polymer, and

(B3) a mixture of (B1) and (B2).

2. The additive mixture as claimed in claim 1, in which the ethylenically  
20 unsaturated ester of component (A) is the vinyl ester of a carboxylic acid having from 1 to 4 carbon atoms.

3. The additive mixture as claimed in claim 2, in which the unsaturated ester is vinyl acetate.

4. The additive mixture as claimed in any one of claims 1 to 3, in which the

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sum, G, of molar content of the unsaturated ester (i) and the number of methyl groups derived from propene per 100 aliphatic carbon atoms of the polymer (ii), wherein:

$$G = [\text{mol\% of unsaturated ester}] + [\text{propene-CH}_3]$$

5 is between 8.0 and 14.0.

5. The additive mixture as claimed in any one of claims 1 to 4, in which component (A) additionally contains from 0.3 to 5.0% by weight of at least one structural unit derived from a moderator comprising a carbonyl group.

6. The additive mixture as claimed in any one of claims 1 to 5, in which the 10 content of the copolymer (B1) of the ethylenically unsaturated compound is at least three mol% higher than that of the ethylenically unsaturated ester in the terpolymer (A).

7. A process for preparing the terpolymer (A) as defined in any one of claims 1 to 6, comprising: reacting a mixture of ethylene, propene and at least one 15 vinyl ester under elevated pressure and elevated temperature in the presence of a free radical-forming initiator; and adjusting the molecular weight of the terpolymer (A) by a moderator comprising a carbonyl group.

8. Use of the additive mixture as claimed in any one of claims 1 to 6, for improving the cold flowability of a fuel oil.

20 9. A process for improving the flowability of a fuel oil, comprising adding the additive mixture as claimed in any one of claims 1 to 6, to the fuel oil.

10. A composition comprising at least one additive mixture as claimed in any one of claims 1 to 6, and at least one oil-soluble polar nitrogen compound.

11. A composition comprising at least one additive mixture as claimed in 25 any one of claims 1 to 6, and at least one alkylphenol-aldehyde resin.

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12. A composition comprising at least one additive mixture as claimed in any one of claims 1 to 6, and at least one olefin polymer.
13. The composition as claimed in any one of claims 10 to 12, further comprising at least one polyoxyalkylene compound.
- 5 14. A fuel oil composition comprising a middle distillate and at least one additive mixture as claimed in any one of claims 1 to 6.