

Description

The present invention relates to a polymerisation inhibitor and a polymerization-inhibiting method for a vinyl compound.

5 The vinyl compound generally has easily polymerizable properties by light and heat, etc. Therefore, to prevent the polymerization of a vinyl compound, various kinds of polymerization inhibitors are used alone or in combination of a plural kind in accordance with the surrounding conditions of the vinyl compound.

Hereinafter, in a group of vinyl compounds, a very polymerizable (meth)acrylic acid (in this specification, a general term of (meth)acrylic acid is given in a case where a common matter for both of acrylic acid and methacrylic acid is mentioned) is cited as an example for a detail explanation.

Hitherto, as a method for producing (meth)acrylic acid, there have been frequently used, for example, a method for producing acrylic acid by a catalytic gas phase oxidation reaction of propylene and/or acrolein and a method for producing methacrylic acid by a catalytic gas phase oxidation reaction of isobutylene and/or methacrolein, etc.

15 In these methods, a gas produced from the catalytic gas phase oxidation reaction is cooled and collected by water to obtain an aqueous solution of (meth)acrylic acid containing such by-products as acetic acid and an aldehyde, etc. and, from this aqueous solution, (meth)acrylic acid is separated and purified by combining processes such as distillation and extraction by a solvent. The method for producing (meth) acrylic acid by the forementioned catalytic gas phase oxidation reaction involves a process to separate, 20 enrich, and purify, etc. the acid by distillation. Also, as methods for producing (meth)acrylic acid other than the above-described, there have been known a method for producing acrylic acid by Reppe's method and a method for producing methacrylic acid by the acetone cyanhydrin method, etc. In these methods there has been involved a process to separate, enrich, and purify (meth)acrylic acid by distillation.

The (meth)acrylic acid has very easily polymerizable properties by light and heat, etc. Therefore, the 25 polymerizing properties of (meth)acrylic acid becomes extremely big, especially, in treating under a high temperature condition such as in the forementioned distillation process. Accordingly, in a case where (meth) acrylic acid having a big polymerizing property like the forementioned is industrially produced, to prevent polymerization of these acids in a distillation process is a very important item in operation of the process and, especially, to establish an effective polymerization-preventive art in a distillation process 30 dealing with the acid under a high temperature is an essentially important item for operating the process continuously for a long period of time and under a stable condition. According to the knowledge of present inventors, the polymerization most easily takes place in a dehydrating process (a water-separating process) during the forementioned distillation course and this fact is a main factor to disturb continuous operations of a production device including a distillation column.

35 When subjecting (meth)acrylic acid to operations such as separation, enriching, and purification using a distillation column, most of the places where a polymerization product is easily formed by a polymerization reaction of the acid are a place of hardly wetting by liquid such as a rear side of a tray, an inside of bubble cap, a rear side of a downcomer, a hollow on a column inside, etc. and a place of easily liquid-stagnating such as a metal fittings (bolt and nut, etc.) for putting-in a tray and a packing part, etc. The polymerization 40 product is hardly soluble in (meth)acrylic acid, water, and usual organic solvents and, once formed in a column, it becomes a seed for polymerization and gradually accumulates. Finally, the column inside is clogged by it and a continuous operation of the production device becomes impossible. Besides, it is very difficult to remove these accumulated polymerization products.

Conventionally, a method of carrying out distillation in the presence of a polymerization inhibitor has 45 been adopted as a measure for preventing polymerization of (meth) acrylic acid in a distillation process when producing (meth) acrylic acid. As polymerization inhibitors of this kind, is hitherto known a polymerization inhibitor (A) composed of the following ingredients: at least one kind of compound selected from the group consisting of hydroquinone, methoquinone (p-methoxyphenol), cresol, phenol, tertiary-butylcatechol, diphenylamine, phenothiazine, and methylene blue, at least one kind of copper dithiocarbamate selected 50 from the group consisting of copper dimethyldithiocarbamate, copper diethyldithiocarbamate, and copper dibutyldithiocarbamate, and molecular oxygen (for acrylic acid, refer to Japanese Official Patent Provisional Publication, showa 49-85016 (FR-A-2211440); for methacrylic acid, refer to Japanese Official Patent Gazette, showa 57-61015). Hitherto-known polymerization inhibitors of (meth)acrylic acid other than the above are a polymerization inhibitor (B-1) composed of a manganese salt such as manganese acetate, a 55 polymerization inhibitor (B-2) composed of a manganese salt such as manganese acetate with hydroquinone and/or methoquinone, a polymerization inhibitor (B-3) composed of a manganese salt such as manganese acetate with molecular oxygen, and a polymerization inhibitor (B-4) composed of a manganese salt such as manganese acetate, hydroquinone and/or methoquinone, and molecular oxygen (for all of

these, refer to Japanese Official Patent Provisional Publication, showa 51-98211).

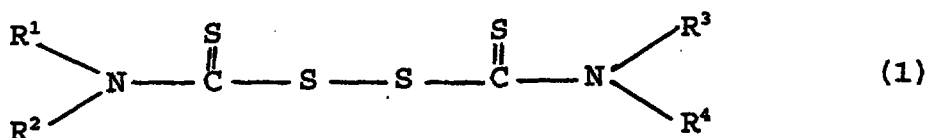
However, it was found by a subsequent examination that the forementioned polymerization inhibitors of (A) and from (B-1) to (B-4) known in public have the following problems.

That is, the polymerization inhibitor (A) disclosed in the Japanese Official Patent Provisional Publication, showa 49-85016 (FR-A-2211440) and Japanese Official Patent Gazette, showa 57-61015, is very low in the polymerization-inhibiting effects in a case where polymerization of (meth)acrylic acid very easily occurs by containing water, acetic acid, and aldehyde compounds in the feed composition as in an azeotropic separation column (a water-separating column) of an aqueous (meth)acrylic acid solution in the distillation process, when (meth)acrylic acid is produced by a catalytic gas phase oxidation reaction. Due to the low inhibiting effect, there was a problem that, with generation of a popcorn polymer and a sticky polymer in the course of distillation, continuous operation in a long period of time of a production device including a distillation column became impossible. Also, since this polymerization inhibitor (A) contains a copper salt having a corrosive character, there is a problem that the distillation column easily corrodes during a continuous operation in a long period of time.

On the other hand, the polymerization inhibitors of from (B-1) to (B-4) disclosed in the Japanese Official Patent Provisional Publication, showa 51-98211, contains a manganese salt having a low corrosive character, so that there is no problem about corrosion of the distillation column. The polymerization inhibitors of from (B-1) to (B-4) have sufficient polymerization-inhibiting effects on the products from (meth)acrylic acid, but the polymerization-inhibiting effects is insufficient, similarly to the case of the polymerization-inhibitor (A), in a case where polymerization of (meth)acrylic acid very easily occurs as in an azeotropic separation column of an aqueous (meth)acrylic acid solution in the distillation process, when (meth)acrylic acid is produced by a catalytic gas phase oxidation reaction. Thus, there was a problem that, with generation of a popcorn polymer and a sticky polymer during distillation, continuous operation in a long period of time of a production device became impossible.

Also, there were problems similar to the forementioned in the conventional polymerization inhibitors and polymerization-inhibiting methods of a vinyl compound other than (meth)acrylic acid.

DE-A-2030573 discloses a thiuram disulfide having the following general formula:



and its use as a polymerization inhibitor for a norbornylene group-containing vinyl compound. However, DE-A-2030573 does not disclose use of the thiuram disulfide in combination with other conventional polymerization inhibitors. The use of the thiuram disulfide alone has only an insufficient polymerization-inhibiting effect in practice under conditions where a vinyl compound readily polymerizes, for example, in distillation.

EP-A-0155898 discloses a composition comprising a vinyl aromatic compound and an effective amount of at least one of zinc dithiocarbamate and nickel dithiocarbamate and discloses a polymerization-inhibiting method for a vinyl aromatic compound which comprises adding to the vinyl aromatic compound an effective amount of at least one of zinc dithiocarbamate and nickel dithiocarbamate as polymerization inhibitors. However, in practice, the zinc dithiocarbamate and nickel dithiocarbamate have only a poor polymerization-inhibiting effect on a vinyl compound. In addition, the nickel dithiocarbamate, similarly to the aforementioned copper salts, has the disadvantage of having a corrosive character.

Under these circumstances, an object of the present invention is to provide a polymerization inhibitor and a polymerization-inhibiting method both of which make continuous operation of a device for producing vinyl compounds in a long period of time possible and make corrosion of the device quite small, and also, are superior in polymerisation inhibition in case of transferring and storing the vinyl compound products and in other cases.

To solve the forementioned object, the present inventors carried out extensive studies. As a result, the inventors' experiments led to a finding that, if a dithiocarbamic acid manganese salt or a thiuram compound which is explained later in detail is used as an effective ingredient being involved in the polymerization inhibitor, the polymerization-inhibiting effects greatly increase when compared with the forementioned conventional polymerization inhibitors, so that continuous operation of a production device in a long period of time becomes possible, and also, corrosion of the device becomes quite small. Thus, the present invention was completed.

Therefore, a polymerization inhibitor for a vinyl compound relating to the present invention comprises, as an effective component, at least one kind of dithiocarbamic acid manganese salts, in which two hydrocarbon groups of an identical kind or each other different kinds selected from the group consisting of a methyl group, an ethyl group, a propyl group, a butyl group, and a phenyl group are bonded with the nitrogen atom and also, the propyl group or butyl group may be a straight chain type or may be a branch type (hereinafter, this compound is simply referred to as "manganese dithiocarbamate").

First, a polymerization-inhibiting method for a vinyl compound relating to the present invention involves a use of the polymerization inhibitor comprising the forementioned manganese dithiocarbamate (hereinafter, this method is referred to as "the first polymerization-inhibiting method").

The thiuram compounds used in the present invention are practically exemplified by tetramethylthiuram disulfide, tetraethylthiuram disulfide, tetrapropylthiuram disulfide, tetrabutylthiuram disulfide, tetraoctylthiuram disulfide, tetraphenylthiuram disulfide.

A polymerization-inhibiting method for vinyl compound relating to the present invention is not limited to the above-described ones. That is, in the course of the forementioned extensive studies, the inventors have confirmed by experiments that, if a copper dithiocarbamate and a manganese salt are jointly used as a polymerization inhibitors, the amount for use of the copper dithiocarbamate having high corrosive property can be reduced and corrosion of the production device by the copper dithiocarbamate is depressed.

Therefore, secondly, a polymerization-inhibiting method for a vinyl compound relating to the present invention may comprise a joint use of a copper dithiocarbamate and a manganese salt as polymerization inhibitors, wherein the weight ratio of manganese to copper (Mn/Cu) is in the range of from 1 to 10, (hereinafter, this method is referred to as "the third polymerization-inhibiting method").

In the first polymerization-inhibiting method of this invention, sufficiently superior polymerization-inhibiting effects can be obtained even if it comprises a use of a polymerization inhibitor only containing a manganese dithiocarbamate, but if necessary, it is possible jointly to use at least one kind selected from a group consisting of a copper salt and a manganese salt other than a manganese dithiocarbamate (hereinafter, this is simply referred to as "the other manganese salt") as the polymerization inhibitor as well. In this case, further superior polymerization-inhibiting effects can be obtained.

Preferable examples of the other manganese salt which is, if necessary, used in the first polymerization-inhibiting method of the present invention may be either organic or inorganic salts and they are not especially limited. However, as the preferable organic salts are cited saturated or unsaturated manganese carboxylates having the carbon number of 1 to 8 such as manganese formate, manganese acetate, manganese octanate; other manganese carboxylates such as manganese naphthenates. And as the preferable inorganic salts are cited potassium permanganate.

Preferable examples of a manganese salt which is used in the second polymerization-inhibiting method of the present invention are not especially limited. However, for example, are cited the manganese dithiocarbamates and the other manganese salts as forementioned.

Although copper salts which are, if necessary, used in the first polymerization-inhibiting method of the present invention are not especially limited, their preferable examples are copper dithiocarbamate such as copper dimethyldithiocarbamate, copper diethyldithiocarbamate, copper dipropyldithiocarbamate, copper dibutyldithiocarbamate, copper diphenyldithiocarbamate. Besides them, are also cited saturated or unsaturated copper carboxylates having the carbon number of 1 to 8 such as copper acetate, copper octanate.

The forementioned salts of manganese and copper are used alone or jointly used in a plural kind.

In the first and second polymerization-inhibiting methods, in case of necessity, if benzene derivatives such as hydroquinone etc. or molecular oxygen are jointly used in addition to the forementioned polymerization inhibitors which are individually or jointly used, because of synergistic effect of these polymerization inhibitors, the polymerization-inhibiting effects greatly increase when compared with the forementioned conventional polymerization-inhibiting methods, and continuous operation of a production device for a long period of time becomes possible. As the forementioned benzene derivatives, besides hydroquinone, are cited methoquinone (p-methoxyphenol), cresol, phenol, tertiary-butylcatechol, diphenylamine, phenothiazine, methylene blue. It is specially preferable to use hydroquinone and/or methoquinone among said benzene derivatives.

The vinyl compound to which the polymerization inhibitor and the polymerization-inhibiting method of this invention are applicable is not especially limited. But, for example, an acrylic acid ester, methacrylic acid ester, acrylonitrile, styrene are cited besides the (meth) acrylic acid.

An application range of the polymerization inhibitor and the polymerization-inhibiting method of this invention is not especially limited. For example, a reaction vessel, distilling column, condensation column, a storage tank of a purified vinyl compound, etc. are applied. Practically, if the case producing (meth)acrylic acid by a catalytic gas phase oxidation reaction is explained, an effective application is coexisting of the

present invention's polymerization inhibitor with (meth)acrylic acid in various processes, including various distillation processes such as a rectifying column of (meth)acrylic acid, a separation column between (meth)acrylic acid and a solvent, a separation column between (meth)acrylic acid and a light portion such as acetic acid and also, which include a distillation operation of stripper etc. of a light portion such as acrolein, methacrolein.

In the polymerization-inhibiting method of this invention, each polymerization-inhibiting component is usually used by adding it into a vinyl compound or a solution of this. This adding method is not especially limited. For example, since a manganese dithiocarbamate or a thiuram compound is easily soluble in a vinyl compound, it may be directly added in form of a solid, a powder or may be added in form of a solution dissolving it into a proper organic solvent. Also, other polymerization-inhibiting components, according to the kind, may be directly added in form of a solid, a powder or may be added in form of a solution in which they are dissolved into a proper organic solvent. Besides, molecular oxygen which is used in case of necessity may be directly mingled into a vinyl compound or a solution of this by an air-bubbling method or may be indirectly mingled into a vinyl compound or a solution of this in form of a solution of the other polymerization-inhibiting component in which molecular oxygen is dissolved.

The time of adding each polymerization-inhibiting component is not especially limited. It may be separately added to the vinyl compound or a solution of this, or may be added at one time, for example, in form of one solution.

Practically, for example, in a distillation process in producing (meth)acrylic acid, since polymerization-inhibiting components other than molecular oxygen are relatively soluble in (meth)acrylic acid as well as in an organic solvent being used in the process for producing these acids, they may be introduced in the process by dissolving them in a supplying solution or in a reflux solution. Also, molecular oxygen is transferred in a gas form from the bottom of a distillation column or that of a separation column and/or from a reboiler.

In the first polymerization-inhibiting method for vinyl compounds relating to the present invention, an amount for use of a polymerization inhibitor generally varies with the composition of a polymerization inhibitor (the kind of combining ingredients in a polymerization inhibitor), operation conditions, etc., and it is not especially limited. For example, in a case where the manganese dithiocarbamate is used alone, its preferable adding amount is from 10 to 50 ppm (weight standard) against a boiling up amount of a vinyl compound. Furthermore, in a case where the manganese salt (the manganese salt other than the manganese dithiocarbamate in case of the first polymerization-inhibiting method) or copper salt (B) is jointly used in addition to the manganese dithiocarbamate (A), it is preferred that a total adding amount of these compounds (A + B) is adjusted at from 20 to 100 ppm (weight standard) against a boiling up amount of a vinyl compound. Furthermore, in a case where the manganese salt (the manganese salt other than the manganese dithiocarbamate in case of the first polymerization-inhibiting method) or copper salt (B) and the benzene derivatives such as hydroquinone, methoquinone, (C) are jointly used in addition to the manganese dithiocarbamate (A), it is preferred that a total adding amount of these compounds (A + B + C) is adjusted at from 20 to 500 ppm (weight standard) against a boiling up amount of a vinyl compound. Also, in a case where a polymerization-inhibiting method of the present invention is carried out, if the method is carried out in the presence of molecular oxygen, the effects lasts. Therefore, it is preferable to pour molecular oxygen in amount of from about 0.05 to 0.5 % by volume against a boiling up amount of a vinyl compound.

An amount for use of the copper dithiocarbamates and manganese salts used in the second polymerization-inhibiting method and the benzene derivative such as hydroquinone, methoquinone and molecular oxygen used in case of necessity varies depending upon the kind of using polymerization inhibitors and operation conditions, and it is not especially limited. However, for example, it is preferred that a total adding amount ($x_1 + x_2 + x_3$) of the copper dithiocarbamate (x_1), manganese salt (x_2), and benzene derivative (x_3) is adjusted at 200 to 500 ppm (weight standard) against a boiling up amount of a vinyl compound and an amount of pouring molecular oxygen is adjusted at 0.05 to 0.5 % by volume against a boiling up amount of vinyl compound. Besides, in the second polymerization-inhibiting method the ratio of the manganese salt to the copper dithiocarbamate is so adjusted that the weight ratio (Mn/Cu) of the manganese atom in the manganese salt to the copper atom in the copper dithiocarbamate is in a range of from 1 to 10, preferably in a range of from 2 to 4. In a case where the Mn/Cu ratio is less than 1, a problem of the device's corrosion takes place and, in a case where the ratio exceeds 10, according to operating conditions, the polymerization-inhibiting effect is not sufficient.

If formulated so as to contain a manganese dithiocarbamate or a thiuram compound jointly with the aforementioned other polymerization-inhibitors as an effective ingredient, the polymerization-inhibiting effects are much elevated when compared with those of conventional polymerization inhibitors and, because polymerization of a vinyl compound is sufficiently prevented even under a condition that the vinyl

compound easily polymerize, continuous operation in a long period of time of a device for producing the vinyl compound, which includes a distillation column of the vinyl compound, becomes possible, and the superior polymerization-inhibiting effects are also displayed in case of transferring and storing the vinyl compound products and in other cases. Furthermore, since the manganese dithiocarbamate and the thiuram compound have only a very weak corrosive property, corrosion of the production device is slight.

Besides, also in case that a copper dithiocarbamate and a manganese salt are jointly used as polymerization inhibitors in the defined Mn/Cu weight ratio, similarly as forementioned, the polymerization of a vinyl compound is sufficiently prevented by a synergistic effect of the above polymerization inhibitors. Because of this, it is possible continuously to operate a device for producing the vinyl compound in a long period of time, and the superior polymerization-inhibiting effects are also displayed in case of transferring and storing the vinyl compound products and in other cases. Furthermore, since the manganese salt weakens the corrosive property of the copper dithiocarbamate, corrosion of the device becomes small.

Thus, according to the polymerization inhibitor and polymerization-inhibiting method for a vinyl compound relating to the present invention, the polymerization of a vinyl compound is sufficiently prevented even under the conditions that the vinyl compound easily undergoes polymerization, and thereby, continuous operation in a long period of time of a device for producing the vinyl compound, which includes a distillation column of the vinyl compound, becomes possible, and also, corrosion of the device for producing is slight. Also, the polymerization inhibitor and polymerization-inhibiting method for a vinyl compound are applicable not only in case of producing the vinyl compound, but also in case of transferring and storing the product of the compound and in other cases.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, practical examples and comparative examples of the present invention are shown together. Besides, a standard of the unit "ppm" in the examples and comparative examples are by weight,

Example 1.1

An acrylic acid solution was prepared by adding manganese dibutyldithiocarbamate as a polymerization inhibitor in a proportion of 1 ppm to purified acrylic acid (a vinyl compound).

Next, with an attempt of removing an effect of molecular oxygen upon the polymerization-inhibiting effect and of seeing the polymerization-inhibiting effect by only manganese dibutyldithiocarbamate, 5 ml of the acrylic acid solution was taken into a 20 ml test tube, oxygen dissolved in the acrylic acid solution was removed by bubbling a nitrogen gas for 1 minute with a stream amount of 30 ml/minute, and the test tube was sealed,

This test tube was immersed in an oil bath maintained at 130 °C and a polymerization-initiating time of acrylic acid was measured. This time is a time of from immersing a test tube in an oil bath until getting turbidity in the solution sealed in the test tube. Results are shown in the following Table 1.1

Examples 1.2 to 1.16 and comparative examples 1.1 to 1.23

The procedure of example 1.1 was repeated except that the kind of vinyl compounds, the kind and adding amount of polymerization-inhibitors, the heating temperature, and addition of a polymerization initiator (AIBN: azoisobutyronitrile) are varied as shown in the following Tables 1.1 to 1.8, whereby the polymerization-initiating time of vinyl compounds was measured and the results are shown in the Tables 1.1 to 1.8.

Besides, in the following Tables 1.1 to 1.8, the "none" in the column "joint use of molecular oxygen", as in the example 1.1, means that an effect of molecular oxygen upon the polymerization-inhibiting effect is removed by bubbling of a nitrogen gas into a solution of a vinyl compound for 1 minute with a stream of 30 ml/minute, and the "yes" in the same column means that the molecular oxygen was together used as a polymerization inhibitor by bubbling of air instead of a nitrogen gas into the solution for 1 minute with a stream of 30 ml/minute.

Table 1.1

	vinyl compound	polymerization inhibitor				adding amount of polymerization initiator (AIBN) (ppm)*	heating temperature (°C)	polymerization initiating time (minutes)
		solid portion		joint use of molecular oxygen	adding amount (ppm)*			
		kind	adding amount (ppm)*					
example 1.1	acrylic acid	manganese dibutylthiocarbamate	1	none	0	130	26	
comparative example 1.1	acrylic acid	manganese acetate	1	none	0	130	17	
example 1.2	acrylic acid	manganese dibutylthiocarbamate and hydroquinone	1 50	none	0	130	75	
comparative example 1.2	acrylic acid	manganese acetate and hydroquinone	1 50	none	0	130	24	
example 1.3	acrylic acid	manganese dibutylthiocarbamate	1	yes	0	130	71	
comparative example 1.3	acrylic acid	copper dibutylthiocarbamate	1	yes	0	130	22	

* (footnote): value (weight standard) against vinyl compound.

Table 1. 2

	vinyl compound	polymerization inhibitor				adding amount of polymerization initiator (AIBN) (ppm)*	heating temperature (°C)	polymerization initiating time (minutes)
		solid portion		joint use of molecular oxygen				
		kind	adding amount (ppm)*					
example 1.4	acrylic acid	manganese dibutylthiocarbamate and copper acetate	1 1	yes	0	130	84	
comparative example 1.4	acrylic acid	manganese acetate	1	yes	0	130	50	
example 1.5	acrylic acid	manganese acetate and copper dibutylthiocarbamate	1 1	yes	0	130	72	
comparative example 1.5	acrylic acid	hydroquinone	50	yes	0	130	5	
comparative example 1.6	acrylic acid	methoquinone	50	yes	0	130	5	
comparative example 1.7	acrylic acid	phenothiazine	5	yes	0	130	22	

* (footnote): value (weight standard) against vinyl compound.

Table 1. 3

	vinyl compound	polymerization inhibitor				adding amount of polymerization initiator (AIBN) (ppm)*	heating temperature (°C)	polymerization initiating time (minutes)
		solid portion		joint use of molecular oxygen				
		kind	adding amount (ppm)*					
example 1.6	acrylic acid	manganese dibutyl di thiocarbamate and hydroquinone	1 50	yes	0	130	200 or more	
comparative example 1.8	acrylic acid	copper dibutyl di thiocarbamate and hydroquinone	1 50	yes	0	130	50	
example 1.7	acrylic acid	manganese dibutyl di thiocarbamate, copper acetate, and hydroquinone	1 1 50	yes	0	130	200 or more	
comparative example 1.9	acrylic acid	manganese acetate and hydroquinone	1 50	yes	0	130	81	

* (footnote): value (weight standard) against vinyl compound.

Table 1.4

	vinyl compound	polymerization inhibitor				adding amount of polymerization initiator (AIBN) (ppm)*	heating temperature (°C)	polymerization initiating time (minutes)
		solid portion		joint use of molecular oxygen				
		kind	adding amount (ppm)*					
example 1.8	methacrylic acid	manganese dibutyl di thiocarbamate	1	none	0	160	35	
comparative example 1.10	methacrylic acid	manganese acetate	1	none	0	160	20	
example 1.9	methacrylic acid	manganese dibutyl di thiocarbamate and hydroquinone	1 50	none	0	160	81	
comparative example 1.11	methacrylic acid	manganese acetate and hydroquinone	1 50	none	0	160	29	

* (footnote): value (weight standard) against vinyl compound.

Table 1.5

	vinyl compound	polymerization inhibitor				adding amount of polymerization initiator (AIBN) (ppm)*	heating temperature (°C)	polymerization initiating time (minutes)
		solid portion		joint use of molecular oxygen				
		kind	adding amount (ppm)*					
example 1.10	methacrylic acid	manganese dibutyl di thiocarbamate	1	yes	0	160	85	
comparative example 1.12	methacrylic acid	copper dibutyl di thiocarbamate	1	yes	0	160	26	
comparative example 1.13	methacrylic acid	manganese acetate	1	yes	0	160	63	
comparative example 1.14	methacrylic acid	hydroquinone	50	yes	0	160	5	
comparative example 1.15	methacrylic acid	methoquinone	50	yes	0	160	5	
comparative example 1.16	methacrylic acid	copper dibutyl di thiocarbamate and phenothiazine	1 5	yes	0	160	30	

* (footnote): value (weight standard) against vinyl compound.

Table 1. 6

	vinyl compound	polymerization inhibitor				adding amount of polymerization initiator (AIBN) (ppm)*	heating temperature (°C)	polymerization initiating time (minutes)
		solid portion		joint use of molecular oxygen				
		kind	adding amount (ppm)*					
example 1.11	methacrylic acid	manganese dibutylthiocarbamate and hydroquinone	1 50	yes	0	160	200 or more	
comparative example 1.17	methacrylic acid	copper dibutylthiocarbamate and hydroquinone	1 50	yes	0	160	74	
comparative example 1.18	methacrylic acid	manganese acetate and hydroquinone	1 50	yes	0	160	102	

* (footnote): value (weight standard) against vinyl compound.

Table 1.7

	vinyl compound	polymerization inhibitor				adding amount of polymerization initiator (AIBN) (ppm)*	heating temperature (°C)	polymerization initiating time (minutes)
		solid portion		joint use of molecular oxygen				
		kind	adding amount (ppm)*					
example 1.12	methyl acrylate	manganese dibutylthiocarbamate and hydroquinone	1 10	yes	0	100	200 or more	
comparative example 1.19	methyl acrylate	hydroquinone	10	yes	0	100	80	
example 1.13	octyl acrylate	manganese dibutylthiocarbamate and hydroquinone	1 10	yes	1000	70	200 or more	
comparative example 1.20	octyl acrylate	hydroquinone	10	yes	1000	70	90	
example 1.14	methyl methacrylate	manganese dibutylthiocarbamate and hydroquinone	1 10	yes	200	80	200 or more	
comparative example 1.21	methyl methacrylate	hydroquinone	10	yes	200	80	110	

* (footnote): value (weight standard) against vinyl compound.

Table 1.8

	vinyl compound	polymerization inhibitor				adding amount of polymerization initiator (AIBN) (ppm)*	heating temperature (°C)	polymerization initiating time (minutes)
		solid portion		joint use of molecular oxygen				
		kind	adding amount (ppm)*					
example 1.15	acrylonitrile	manganese dibutyldithiocarbamate and hydroquinone	10	yes	300	70	70	
comparative example 1.22	acrylonitrile	hydroquinone	10	yes	300	70	35	
example 1.16	styrene	manganese dibutyldithiocarbamate and hydroquinone	10	yes	3000	70	200 or more	
comparative example 1.23	styrene	hydroquinone	10	yes	3000	70	65	

* (footnote): value (weight standard) against vinyl compound.

From the results of the Tables 1.1 to 1.8, the below-described 1.(a) to 1.(d) were confirmed.

1.(a) The polymerization inhibitors used in the examples including manganese dibutyldithiocarbamate, when compared with the polymerization inhibitors used in the comparative examples not including manganese dibutyldithiocarbamate, showed a high polymerization-inhibiting effect for various kinds of vinyl compounds.

1.(b) Even in the case where manganese dibutyldithiocarbamate is used alone, a sufficient polymerization-inhibiting effect is observed.

1.(c) If either one of hydroquinone or molecular oxygen is in a joint use with manganese dibutyldithiocarbamate, the polymerization-inhibiting effect further increases.

1.(d) If both of hydroquinone and molecular oxygen are in a joint use with manganese dibutyldithiocarbamate, the polymerization-inhibiting effect becomes the best.

Example 1.17

A continuous operation of an azeotropic separation of an aqueous acrylic acid solution was carried out, using a distillation column of a inner diameter 105 mm which was interiorly furnished with a stainless steel-made sieve tray having 50 steps at a step interval of 147 mm and equipped with a distillate tube at the upper part and a material supplying tube at the central part.

The polymerization-inhibiting ingredients used were manganese dibutyldithiocarbamate, hydroquinone, and molecular oxygen. Dibutyldithiocarbamate and hydroquinone were both introduced into the column from both positions of the feed step and the column top. Introduction from the feed step was carried out in form of adding followed by dissolving a defined amount into the undermentioned supplying material and, that from the column top was in form of adding followed by dissolving a defined amount into the undermentioned refluxing solution. A defined amount of molecular oxygen was supplied to a bottom part of the column. The each amount of polymerization inhibitors was 20 ppm of manganese dibutyldithiocarbamate and 200 ppm of hydroquinone against a boiling up amount of acrylic acid. Also, the poured oxygen amount was 0.3 % by volume against a boiling up amount of acrylic acid.

The polymerization-inhibiting effect is confirmed by a pressure drop of the column inside, by flooding or by inspecting the column taken apart to pieces.

An acrylic acid containing 30 % by weight of water and 2.5 % by weight of acetic acid, which was obtained from a catalytic gas phase oxidation reaction of propylene, was used as a supplying material and methyl isobutyl ketone was used as a refluxing liquid, and distillation was carried out under the conditions of temperature at the column top 46 °C, temperature at the column bottom 97 °C, pressure at the column top 112 mmHg, amount of a supplying solution 10.56 litre/hr, and refluxing ratio (R/D) = 0.92 (mole standard).

The liquid composition taken off from the column bottom under a stationary state was 97.0 % by weight of acrylic acid, 0.5 % by weight of acetic acid, and 2.5 % by weight of others. The refluxing solution was used by recycling the distilled oil phase.

In operating for 14 days under these conditions, a stable state was always obtained and, after the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at the end of operation, and the mdd value was zero. Here, the mdd value means a decreasing weight amount of a test piece and it is an indication for the presence or absence of corrosion of a device. Its unit is mg/(dm²*day) and, according to its magnitude, the corrosion is evaluated by the following ①, ②, and ③ standards (the mdd values in the examples and comparative examples given below are the same).

① mdd < 1 : more than sufficient fitness for use

② 1 ≤ mdd < 5 : fitness for use

③ mdd ≥ 5 : somewhat difficult for use

Example 1.18

A continuous operation of an azeotropic separation of an aqueous methacrylic acid solution was carried out, using a distillation column of a inner diameter 105 mm which was interiorly furnished with a stainless steel-made sieve tray having 50 steps at a step interval of 147 mm and equipped with a distillate tube at the upper part and a material supplying tube at the central part.

The polymerization-inhibiting ingredients used were manganese dimethyldithiocarbamate, hydroquinone, and molecular oxygen. Manganese dimethyldithiocarbamate and hydroquinone were both introduced into the column from both positions of the feed step and the column top. Introduction from the feed step was carried out in form of adding followed by dissolving a defined amount into the undermentioned supplying material and that from the column top was in form of adding followed by dissolving a defined amount into the undermentioned refluxing solution. A definite amount of molecular oxygen was supplied to a bottom part of the column. Each amount of used polymerization-inhibiting ingredients was 20

ppm of manganese dimethyldithiocarbamate and 200 ppm of hydroquinone against a boiling up amount of methacrylic acid. Also, the poured oxygen amount was 0.3 % by volume against a boiling up amount of methacrylic acid.

The polymerization-inhibiting effect is confirmed by a pressure drop of the column inside, by flooding, or by inspecting the column taken apart to pieces.

An aqueous methacrylic acid solution obtained from a catalytic gas phase oxidation reaction of isobutylene, which contains 37 % by weight of methacrylic acid, 9.05 % by weight of acetic acid, and 50 % by weight of water, was subjected to an extracting operation by n-heptane with an extraction ratio of 1.3. The thus-obtained n-heptane phase containing 76.4 % by weight of n-heptane, 21.8 % by weight of methacrylic acid, and 1.3 % by weight of acetic acid was used as a supplying material and distilled n-heptane was used as a refluxing solution. Distillation was carried out under the conditions of temperature at the column top 42 °C, temperature at the column bottom 122 °C, pressure at the column top 105 mmHg, and refluxing ratio = 1.0 (weight standard).

The liquid composition taken off from the column bottom under a stationary state was 99.7 % by weight of methacrylic acid.

In continuously operating for 14 days under these conditions, a stable state was always obtained and, after the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at an end of the operation and, the mdd value was zero.

Example 1.19

The procedure of example 1.17 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that manganese diethyldithiocarbamate was used as manganese dithiocarbamate instead of manganese dibutyldithiocarbamate.

In continuously operating for about 14 days, a stable condition was always obtained and, after the operation was stopped, the results obtained by inspecting an inside of the distillation column did not show any occurrence of polymerization products.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at an end of the operation and, the mdd value was zero.

Example 1.20

The procedure of example 1.17 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that manganese diphenyldithiocarbamate was used as manganese dithiocarbamate instead of manganese dibutyldithiocarbamate.

In continuously operating for about 14 days, a stable condition was always obtained and, after the operation was stopped, the results obtained by inspecting an inside of the distillation column did not show any occurrence of polymerization products.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not at all recognized at an end of the operation and, the mdd value was zero.

Example 1.21

The procedure of example 1.17 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that copper dibutyldithiocarbamate, in an amount of 10 ppm against a boiling up amount of acrylic acid, was added as the polymerization-inhibiting ingredients as well.

In continuously operating for about 14 days, a stable condition was always obtained and, after the operation was stopped, the results obtained by inspecting an inside of the distillation column did not show any occurrence of polymerization products.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not at all recognized at an end of the operation and, the mdd value was zero.

Example 1.22

Using an evaporating vessel of an inside diameter 105 mm, a continuous operation was carried out to distill an acrylic acid solution.

The polymerization-inhibiting ingredients used were manganese dibutyldithiocarbamate, methoquinone, and molecular oxygen. Manganese dibutyldithiocarbamate and methoquinone were both introduced into the column from both positions of the feed and the condenser. Introduction was carried out in form of adding followed by dissolving a defined amount into the undermentioned supplying material. An definite amount of molecular oxygen was supplied to a bottom part of the column. The amounts of manganese dibutyldithiocarbamate and methoquinone used as polymerization inhibitors were respectively 12 ppm and 120 ppm against a boiling up amount of acrylic acid. Also, the poured oxygen amount was 0.3 % by volume against a boiling up amount of acrylic acid.

The polymerization-inhibiting effect is confirmed by a pressure drop of the column inside or by inspecting the column taken apart to pieces.

A crude acrylic acid of purity 99.0 % by weight containing 500 ppm of hydrazine was used as a supplying material and it was distilled under the conditions of temperature at the column top 63 °C and operating pressure 35 mmHg.

The distillate composition under a stationary condition was 99.9 % by weight of acrylic acid.

In continuously operating for about 14 days, a stable condition was always obtained and, after the operation was stopped, the results obtained by inspecting an inside of the distillation column did not show any occurrence of polymerization products.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at all after an end of the operation and, the mdd value was zero.

Comparative example 1.24

The procedure of example 1.17 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that copper dibutyldithiocarbamate instead of manganese dibutyldithiocarbamate was used in 20 ppm against a boiling up amount of acrylic acid.

After continuously operating for about 14 days, the results obtained by inspecting an inside of the distillation column slightly showed occurrence of a popcorn polymer. Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was recognized after an end of the operation, and the test piece showed the mdd value of 5.0.

From these results, when copper dithiocarbamate is used instead of manganese dithiocarbamate, decrease of the polymerization-inhibiting effect is seen and corrosion of the device takes place.

Comparative example 1.25

The procedure of example 1.17 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that manganese acetate instead of manganese dibutyldithiocarbamate was used in 20 ppm against a boiling up amount of acrylic acid.

As a result, pressure drop of the column inside was recognized after 2 days from initiation of operation, and continuation of the operation became difficult. Thus, the operation was stopped and, for inspection, the column was taken apart to pieces and thereby, formation of a sticky polymer was found in the column.

From the result, if a manganese salt other than manganese dithiocarbamate is used, decrease of the polymerization-inhibiting effect was confirmed in distillation.

COMPARATIVE EXAMPLE 2.1a

An acrylic acid solution was prepared by adding tetrabutylthiuram disulfide (hereinafter, abbreviated to TBDS) as a polymerization inhibitor in a proportion of 2 ppm to purified acrylic acid. The acrylic acid solution, 5 ml, was taken into a 20 ml test tube to dissolve oxygen in the acrylic acid solution by bubbling air for 1 minute with a stream amount of 30 ml/minute, and then, the test tube was sealed. This test tube was immersed in an oil bath maintained at 130 °C and a polymerization-initiating time of acrylic acid was measured. But this time is a time of from immersing a test tube in an oil bath until getting turbidity in the solution sealed in the test tube. Results are shown in the following Table 2.1

Comparative examples 2.1b and 2.2

The polymerization-initiating time of acrylic acid was measured in a way similar to the comparative example 2.1a except that 50 ppm of hydroquinone or methoquinone was added as a polymerization inhibitor instead of TBTDS. Results obtained are shown in the following Table 2.1

Example 2.1

The polymerization-initiating time of acrylic acid was measured in a way similar to the comparative example 2.1a except that 2 ppm of TBTDS and 1 ppm of manganese acetate were added as polymerization inhibitors. Results obtained are shown in the following Table 2.1

Example 2.2

The polymerization-initiating time of acrylic acid was measured in a way similar to the comparative example 2.1a except that 2 ppm of TBTDS, 1 ppm of manganese acetate, and 50 ppm of hydroquinone were added as polymerization inhibitors. Results obtained are shown in the following Table 2.1

Comparative examples 2.3 and 2.4

The polymerization-initiating time of acrylic acid was measured in a way similar to the example 2.1 or 2.2 except that TBTDS was not at all added as a polymerization inhibitor. Results obtained are shown in the following Table 2.1

Comparative example 2.5

The polymerization-initiating time of acrylic acid was measured in a way similar to the comparative example 2.1a except that 1 ppm of copper dibutyldithiocarbamate and 50 ppm of hydroquinone were added as polymerization inhibitors instead of TBTDS. Results obtained are shown in the following Table 2.1

Example 2.3

The polymerization-initiating time of acrylic acid was measured in a way similar to the comparative example 2.1a except that 2 ppm of TBTDS and 1 ppm of manganese acetate were added as polymerization inhibitors and that bubbling of a nitrogen gas instead of air was carried out to remove oxygen in the acrylic acid solution. Results obtained are shown in the following Table 2.2

Example 2.4

The polymerization-initiating time of acrylic acid was measured in a way similar to the comparative example 2.1a except that 2 ppm of TBTDS, 1 ppm of manganese acetate, and 50 ppm of hydroquinone were added as polymerization inhibitors and that bubbling of a nitrogen gas instead of air was carried out to remove oxygen in the acrylic acid solution. Results obtained are shown in the following Table 2.2

Comparative examples 2.6 and 2.7

The polymerization-initiating time of acrylic acid was measured in a way similar to the example 2.3 or 2.4 except that TBTDS was not at all added as a polymerization inhibitor. Results obtained are shown in the following Table 2.2.

Table 2.1

	polymerization inhibitor		oxygen in acrylic acid solution	heating temperature (°C)	polymerization initiating time (minutes)
	kind	adding amount (ppm)*			
comparative example 2.1a	TBDS	2	yes	130	17
comparative example 2.1b	hydroquinone	50	yes	130	5
comparative example 2.2	methoquinone	50	yes	130	5
example 2.1	TBDS and manganese acetate	2 1	yes	130	70
example 2.2	TBDS, manganese acetate, and hydroquinone	2 1 50	yes	130	200 or more
comparative example 2.3	manganese acetate	1	yes	130	50
comparative example 2.4	manganese acetate and hydroquinone	1 50	yes	130	81
comparative example 2.5	copper dibutylthiocarbamate and hydroquinone	1 50	yes	130	50

* (footnote): value (weight standard) against acrylic acid.

Table 2.2

	polymerization inhibitor		oxygen in acrylic acid solution	heating temperature (°C)	polymerization initiating time (minutes)
	kind	adding amount (ppm)*			
example 2.3	TBDS and manganese acetate	2 1	none	130	27
example 2.4	TBDS, manganese acetate, and hydroquinone	2 1 50	none	130	72
comparative example 2.6	manganese acetate	1	none	130	17
comparative example 2.7	manganese acetate and hydroquinone	1 50	none	130	24

* (footnote): value (weight standard) against acrylic acid.

Examples 2.5 to 2.8 and comparative examples 2.8a to 2.14

The procedure of comparative example 2.1a was repeated except that methacrylic acid was used instead of acrylic acid, the heating temperature was changed to 160 °C, and the kind and adding amount of polymerization-inhibitors and the kind of a bubbling gas into the acid solution were varied as shown in the following Tables 2.3 and 2.4, whereby the polymerization-initiating time of methacrylic acid was measured and the results are shown in the Tables 2.3 and 2.4.

Table 2.3

	polymerization inhibitor		oxygen in methacrylic acid solution	heating temperature (°C)	polymerization initiating time (minutes)
	kind	adding amount (ppm)*			
comparative example 2.8a	TBDS	2	yes	160	22
comparative example 2.8b	hydroquinone	50	yes	160	5
comparative example 2.9	methoquinone	50	yes	160	5
example 2.5	TBDS and manganese acetate	2 1	yes	160	83
example 2.6	TBDS, manganese acetate, and hydroquinone	2 1 50	yes	160	200 or more
comparative example 2.10	manganese acetate	1	yes	160	63
comparative example 2.11	manganese acetate and hydroquinone	1 50	yes	160	102
comparative example 2.12	copper dibutylthiocarbamate and hydroquinone	1 50	yes	160	50

* (footnote): value (weight standard) against methacrylic acid.

Table 2.4

	polymerization inhibitor		oxygen in methacrylic acid solution	heating temperature (°C)	polymerization initiating time (minutes)
	kind	adding amount (ppm)*			
example 2.7	TBDS and manganese acetate	2 1	none	160	37
example 2.8	TBDS, manganese acetate, and hydroquinone	2 1 50	none	160	80
comparative example 2.13	manganese acetate	1	none	160	20
comparative example 2.14	manganese acetate and hydroquinone	1 50	none	160	29

* (footnote): value (weight standard) against methacrylic acid.

Examples 2.9 to 2.13 and comparative examples 2.15 to 2.19

The procedure of comparative example 2.1a was repeated except that the kind of vinyl compounds, the kind and adding amount of polymerization-inhibitors, the kind of a bubbling gas into the vinyl compound solution, and the heating temperature, were varied as shown in the following Tables 2.5 and 2.6, whereby the polymerization-initiating time of vinyl compounds was measured. But, in the examples 2.11 to 2.13 and comparative examples 2.17 to 2.19, a polymerization initiator (azoisobutyronitrile; abbreviated to AIBN in the Tables 2.5 and 2.6) was added in amounts as shown in the Tables 2.5 and 2.6 besides of the polymerization-inhibitors.

The results obtained are shown in the Tables 2.5 and 2.6.

Table 2.5

	vinyl compound	polymerization inhibitor		adding amount of ALBN (ppm)*	oxygen in vinyl compound solution	heating temperature (°C)	polymerization initiating time (minutes)
		kind	adding amount (ppm)*				
example 2.9	methyl acrylate	TBDS and hydroquinone	2 10	none	yes	100	133
comparative example 2.15	methyl acrylate	hydroquinone	10	none	yes	100	80
example 2.10	octyl acrylate	TBDS and hydroquinone	2 10	none	yes	70	149
comparative example 2.16	octyl acrylate	hydroquinone	10	none	yes	70	90
example 2.11	methyl methacrylate	TBDS and hydroquinone	2 10	200	yes	80	160
comparative example 2.17	methyl methacrylate	hydroquinone	10	200	yes	80	110

* (footnote): value (weight standard) against vinyl compound.

Table 2. 6

	vinyl compound	polymerization inhibitor		adding amount of AIBN (ppm)*	oxygen in vinyl compound solution	heating temperature (°C)	polymerization initiating time (minutes)
		kind	adding amount (ppm)*				
example 2.12	acrylonitrile	TBDS and hydroquinone	2 10	300	yes	70	52
comparative example 2.18	acrylonitrile	hydroquinone	10	300	yes	70	35
example 2.13	styrene	TBDS and hydroquinone	2 10	3000	yes	70	97
comparative example 2.19	styrene	hydroquinone	10	3000	yes	70	65

* (footnote): value (weight standard) against vinyl compound.

Example 2.14

A continuous operation of an azeotropic separation of an aqueous acrylic acid solution was carried out, using a distillation column of a inner diameter 105 mm which was interiorly furnished with a stainless steel-made sieve tray having 50 steps at a step interval of 147 mm and equipped with a distillate tube at the

upper part and a material supplying column at the central part, and also, using TBTDS, acetate manganese, and hydroquinone as polymerization inhibitors.

An aqueous acrylic acid solution containing 66.5 % by weight of acrylic acid, 30 % by weight of water and 2.5 % by weight of acetic acid, which was obtained from a catalytic gas phase oxidation reaction of propylene, was supplied to the central step of the distillation column. Methyl isobutyl ketone was used as an azeotropic solvent. An distillate liquid was separated into an oil phase and a water phase, and the water phase was taken off and the oil phase was used as a refluxing liquid. Distillation was carried out under the conditions of temperature at the column top 46 °C, temperature at the column bottom 97 °C, pressure at the column top 112 mmHg, amount of a supplying solution 10.56 litre/hr, and refluxing ratio (R/D) = 0.92 (mole standard). During the distillation, acetate manganese, TBTDS and hydroquinone were introduced from the column top into the column, in form of adding and dissolving the acetate manganese into the distilled water phase, and adding and dissolving the TBTDS and hydroquinone into the refluxing liquid. Also, molecular oxygen was supplied to a bottom part of the column. The each amount of polymerization inhibitors was 18 ppm of TBTDS, 11 ppm of manganese acetate, and 200 ppm of hydroquinone against a boiling up amount of acrylic acid. Also, the poured oxygen amount was 0.3 % by volume against a boiling up amount of acrylic acid. The liquid composition taken off from the column bottom under a stationary state was 97.0 % by weight of acrylic acid, 0.5 % by weight of acetic acid, and 2.5 % by weight of others.

In operating for 14 days under these conditions, a stable state was always obtained without matters of a pressure drop of the column inside, flooding, etc. After the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, in this experiment, in order to examine corrosion of the device materials, a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.) was beforehand arranged in the column inside. When the test piece was taken out at the end of operation, its corrosion was not recognized at all, and the mdd value was zero.

Example 2.15

A continuous operation for distillation of methacrylic acid was carried out, using a distillation column of an inner diameter 105 mm which was interiorly furnished with a stainless steel-made sieve tray having 50 steps at a step interval of 147 mm and equipped with a distillate tube at the upper part and a material supplying tube at the central part, and also, using TBTDS, acetate manganese, and hydroquinone as polymerization inhibitors.

An aqueous methacrylic acid solution obtained by collecting gas products in a catalytic gas phase oxidation reaction of isobutylene was subjected to an extracting operation by n-heptane. The thus-obtained n-heptane phase containing 76.4 % by weight of n-heptane, 21.8 % by weight of methacrylic acid, and 1.3 % by weight of acetic acid was used as a material supplied to the distillation column. This material was supplied from the material supplying tube to the central step of the distillation column, and distillation was carried out under the conditions of temperature at the column top 42 °C, temperature at the column bottom 122 °C, pressure at the column top 105 mmHg, and refluxing ratio = 1.0 (weight standard). During the distillation, acetate manganese, TBTDS and hydroquinone were introduced from the column top into the column, in form of adding and dissolving the acetate manganese into water, and adding and dissolving the TBTDS and hydroquinone into the refluxing liquid. Also, molecular oxygen was supplied to a bottom part of the column. The each amount of polymerization inhibitors was 18 ppm of TBTDS, 11 ppm of manganese acetate, and 200 ppm of hydroquinone against a boiling up amount of methacrylic acid. Also, the poured oxygen amount was 0.3 % by volume against a boiling up amount of methacrylic acid. The liquid composition taken off from the column bottom under a stationary state was 99.7 % by weight of methacrylic acid.

In operating for 14 days under these conditions, a stable state was always obtained without matters of a pressure drop of the column inside, flooding, etc. After the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, in this experiment, in order to examine corrosion of the device materials, a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.) was beforehand arranged in the column inside. When the test piece was taken out at the end of operation, its corrosion was not recognized at all, and the mdd value was zero.

Example 2.16

A continuous operation was carried out to distill an acrylic acid solution, using an evaporating vessel of an inside diameter 105 mm and as polymerization inhibitors, TBTDS, manganese acetate, and methoquinone.

A crude acrylic acid of purity 99.0 % by weight containing 500 ppm of hydrazine was used as a supplying material and it was distilled under the conditions of temperature at the column top 63 °C and operating pressure 35 mmHg. During the distillation, TBTDS, acetate manganese, and methoquinone in the amounts respectively corresponding to 11 ppm, 7 ppm, and 120 ppm against a boiling up amount of acrylic acid were supplied to the distillation column together with the supplying material, in form of adding and dissolving these TBTDS, acetate manganese, and methoquinone into the supplying material. Also, molecular oxygen was supplied to a bottom part of the column in the amount corresponding to 0.3 % by volume against a boiling up amount of acrylic acid. The liquid composition taken off from the column bottom under a stationary state was 99.9 % by weight of acrylic acid.

In operating for 14 days under these conditions, a stable state was always obtained without matters of a pressure drop of the column inside, flooding, etc. After the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, corrosion of a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.) beforehand arranged in the column inside was not at all recognized at the end of operation, and the mdd value was zero.

Example 2.17

The procedure of example 2.14 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that copper acetate instead of manganese acetate was used.

In operating for about 14 days under these conditions, a stable state was always obtained without matters of a pressure drop of the column inside, flooding, etc. But, when a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.) beforehand arranged in the column inside was examined, it showed the mdd value of 5.0. From the results, it was confirmed that corrosion of the device becomes slightly large by joint use of TBTDS and copper acetate, compared with joint use of TBTDS and manganese acetate.

From the results seen above, the following findings, 2.(a) to 2.(d), were confirmed.

2.(a) If a manganese salt or a copper salt is jointly used in addition to the thiuram compound represented by the general formula (1) of the present invention, the polymerization-inhibiting effect increases.

2.(b) If hydroquinone and/or methoquinone are jointly used in addition to the above 2.(a) composition, the polymerization-inhibiting effect further increases.

2.(c) In the example in which the thiuram compound represented by the general formula (1) of the present invention was used, compared with the comparative example in which hydroquinone or the like was used instead of the thiuram compound, the polymerization-inhibiting effect on the vinyl compounds is high.

2.(d) In a case where the thiuram compound represented by the general formula (1) of the present invention is jointly used with a manganese salt, fewer corrosion of a device is found in addition to a superior polymerization-inhibiting effect, and a continuous operation in a long period of time of a device for producing vinyl compounds becomes possible.

Example 3.1

A continuous operation of an azeotropic separation of an aqueous acrylic acid solution was carried out, using a distillation column of a inner diameter 105 mm which was interiorly furnished with a stainless steel-made sieve tray having 50 steps at a step interval of 147 mm and equipped with a distillate tube at the upper part and a material supplying tube at the central part.

The polymerization inhibitors used were manganese acetate, copper dibutyldithiocarbamate, hydroquinone, and molecular oxygen. Copper dibutyldithiocarbamate was introduced into the column from the top in form of adding followed by dissolving the defined amount into the undermentioned refluxing solution. Manganese acetate was introduced into the column from both positions of the feed step and the column top, its introduction from the feed step being carried out in form of adding followed by dissolving the defined amount into the undermentioned supplying material and, that from the column top being in form of adding followed by dissolving the defined amount into water. Hydroquinone was introduced into the column from both positions of the feed step and the column top, its introduction from the feed step being

carried out in form of adding followed by dissolving the defined amount into the undermentioned supplying material and, that from the column top being in form of adding followed by dissolving the defined amount into the undermentioned refluxing solution. A defined amount of molecular oxygen was supplied to a bottom part of the column. The each amount of polymerization inhibitors was 30 ppm of manganese acetate, 20 ppm of copper dibutyldithiocarbamate and 200 ppm of hydroquinone against a boiling up amount of acrylic acid. Also, the weight ratio of manganese atom to copper atom (Mn/Cu) in this case was 3.5. Also, the poured oxygen amount was 0.3 % by volume against a boiling up amount of acrylic acid.

The polymerization-inhibiting effect is confirmed by a pressure drop of the column inside, by flooding or by inspecting the column taken apart to pieces.

An acrylic acid containing 30 % by weight of water and 2.5 % by weight of acetic acid, which was obtained from a catalytic gas phase oxidation reaction of propylene, was used as a supplying material and methyl isobutyl ketone was used as a refluxing liquid, and distillation was carried out under the conditions of temperature at the column top 46 °C, temperature at the column bottom 97 °C, pressure at the column top 112 mmHg, amount of a supplying solution 10.56 litre/hr, and refluxing ratio (R/D) = 0.92 (mole standard).

The liquid composition taken off from the column bottom under a stationary state was 97.0 % by weight of acrylic acid, 0.5 % by weight of acetic acid, and 2.5 % by weight of others. The refluxing solution was used by recycling the distilled oil phase.

The distillation percent of acetic acid is 85.2 % under the forementioned stationary conditions, and the present distillation experiment had a condition which separates acetic acid together with water from an acrylic acid containing 30 % by weight of water and 2.5 % by weight of acetic acid.

In continuously operating for about 14 days under these conditions, a stable state was always obtained and, after the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at the end of operation, and the mdd value was zero.

Example 3.2

A continuous distillation operation was carried out in a way similar to the example 3.1 except that acrylic acid was changed to methacrylic acid. But an aqueous methacrylic acid solution obtained from a catalytic gas phase oxidation reaction of isobutylene, which contains 37 % by weight of methacrylic acid, 9.07 % by weight of acetic acid, and 50 % by weight of water, was subjected to an extracting operation by n-heptane with an extraction ratio of 1.3. The thus-obtained n-heptane phase containing 76.4 % by weight of n-heptane, 21.8 % by weight of methacrylic acid, and 1.3 % by weight of acetic acid was used as a supplying material. Distillation was carried out under the conditions of temperature at the column top 42 °C, temperature at the column bottom 122 °C, pressure at the column top 105 mmHg, and refluxing ratio = 1.0 (weight standard).

In continuously operating for about 14 days under these conditions, a stable state was always obtained and, after the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at the end of operation, and the mdd value was zero.

Example 3.3

A continuous distillation operation was carried out in a way similar to the example 3.1 except that manganese octanate instead of manganese acetate was used as a manganese salt. But the use amount of manganese octanate was 60 ppm against a boiling up amount of acrylic acid. Also, the weight ratio of manganese atom to copper atom (Mn/Cu) in this case was 3.5.

In continuously operating for about 14 days under these conditions, a stable state was always obtained and, after the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at the end of operation, and the mdd value was zero.

Example 3.4

A continuous distillation operation was carried out in a way similar to the example 3.1 except that potassium permanganate instead of manganese acetate was used as a manganese salt. But the use amount of potassium permanganate was 30 ppm against a boiling up amount of acrylic acid. Also, the weight ratio of manganese atom to copper atom (Mn/Cu) in this case was 3.8.

In continuously operating for about 14 days under these conditions, a stable state was always obtained and, after the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at the end of operation, and the mdd value was zero.

Example 3.5

A continuous distillation operation was carried out in a way similar to the example 3.1 except that copper dimethyldithiocarbamate instead of copper di butyldithiocarbamate was used as a copper dithiocarbamate. But the use amount of copper dimethyldithiocarbamate was 20 ppm against a boiling up amount of acrylic acid. Also, the weight ratio of manganese atom to copper atom (Mn/Cu) in this case was 3.2.

In continuously operating for about 14 days under these conditions, a stable state was always obtained and, after the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at the end of operation, and the mdd value was zero.

Example 3.6

A continuous distillation operation was carried out in a way similar to the example 3.1 except that methoquinone was used instead of hydroquinone. But the use amount of methoquinone was 200 ppm against a boiling up amount of acrylic acid.

In continuously operating for about 14 days under these conditions, a stable state was always obtained and, after the operation was stopped, the results obtained from inspecting an inside of the distillation column did not show any occurrence of polymerization.

Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was not recognized at the end of operation, and the mdd value was zero.

COMPARATIVE EXAMPLE 3.1

The procedure of example 3.1 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that the use amount of manganese acetate only was increased to 100 ppm and that the weight ratio between manganese atom and copper atom (Mn/Cu) was 12. As a result, after 5 days from initiation of operation, pressure drop of the column inside was very slightly recognized. From the result, if the weight ratio between manganese atom and copper atom (Mn/Cu) is too high (ie exceeds 10) decrease of the polymerization-inhibiting effect was confirmed.

COMPARATIVE EXAMPLE 3.2

The procedure of example 3.1 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that manganese acetate was not at all used. After continuously operating for about 14 days, the results obtained by inspecting an inside of the distillation column slightly showed occurrence of a popcorn polymer. Also, corrosion in a SUS 316 test piece (made by Nippon Yakin Kogyo Co., Ltd.), which was beforehand arranged in the column inside, was recognized, and the test piece showed the mdd value of 5.0.

From these results, when a copper dithiocarbamate, a phenol compound, and molecular oxygen are only used without a manganese salt, decrease of the polymerization-inhibiting effect is seen and corrosion of the device takes place.

Comparative example 3.3

The procedure of example 3.1 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that copper dibutyldithiocarbamate was not used. As a result, pressure drop of the column inside was recognized after 2 days from initiation of operation, and continuation of the operation became difficult. Thus, the operation was stopped and, for inspection, the column was taken apart to pieces and thereby, formation of a sticky polymer was found in the column. From the result, if a manganese salt other than a manganese dithiocarbamate, a phenol compound, and molecular oxygen are only used without use of a copper dithiocarbamate, decrease of the polymerization-inhibiting effect was confirmed in distillation.

Claims

1. A polymerization inhibitor for a vinyl compound, which comprises, as an effective component, at least one kind of manganese dithiocarbamate having a nitrogen atom bonded with two hydrocarbon groups of an identical kind or of different kinds to each other, said hydrocarbon groups each being selected from the group consisting of a methyl, an ethyl, a propyl, a butyl, and a phenyl group, wherein said propyl or butyl group may be either a straight chain type or a branched type.
2. A method of inhibiting polymerization of a vinyl compound, which method comprises use of a polymerization inhibitor as claimed in Claim 1.
3. The method as claimed in Claim 2, which method further comprises the use of at least one kind of polymerization inhibitor selected from the group consisting of a manganese salt other than a manganese dithiocarbamate, a copper salt and a benzene derivative.
4. A method of inhibiting polymerisation of a vinyl compound, which method comprises the joint use of a copper dithiocarbamate and a manganese salt as polymerization inhibitors, wherein the weight ratio of manganese to copper (Mn/Cu) is in the range of from 1 to 10.
5. The method as claimed in Claim 4, which further comprises the use of a benzene derivative as a polymerization inhibitor.
6. The method as claimed in any one of Claims 2 to 5, wherein the vinyl compound is selected from the group consisting of acrylic acid, methacrylic acid, an acrylic acid ester, a methacrylic acid ester and acrylonitrile.

Patentansprüche

1. Polymerisationsinhibitor für eine Vinylverbindung, die als eine wirksame Komponente wenigstens eine Sorte eines Mangan-Dithiocarbamats mit einem Stickstoffatom enthält, das mit zwei Kohlenwasserstoffgruppen einer identischen Sorte oder zueinander unterschiedlicher Sorten gebunden ist, wobei die Kohlenwasserstoffgruppen jeweils ausgewählt sind aus der Gruppe, bestehend aus einer Methyl-, einer Ethyl-, einer Propyl-, einer Butyl- und einer Phenylgruppe, wobei die Propyl- oder die Butylgruppe entweder ein gerader Kettentyp oder ein verzweigter Typ sein kann.
2. Verfahren zum Verhindern der Polymerisation einer Vinylverbindung, wobei das Verfahren aus der Verwendung eines Polymerisations-Inhibitors gemäß dem Anspruch 1 umfaßt.
3. Verfahren nach Anspruch 2, wobei das Verfahren weiterhin die Verwendung von wenigstens einer Sorte eines Polymerisations-Inhibitors umfaßt, ausgewählt aus der Gruppe, bestehend aus einem Mangansalz anders als ein Mangan-Dithiocarbamat, einem Kupfersalz und einem Benzolderivat.
4. Verfahren zur Verhinderung der Polymerisation einer Vinylverbindung, wobei das Verfahren die gemeinsame Verwendung eines Kupfer-Dithiocarbamats und eines Mangansalzes als Polymerisation-Inhibitoren umfaßt, wobei das Gewichtsverhältnis von Mangan zu Kupfer (Mn/Cu) in dem Bereich von 1 bis 10 liegt.

Comparative example 3.3

The procedure of example 3.1 was repeated with the same device and conditions to carry out distillation of the aqueous acrylic acid solution, except that copper dibutyldithiocarbamate was not used. As a result, pressure drop of the column inside was recognized after 2 days from initiation of operation, and continuation of the operation became difficult. Thus, the operation was stopped and, for inspection, the column was taken apart to pieces and thereby, formation of a sticky polymer was found in the column. From the result, if a manganese salt other than a manganese dithiocarbamate, a phenol compound, and molecular oxygen are only used without use of a copper dithiocarbamate, decrease of the polymerization-inhibiting effect was confirmed in distillation.

Claims

1. A polymerization inhibitor for a vinyl compound, which comprises, as an effective component, at least one kind of manganese dithiocarbamate having a nitrogen atom bonded with two hydrocarbon groups of an identical kind or of different kinds to each other, said hydrocarbon groups each being selected from the group consisting of a methyl, an ethyl, a propyl, a butyl, and a phenyl group, wherein said propyl or butyl group may be either a straight chain type or a branched type.
2. A method of inhibiting polymerization of a vinyl compound, which method comprises use of a polymerization inhibitor as claimed in Claim 1.
3. The method as claimed in Claim 2, which method further comprises the use of at least one kind of polymerization inhibitor selected from the group consisting of a manganese salt other than a manganese dithiocarbamate, a copper salt and a benzene derivative.
4. A method of inhibiting polymerisation of a vinyl compound, which method comprises the joint use of a copper dithiocarbamate and a manganese salt as polymerization inhibitors, wherein the weight ratio of manganese to copper (Mn/Cu) is in the range of from 1 to 10.
5. The method as claimed in Claim 4, which further comprises the use of a benzene derivative as a polymerization inhibitor.
6. The method as claimed in any one of Claims 2 to 5, wherein the vinyl compound is selected from the group consisting of acrylic acid, methacrylic acid, an acrylic acid ester, a methacrylic acid ester and acrylonitrile.

Patentansprüche

1. Polymerisationsinhibitor für eine Vinylverbindung, die als eine wirksame Komponente wenigstens eine Sorte eines Mangan-Dithiocarbamats mit einem Stickstoffatom enthält, das mit zwei Kohlenwasserstoffgruppen einer identischen Sorte oder zueinander unterschiedlicher Sorten gebunden ist, wobei die Kohlenwasserstoffgruppen jeweils ausgewählt sind aus der Gruppe, bestehend aus einer Methyl-, einer Ethyl-, einer Propyl-, einer Butyl- und einer Phenylgruppe, wobei die Propyl- oder die Butylgruppe entweder ein gerader Kettentyp oder ein verzweigter Typ sein kann.
2. Verfahren zum Verhindern der Polymerisation einer Vinylverbindung, wobei das Verfahren aus der Verwendung eines Polymerisations-Inhibitors gemäß dem Anspruch 1 umfaßt.
3. Verfahren nach Anspruch 2, wobei das Verfahren weiterhin die Verwendung von wenigstens einer Sorte eines Polymerisations-Inhibitors umfaßt, ausgewählt aus der Gruppe, bestehend aus einem Mangansalz anders als ein Mangan-Dithiocarbamat, einem Kupfersalz und einem Benzolderivat.
4. Verfahren zur Verhinderung der Polymerisation einer Vinylverbindung, wobei das Verfahren die gemeinsame Verwendung eines Kupfer-Dithiocarbamats und eines Mangansalzes als Polymerisation-Inhibitoren umfaßt, wobei das Gewichtsverhältnis von Mangan zu Kupfer (Mn/Cu) in dem Bereich von 1 bis 10 liegt.



5. Verfahren nach Anspruch 4, welches weiterhin die Verwendung eines Benzolderivats als ein Polymerisation-Inhibitor umfaßt.
6. Verfahren nach einem der Ansprüche 2 bis 5, bei welchem die Vinylverbindung ausgewählt ist aus der Gruppe, bestehend aus Acrylsäure, Methacrylsäure, einem Acrylsäureester, einem Methacrylsäureester und einem Acrylonitril.

Revendications

1. Inhibiteur de polymérisation d'un composé vinylique, qui comprend comme matière active au moins un type de dithiocarbamate de manganèse ayant un atome d'azote lié à deux groupes hydrocarbonés de nature identique ou de natures différentes, lesdits groupes hydrocarbonés étant chacun choisis parmi l'ensemble comprenant les groupes méthyle, éthyle, propyle, butyle et phényle, lesdits groupes propyle ou butyle pouvant être du type à chaîne droite ou du type ramifié.
2. Procédé pour inhiber la polymérisation d'un composé vinylique, lequel procédé consiste à utiliser un inhibiteur de polymérisation selon la revendication 1.
3. Procédé selon la revendication 2, lequel procédé consiste en outre à utiliser au moins un type d'inhibiteur de polymérisation choisi parmi l'ensemble comprenant les sels de manganèse autres que le dithiocarbamate de manganèse, les sels de cuivre et les dérivés du benzène.
4. Procédé pour inhiber la polymérisation d'un composé vinylique, lequel procédé consiste à utiliser simultanément un dithiocarbamate de cuivre et un sel de manganèse comme inhibiteurs de polymérisation, où le rapport pondéral du manganèse au cuivre (Mn/Cu) est compris dans l'intervalle de 1 à 10.
5. Procédé selon la revendication 4, qui consiste en outre à utiliser un dérivé du benzène comme inhibiteur de polymérisation.
6. Procédé selon l'une quelconque des revendications 2 à 5, dans lequel le composé vinylique est choisi parmi l'ensemble comprenant l'acide acrylique, l'acide méthacrylique, les acrylates, les méthacrylates et l'acrylonitrile.



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