

SYNERGISTIC COMBINATIONS OF CARBOXYLATES FOR USE AS FREEZING
POINT DEPRESSANTS AND CORROSION INHIBITORS IN HEAT TRANSFER
FLUIDS

FIELD OF THE INVENTION

The present invention relates to aqueous heat transfer fluids particularly antifreeze coolants and general cooling fluids that provide both frost protection and corrosion protection by use of synergistic combinations of carboxylic acids. The heat transfer fluids of this invention are non-toxic, environmentally friendly and provide improved heat-transfer properties, compared to traditional glycol based coolants and heat-transfer fluids. Improved corrosion protection is obtained compared to formate and acetate based heat transfer fluids using conventional corrosion inhibitors. The heat transfer fluids of the present invention can be used in any heat-exchange application including industrial heat-exchangers, refrigeration- and cooling systems, cooling towers, open and closed heat exchangers and for cooling internal combustion engines. The fluids protect the equipment from frost and corrosion damage.

BACKGROUND OF THE INVENTION

Effective Heat Exchange

Heat transfer fluids, whether used for heat-transfer in industrial or automotive applications have been, almost without exception, water-based. The efficiency of a heat transfer fluid to transport heat away from heat producing surfaces can be expressed in terms of the specific heat and thermal conductivity of the fluid. Specific heat of a substance is the

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ratio of its thermal capacity to that of water. The thermal capacity is the quantity of heat necessary to produce unit change of temperature in unit mass. Thermal conductivity of a substance is the time rate of transfer of heat by conduction through a mass of unit thickness, across a unit area for a unit difference of temperature. Viscosity of the heat transfer fluid is also a factor in evaluating the overall heat exchange efficiency - a better fluidity will contribute to an effective heat transport. Compared to most other heat-transfer fluids, water has the highest specific heat, the highest thermal conductivity and lowest viscosity. Whilst water is a most effective heat transfer fluid, it does not provide the required freezing and corrosion protection.

Freezing Point Depressant

Heat transfer fluids and engine coolants are known that contain high concentrations of inorganic salts to depress the freezing point. Calcium chloride is an example of the salts used to that purpose. Like other inorganic salts used for frost protection, it is extremely corrosive and corrosion cannot be adequately prevented by inhibitors. Another disadvantage of such coolants is that at very low temperatures, the solubility of inorganic salts is reduced. These drawbacks limit the use of inorganic salts as freezing point depressants in water.

Petroleum products, such as kerosene, have also been used in heat-exchange and cooling systems as a total replacement for water, but their adverse effect on rubber hoses, poor heat-transfer, and flammability has made their use impractical. Organic hydroxy compounds were found more reliable and ethylene glycol came into widespread use. Other heat transfer fluid

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bases included glycerol, the lower boiling point alcohols such as methanol, and propylene glycol. Of these only propylene glycol is still under active consideration because of its low toxicity compared to ethylene glycol. In general, water/glycol mixtures are used today because they are chemically stable and compatible with the elastomers and plastics used in heat-exchange systems. In addition, they provide cost efficient freezing and boiling protection and can be formulated with inhibitors to provide the required corrosion protection. However, ethylene glycol is preferred as a heat transfer fluid base because of its high boiling point and flash point compared to methyl alcohol, its lower viscosity (better fluidity) and low cost compared to propylene glycol. Propylene glycol is used in applications where a lower toxicity is desirable. The heat-exchange capacity of water/freezing point depressant solutions is reduced with increasing freezing point depressant content.

Pure water remains a better heat transfer fluid compared to any mixture of ethylene- or propylene glycol. A compromise between the required freezing protection and heat exchange efficiency has to be made. Aqueous glycol solutions have higher viscosities at higher glycol concentrations. A better fluidity is thus obtained in solutions containing less freezing point depressant. Alkali salts of low molecular organic acids such as alkali metal acetate and alkali metal formate can also provide frost protection when dissolved in water. Compared to glycol, acetate and formate solutions have improved heat-transfer properties and lower viscosities, for a same level of frost protection. They are also more environmentally friendly than glycols. Formate and acetate based fluids have found

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applications as heat-exchange fluid and airport runway deicing fluids. US Patent 5,104,562 describes a coolant composition containing a potassium formate and potassium acetate.

Corrosion Protection

Corrosion in heat-exchange- and engine cooling systems will have two main effects: deterioration of the metal component either by uniform wastage or localised attack (pitting, crevice corrosion), and the production of insoluble corrosion products that will tend to block heat-exchangers, thermostat valves, filters and other components and to impede heat transfer by deposition on heat exchange surfaces. Regardless of the composition of the freezing point depressant, corrosion inhibitors are needed to reduce and control corrosion of the metals in contact with the fluid.

DISCLOSURE OF THE INVENTION

One aspect of the invention is that specific aqueous solutions of organic carboxylates show very low freezing points at eutectic compositions i.e. compositions mixed in such proportions that the freezing-point is a minimum, the constituents freezing simultaneously. This is very important, as the total organic salt content can be significantly reduced compared with conventional monocarbon carboxylates (formate or acetate) systems offering the same frost protection. The advantage is not only in improved economics but also, in better heat-transfer due to a higher specific heat and improved fluidity resulting from the higher water content at the same frost protection. In particular, it has been found that solutions of low carbon (C_1 - C_2) carboxylic acid salts, in

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combination with higher carbon (C_3 - C_5) carboxylic acid salts, provide synergistic frost protection. Very effective eutectica have been found for the combination of the alkali salts of a C_1 carboxylic acid (methanoic- or formic acid) and a C_3 carboxylic acid (propanoic- or propionic acid).

Another aspect of the present invention is that improved synergistic frost protection and corrosion protection is found by adding one or a plurality of C_6 - C_{12} carboxylic acids. It has been found that higher carbon carboxylates (C_{12} - C_{16}) also increase the corrosion protection, but their solubility in the salt solutions is very limited. Optionally the addition of hydrocarbyl triazoles or thiazoles can further improve the corrosion protection.

DETAILED DESCRIPTION AND EXAMPLES

Synergistic Frost Protection in Solutions of Lower Carbon (C_1 - C_3) and Higher Carbon (C_3 - C_5) Carboxylic Acid Salts

The freezing point of carboxylate mixtures according to this invention are much lower than expected in comparison to freezing point reduction as determined separately for each component. Preferred ratios are from 3:1 to 1:3, preferably 1:1. This may be demonstrated by experimental data on aqueous mixtures of potassium formate (C_1) and sodium propanoate (C_3). Table 1 shows the results of freezing point determinations for different solutions of the C_1 and C_3 carboxylates.

TABLE 1

Weight Ratio Potassium Formate (C ₁): Sodium Propanoate (C ₃) Water 100	Freezing Temperature °C
40:0	-36
35:5	-38
30:10	-42
20:20	-48
25:15	-45
0:40	-32

The pure solution of potassium formate (40:0) in water has a freezing point of -36°C. The same concentration of sodium propanoate (40:0) in water has a freezing point of -32°C. In mixtures of the two components a freezing point below -48°C is found at a ratio 20:20, which is remarkably lower than the expected mid-point of -34°C calculated using the addition rule. The laws of molecular freezing point depression are apparently no longer valid for this type of solution. The combination of the added organic salts seem to interfere with the solidification of water to ice crystals in a way that it inhibits the possibility to obtain a regular crystal structure in the water molecules. Without being bound by theory, it is also believed that the selected cations play an important role in the synergistic freezing point depression. Substitution of the sodium by potassium in the propanoate does not yield as great a frost protection effect. Thus a most preferred system is the combination of a C₁ potassium carboxylate salt and a C₃ sodium carboxylate salt.

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Similar synergistic effects are found when combining other solutions of differing carbon number e.g. aqueous mixtures of acetate salts (C_2) and butyrate salts (C_4).

Further Improved Synergistic Frost Protection and Corrosion Protection upon Addition one or more C_6 - C_{12} Carboxylic Acids to Aqueous Solutions of Low Carbon (C_1 - C_5) and Higher Carbon (C_3 - C_5) Carboxylic Acid Salts

The use of C_6 - C_{12} carboxylates as corrosion inhibitors has been investigated in aqueous solutions of low carbon (C_1 - C_5) and higher carbon (C_3 - C_5) carboxylic acid salts used as freezing point depressants. Different combinations of conventional inhibitors such as borax, benzoates, molybdates and nitrites are currently used with hydrocarbyl triazole for corrosion protection in acetate and formate salt solutions. Some of these inhibitors are toxic and harmful to the environment. Others are not very stable in organic salts solutions and may precipitate out of solution under conditions of high temperatures or severe frost. By using C_6 - C_{12} carboxylate inhibitors in C_1 - C_5 carboxylate freezing point depressant solutions at from 1 to 10%, it has been found that these problems may be resolved. Overall stability of the product is improved. A further synergistic improvement of the frost protection properties was found. On their own, C_6 - C_{12} carboxylates are poor freezing point depressants. The addition of small amounts of C_6 - C_{12} acids to the combination of acids further improves the frost properties, significantly far beyond what could be expected. Table 2 shows the freezing point depression gained by the addition of 5% sodium heptanoate (C_7).

TABLE 2

Weight Ratio Potassium Formate (C ₁): Sodium Propanoate (C ₃): Sodium Heptanoate (C ₇) Water 100	Freezing Temperature °C
40:0:5	-42
35:5:5	-46
30:10:5	-49
20:20:5	n.d.*
25:15:5	-50
0:40:5	n.d.*

A comparison between the corrosion protection of different low carbon containing organic acid salts solutions with traditional inhibitor packages and the newly developed synergistic combinations of carboxylate based solutions shows that there is a significant improvement in corrosion protection.

The present invention will be described with reference to the following non-limiting examples. Tables 3 and 4 show the results of corrosion tests.

EXAMPLES

Comparative Example A (Traditional Formate-Based Formulation)

One litre of an aqueous antifreeze formulation was prepared comprising of 320 g potassium hydroxide, 275 ml formic acid (98%), 15 g sodium benzoate and 2 g tolyltriazole pH = 8.8.

* : not determined (freezing point is below -50°C)

Invention Example 1

One litre of an aqueous formulation was prepared comprising of 320 g potassium hydroxide, 275 ml formic acid (98%), 13 g 2-ethylhexanoic acid, 1 g sebacic acid, 0.8 g tolyltriazole and 4 g sodium hydroxide, adjusted to pH 9.

Invention Example 2

One litre of an aqueous antifreeze formulation was prepared comprising of 115 g potassium hydroxide, 110 ml formic acid (98%), 200 g sodium propanoate, 16.2 g 2-ethylhexanoic acid, 1.26 g sebacic acid, 1.0 g tolyltriazole and 4 g sodium hydroxide, adjusted to pH 9.

Comparative Example B (Traditional Acetate-Based Formulation)

One litre of an aqueous antifreeze formulation was prepared comprising of 400 g potassium hydroxide, 60 ml formic acid (98%), 360 ml acetic acid (99.5%), 800 ml water, 5 g sodium benzoate and 1 g benzotriazole.

Invention Example 3

One litre of an aqueous antifreeze formulation was prepared comprising 400 g potassium formate, 16.2 g 2-ethylhexanoic acid, 1.26 g sebacic acid, 1.0 g tolyltriazole and 4 g sodium hydroxide, adjusted to pH 8.8.

Invention Example 4

One litre of an aqueous formulation was prepared comprising of 115 g potassium hydroxide, 110 ml formic acid (98%), 200 g sodium propanoate, 13 g 2-ethylhexanoic acid, 1 g sebacic acid, 0.8 g tolyltriazole and 4 g sodium hydroxide, adjusted to pH 8.2.

TABLE 3Glassware Corrosion Tests - 336 Hours - similar to ASTM D1384

		Weight loss (mg/coupon)					
		Copper	Solder	Brass	Steel	Iron	Aluminium
(Comparative)	Ex. A	9.9	115.4	1.2	4.0	174.5	-0.1
(Invention)	Ex. 1	2.9	88.2	2.8	38.6	96.3	-3.2
(Invention)	Ex. 2	3.0	79.8	2.5	12.4	19.8	

TABLE 4Aluminium Hot Corrosion Test Similar to ASTM D4340

	Formulation	Weight loss on aluminium coupon (mg/cm ² /week)
(Invention)	Ex. 1	0.51
(Comparative)	Ex. B	7.01
(Invention)	Ex. 3	1.54
(Invention)	Ex. 4	1.47

It is seen that the examples according to the present invention show a reduction in weight loss of many metals, e.g. copper, solder and iron. The weight loss on aluminium coupons (Table 4) is significant as aluminium is a major component of automotive engines.



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CLAIMS

1. An aqueous fluid composition for use as a heat transfer fluid comprising a mixture of a C_1-C_2 carboxylic acid salt and a C_3-C_5 carboxylic acid salt.
2. A composition as claimed in Claim 1 further comprising a C_6-C_{12} carboxylate.
3. A composition as claimed in Claim 1 or Claim 2 further comprising a hydrocarbyl thiazole or hydrocarbyl triazole.
4. A composition as claimed in any preceding claim wherein the ratio of C_1-C_2 carboxylic acid salt to C_3-C_5 carboxylic acid salt to from 3:1 to 1:3.
5. A composition wherein the ratio of C_1-C_2 carboxylic acid salt to C_3-C_5 carboxylic acid salt is 1:1.
6. A composition wherein the C_1-C_2 carboxylic acid salt is potassium.
7. A composition wherein the C_3-C_5 carboxylic acid salt is sodium.
8. A composition as claimed in any one of Claims 2 to 7 wherein the C_6-C_{12} carboxylate is present in solution at from 1 to 10 wt %.

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9. A composition as claimed in any one of Claims 2 to 8 comprising a mixture of potassium formate, sodium propanoate and sodium heptanoate.

10. A composition as claimed in Claim 10 in a ratio of 20:20:5 respectively.

11. A composition as claimed in any preceding claim having a pH of from 8 to 9.5.

12. The use of a composition as claimed in any preceding claims as a coolant composition.

13. The use of a composition as a coolant composition in automotive engines.



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