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(54) **Contacts for vacuum switches.**

(57) Contact members provided at the opposing ends of a pair of relatively separable electroconductive rods disposed in a vacuum vessel of a vacuum switch contains 0.005 - 2% by weight of boron in addition to a highly electroconductive component and a welding prevention component to obtain improved workability and reduced arc restriking probability.

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# CONTACTS FOR VACUUM SWITCHES

## BACKGROUND OF THE INVENTION

This invention relates to a vacuum switch and, more particularly, to a contact material for use in a vacuum switch exhibiting improved working characteristics and reduced occurrence frequency of restriking phenomenon.

Generally, a vacuum switch has excellent characteristics in comparison with other circuit breakers in respects of small size, light weight, maintenance cost, and adaptability for various environments.

In recent years, the vacuum switch has been widely utilized and a vacuum switch generally used for a circuit operating at a voltage of below 36 KV has now been applied to a circuit operating at a high voltage of above 72 KV, for example. In accordance with the increase in the operating voltage, the development of a contact material exhibiting reduced arc restriking phenomenon has been required. Copper base alloys containing welding prevention components such as Bi, Pb, Te, and Sb which have heretofore been used as a contact material for a vacuum switch with high breakdown voltage and large capacity do not always satisfy the requirement.

In order to obtain a contact material which does not manifest any appreciable arc restriking phenomenon under high voltage, it is generally desirable that (1) the quantity of brittle welding prevention components which tend to decrease breakdown strength should be limited to be as small as possible and (2) quantity of gas impurities and pin-holes should be highly suppressed. Moreover, with a contact alloy containing elements having high vapor pressures such as Bi, Pb, Te or the like, air voids are liable to be formed in an ingot. More particularly, in pouring the alloy into a mold having a small diameter, serious casting problems often occur. For example, a lot of air voids are formed near the surface of the ingot and shrinkage holes are formed in the interior. Although an oriented solidification method has been adapted in order to eliminate these problems, disadvantages accompanied by the addition of the welding prevention components cannot sufficiently be avoided. In particular, the contact alloy containing welding prevention components described above exhibits drawbacks such as low workability and generation of segregation because of low solubility of these components into matrix, which results in brittleness of the contact alloy.

## SUMMARY OF THE INVENTION

An object of this invention is to provide a vacuum switch having separable electrode rods provided with improved contact members capable of exhibiting little or no drawbacks such as reduction of workability and arc restriking phenomenon while maintaining the desired welding resistance.

Another object of this invention is to provide a contact material consisting of a small amount of boron in addition to components of a conventional contact material

According to this invention there is provided a vacuum switch of the type comprising a vacuum vessel and a pair of relatively separable electroconductive rods disposed in the vacuum vessel and provided with contact members at the opposing ends of the rods and the vacuum switch is characterized in that each of the contact members consists of 0.005 - 2% by weight of boron, a highly electroconductivity component and a welding prevention component.

Although the reason is not entirely apparent why a contact material exhibiting improved workability and little or no arc restriking phenomenon can be obtained by adding a small amount of boron according to this invention, it is considered that this can be attributed to an improvement of fine structure of the contact material prepared by molten casting process. With the prior art contact material (alloy) for the vacuum switch, it is found that added welding prevention components such as Bi, Pb, Te, and

Sb exhibit low solid solubility against a highly electroconductive component matrix comprising Cu, Ag, or the like and precipitate at the grain boundaries of the alloy to cause embrittlement of the grain boundaries. As a result, when working the contact alloy, working problems such as breaks and spalling are caused and therefore the yield of satisfactory products reduces. Moreover, it is considered that surface roughness of the contact material which is induced by bad workability promotes the generation of arc restriking phenomenon. When the contact material is bonded to a substrate by a brazing material, the brazing material readily diffuses into the grain boundaries which induce boundary corrosion or cracking. Thus, such phenomenon as that the brazing material reaches to the surface opposite to the bonding surface of the contact material, i.e. contact surface thereof, occurs, which fact leads to the reduction in reliability due to the promotion of the arc restriking generation, the phenomenon being called creeping-up of the brazing material.

On the contrary, when boron is added to the conventional contact material according to this invention, compatibility of the high electroconductive component with the welding prevention component can be improved. Accordingly, the segregation of the welding prevention component is prevented and the improvement of the fine structure of the contact material such as grain refinement as well as the reinforcement of the grain boundaries can be achieved. Thus, it is believed that the contact characteristics including prevention of the arc restriking can be improved by virtue of the improvement of the workability and the improvement of surface precision accompanied with the improved workability as well as the prevention of the creeping up of the brazing material which are caused by the addition of the boron. With the contact material of this invention, fine cracks thereof due to mechanical and thermal shocks which are applied to the contact material during interruption are not substantially formed because the grain boundaries are significantly reinforced. If the working conditions are suitably controlled, plastic workings such as rolling, casting and the like can be carried out and no reduction of the highly electroconductivity is found due to the addition of the boron.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 shows a vertical section of a vacuum switch having electrode rods provided with contact members according to this invention; and

FIG. 2 is a fragmentary enlarged view of a contact member shown in FIG. 1.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

This invention will be described in more detail hereinafter and all percentages used herein are weight percentages unless otherwise indicated.

A vacuum switch shown in FIG. 1 comprises a cylindrical insulating casing 2, i.e. vacuum vessel, which defines an air tight vacuum circuit breaking chamber 1 and metallic caps 4 and 5 are provided at both ends of the casing 2 through seal members 3 and 3a. The casing 2 is made of an insulating material. A pair of separable electroconductive rods 6 and 7 provided with stationary and movable electrodes 8 and 9 at the opposing ends are disposed within the vacuum chamber 1 and a bellows 10 is attached to the lower end cap 5 for permitting reciprocation of the movable electrode 9 while maintaining the vacuum condition in the chamber 1. The bellows 10 is covered with a metallic shield 11 to prevent metal vapor from depositing on the inner surface of the vacuum vessel 2 and a cylindrical metallic shield 12 is also disposed in the chamber 1 as shown in FIG. 1 to prevent the metal vapor from depositing thereon.

As shown in FIG. 2, the movable electrode 9 is fixed to the conductive rod 7 by a brazing member 13 or tightly connected thereto by calking and a movable contact 14 is attached to the upper portion of the movable electrode 9 by brazing means 15. The stationary electrode 8 has substantially the same construction as that of the movable electrode 9 and is provided with a stationary contact 14a at its front end.

The contact material of this invention is used for contacts 14 and 14a.

The contact material of this invention is made of material which is not specifically different from those of a conventional contact material except that boron is added. Although Cu and/or Ag are usually used as a highly electroconductive composition, if necessary, these metals can be replaced in part with less than 5% (based on the total weight of the conductive composition) of Fe, less than 5% of Co or less than 1% of Cr. Among these metals or alloys, as the electroconductive composition, Cu or a copper rich alloy is suitable for the purposes of this invention. These conductive components are used in an amount of the balance of the composition as described hereinafter.

As the welding prevention component are used one or more elements of Bi, Pb, Te, Sb, and mixtures thereof which are incorporated into the contact material according to this invention in an amount of from 0.1% to 15%. If the amount of the welding prevention component is less than 0.1%, the welding resistance property against large current decreases and if the amount thereof exceeds 15%, the segregation will occur during manufacture of the contact material, thus hardly obtaining a suitable contact material.

In order to obtain the contact material having excellent workability and arc restriking prevention characteristics, according to the present invention, 0.005% to 2%, preferably from 0.01% to 2% of boron is added to the highly conductive component and the welding prevention component. If the amount of added boron is less than 0.005%, the object of adding it cannot be expected and more than 2%

of boron does not improve its funcation than a case of adding boron of 0.005% - 2%. Thus, it was found that boron tends to segregate from the highly conductive component when the contact material is prepared by melting technique. This means that the use of more than 2% of boron is not suitable. The range of the boron to be added, particularly its lower limit, should be defined as content of boron presenting in the resulting contact material rather than the amount of additive thereof by taking into consideration the effects of grades of the used high conductive component and of the used welding prevention component, melting temperature of the composition, and the fluctuation of the degree of the vacuum in the vacuum chamber.

In order to obtain one example of the contact material according to this invention, the highly conductive component is melted under vacuum of from about $1 \times 10^{-3}$ to $1 \times 10^{-5}$ mmHg at a temperature of from 1000° to 1300°C and the welding prevention component is then added thereto so as to be uniformly dissolved into the molten high conductive component. Thereafter, the resulting mixture is cooled and solidified in a mold, but if necessary, oriented solidification process can be used. The order of addition of boron and the welding prevention component is optional and in order to prevent vaporization and scattering, it is advantageous to add the components after increasing the pressure in the melting furnace by introducing argon gas thereinto. As the source of the boron to be added can be used mother alloys such as Cu-B or borides such as FeB, $Fe_2B$ as well as boron itself.

Contacts, made of the contact material and having desired shape, can be obtained by subjecting the resulting contact material to mechanical workings such as cutting, polishing or the like, or plastic deformation such as rolling, as required.

To aid better understanding of the present invention, examples and control examples are described hereunder, which are based on experiments.

Examples 1 - 10 and Control Examples 1 - 5

Fifteen contact alloys having the compositions shown in Table 1 were prepared by a method comprising the steps of melting Cu under vacuum of about $10^{-5}$ mmHg and at a temperature of 1200°C, completely degassing, adding and melting Cu-B mother alloy (containing 2.2% of B) and welding prevention components (Bi, Pb, Te, or Sb), pouring the molten alloy thus obtained into a mold and cooling and solidifying the poured alloy.

Each test piece of these contact members having a desired shape was subjected to the following test to measure the degree of surface roughness caused by the working and to examine the probability of arc restriking. The results obtained are shown in Table 1.

Surface Roughness Caused by Working

The end surface of a rod shaped contact material having a diameter of 75 mm was finished to obtain surface roughness of less than 6 μ (6-s; Japanese Industrial Standard 0601) by using a WC-Co super hard alloy cutting tool while the contact material was rotated at 180 r.p.m. The number of defects such as spallings, breaks and the like on the end surface were visually measured and the minimum and maximum numbers of the observed defects of six samples are shown in Table 1.

Probability of Arc Restriking

A disc-shaped contact piece having a diameter of 30 mm and a thickness of 5 mm was attached to the end of each electrode rod of a demountable vacuum switch and a circuit having a rating of 6KV and 500 A was interrupted 2000 times. At this time, the observed frequency of the arc restriking was represented by a range of difference (maximum and minimum values) of two circuit breakers. The attachment of the contacts was performed only by baking for 30 minutes at a temperature of 450°C and not only no brazing material was used but also no heating operation was carried out.

Table 1

| Contact material | Composition, % by weight | | | Workability (surface roughening); number of breaks & spalling | Probability of arc restriking (%) |
|---|---|---|---|---|---|
| | Welding prevention component | Boron | Highly conductive component (Cu) | | |
| Control Example 1 | 0.42 Bi | 0 | Balance | 15 - 29 | 2.0 - 2.2 |
| Example 1 | 0.41 Bi | 0.005 | Balance | 2 - 6 | 0.2 - 0.4 |
| Example 2 | 0.44 Bi | 0.01 | Balance | 0 - 2 | 0 - 0.1 |
| Example 3 | 0.38 Bi | 0.08 | Balance | 1 - 2 | 0 - 0.2 |
| Example 4 | 0.40 Bi | 0.9 | Balance | 2 - 3 | 0.1 - 0.4 |
| Example 5 | 0.42 Bi | 1.42 | Balance | 1 - 4 | 0.1 - 0.3 |
| Example 6 | 0.43 Bi | 2.0 | Balance | 2 - 7 | 0.2 - 0.4 |
| Control Example 2 | 1.2 Bi | 0 | Balance | 33 - 85 | 2.8 - 3.4 |
| Example 7 | 1.2 Bi | 0.03 | Balance | 4 - 8 | 0.1 - 0.6 |
| Control Example 3 | 2.9 Te | 0 | Balance | 6 - 18 | 1.4 - 1.8 |
| Example 8 | 3.0 Te | 0.04 | Balance | 1 - 3 | 0.3 - 0.9 |
| Control Example 4 | 0.9 Pb | 0 | Balance | 12 - 22 | 2.6 - 3.8 |
| Example 9 | 1.0 Pb | 0.04 | Balance | 1 - 6 | 0 - 0.6 |
| Control Example 5 | 2.0 Sb | 0 | Balance | 6 - 18 | 1.8 - 2.8 |
| Example 10 | 2.2 Sb | 0.03 | Balance | 4 - 6 | 0.4 - 0.8 |

As can be seen from Table 1, the conventional boron-free contact materials (Control Examples 1 - 5) exhibit significant surface roughness caused by working. Accordingly, restriking occurs with high probability. On the contrary, with the boron containing contact materials according to this invention, it can be understood that these materials exhibit remarkably improved workability and low probability of arc restriking. Regarding the electric conductivity, the boron free contact material of the Control Example 1 exhibit 96 - 97% I.A.C.S. (International Annealed Copper Standard), whereas the contact material of Example 1 exhibits 95 - 97% I.A.C.S. This fact shows that the improved workability can be achieved without substantial reduction of the conductivity according to the contact material of the present invention.

In addition, oxygen content of the contact material of the Control Example 1 is 7 ppm, whereas that of the Example 1 is from about 1/2 to 1/7 of the Control Example 1. This fact shows that the added boron acts as a deoxidizer and the reduction of the oxygen content contributes to the prevention of the arc restriking.

<u>Examples 11 - 12 and Control Examples 6 - 7</u>

Contact alloy materials each having the composition shown in the following Table 2 were prepared by the same manner as above described. Test pieces each having a predetermined shape were prepared and subjected to the following tests to measure the creeping - up amount of silver brazing and the probability of arc restriking. The results obtained with six samples are shown in Table 2.

<u>Amount of Silver Brazing crept up to Surface of Contact Material</u>

A silver brazing plate consisting of 72% of Ag and 28% of Cu and having a diameter of 10 mm and a thickness of 0.1 mm was inserted between a pure copper electrode and a disc-shaped contact piece having a diameter of 15 mm and a thickness of 4.2 mm. The structure thus prepared was heated for 30 minutes in $H_2$ atmosphere at a temperature of 820°C to thereby firmly bond together the materials used. The amount of silver brazing crept up to the contact surface by passing through the contact piece during the heat treatment was measured as count numbers (C.P.S.) by an X-ray microanalyzer under conditions of the absorption current of $5 \times 10^{-8}$A, a scanning time of 50 seconds and an acceleration voltage of 25 KV. Background value of a contact piece to which silver brazing is not applied is shown in Table 2.

Probability of Arc Restriking

With these examples, the probability of arc restriking was measured in the same manner as that of aforementioned examples except that the brazed contacts were used in these examples.

Table 2

| Contact material | Composition, % by weight | | | Creeping property of brazing; count number of Ag, cps | Probability of arc restriking (%) |
|---|---|---|---|---|---|
| | Welding prevention component | Boron | Highly conductive component (Cu) | | |
| Control Example 6 | 0.42 Bi | 0 | Balance | 230 - 450 | 2.2 - 2.6 |
| Example 11 | 0.44 Bi | 0.01 | Balance | 65 - 70 | 0 - 0.1 |
| Control Example 7 | 0.9 Pb | 0 | Balance | 185 - 415 | 2.8 - 4.2 |
| Example 12 | 1.0 Pb | 0.04 | Balance | 65 - 70 | 0 - 0.6 |
| Remark | Background | | | 60 - 70 | |

As can be seen from Table 2, the boron-containing contact materials according to this invention exhibit an extremely small amount of crept-up silver brazing in comparison with the conventional boron-free contact materials and also exhibit count numbers nearly equal to the background. These facts are considered to be caused by the fact that defects such as boundary corrosion and cracks observed in the conventional contact material could be eliminated by the addition of the boron. As a result, the probability of the arc restriking is remarkably reduced.

Although it is difficult to judge whether the arc restriking is governed by the existence of Ag itself on the contact surface or by the lowering of the melting point due to the existence of Ag which results in the surface roughness, it is apparent that the structure of the contact material is not good.

Examples 13 - 15 and Control Examples 8 - 10

With these examples too, contact materials were prepared in substantially the same manner as that of the Example 1 except that in place of the highly conductive component consisting only of Cu were used highly conductive components in which a portion of the copper was replaced with Fe, Co, or Cr in a proportion shown in Table 3. Thereafter, the probability of arc restriking was measured for each of these examples in substantially the same manner as that of the Example 1. The results obtained are shown in the following Table 3, from which it will be found that the probability of the arc restriking was remarkably decreased by the addition of boron.

Table 3

| Contact material | Composition, % by weight | | | Probability of arc restriking (%) |
|---|---|---|---|---|
| | Welding prevention component | Boron | Highly conductive component | |
| Control Example 8 | 0.51 Bi | 0 | 1.7 Fe-Cu balance | 1.0 - 1.3 |
| Example 13 | 0.52 Bi | 0.04 | 1.9 Fe-Cu balance | 0.1 - 0.4 |
| Control Example 9 | 0.47 Bi | 0 | 2.1 Co-Cu balance | 0.9 - 1.4 |
| Example 14 | 0.43 Bi | 0.03 | 2.0 Co-Cu balance | 0.1 - 0.3 |
| Control Example 10 | 0.50 Bi | 0 | 0.7 Cr-Cu balance | 0.9 - 1.4 |
| Example 15 | 0.48 Bi | 0.03 | 0.6 Cr-Cu balance | 0.1 - 0.2 |

Examples 16 and 17

With these examples, contact materials were also prepared in substantially the same manner as that of the Example 1 except that an Ag-Cu alloy (Example 16) and Ag alone (Example 17) were used as the highly conductive component. The workability and the probability of the arc restriking were examined in substantially the same manner as that of the Example 1. The results obtained are shown in the following Table 4 from which advantageous effect caused by the addition of boron will be clearly confirmed.

Table 4

| Contact material | Composition, % by weight | | | Workability (numbers of cut-out and spalling) | Probability of arc restriking (%) |
|---|---|---|---|---|---|
| | Welding prevention component | Boron | Highly conductive component | | |
| Example 16 | 0.47 Bi | 0.08 | 12 Cu-Ag balance | 0 - 2 | 0.2 - 0.5 |
| Example 17 | 0.45 Bi | 0.06 | Ag balance | 0 - 1 | 0.3 - 0.7 |

As stated hereinbefore, according to this invention, contact materials for separable electrodes of a vacuum switch can be obtained by adding a small amount of boron to a contact material consisting of highly conductive components (mainly Cu and/or Ag; partially replaced with Fe, Co or Cr and welding prevention components (such as Bi, Pb, Te, Sb and the like). The contact materials thus obtained exhibit improved workability and arc restriking prevention characteristics without impairing fundamental characteristics required for the contact material such as electroconductivity. These advantageous effects can be achieved by the inherent degassing effect of boron and therefore, substantial improvement of reliability of a vacuum switch can be attained.

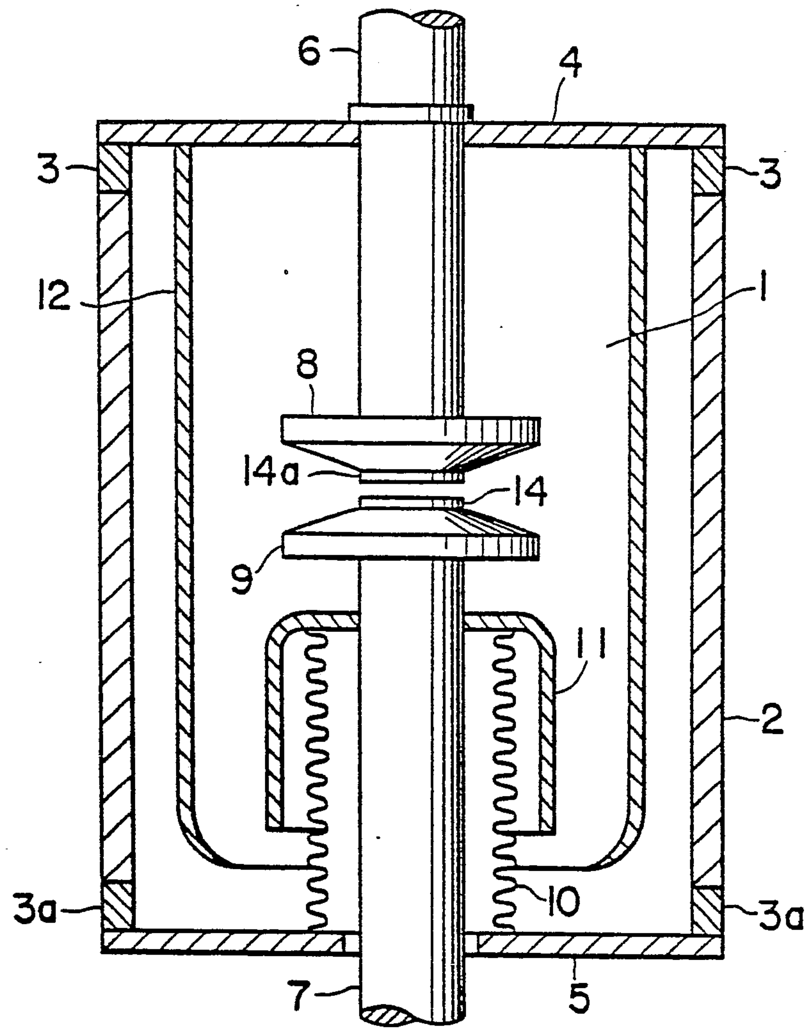
WHAT IS CLAIMED IS:

1. A vacuum switch of the type comprising a vacuum vessel and a pair of relatively separable electroconductive rods disposed in said vacuum vessel and provided with contact members at the opposing ends of said rods, characterized in that each of said contact members consists of 0.005 - 2% by weight of boron, a highly electroconductive component and a welding prevention component.

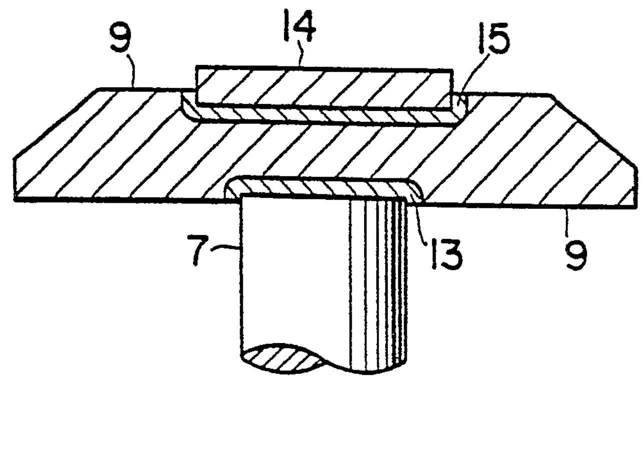
2. The vacuum switch according to claim 1 wherein said highly electroconductive component is selected from either one or both of copper and silver or an alloy in which a portion of said either one or both of copper and silver is replaced with less than 5% of iron, less than 5% of cobalt or less than 1% of chromium.

3. The vacuum switch according to claim 1 or 2 wherein said welding prevention component comprises at least one metal selected from the group consisting of bismuth, lead, tellurium, or tin.

F I G. 1




F I G. 2



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Application number

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# EUROPEAN SEARCH REPORT

EP 83 10 6046

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl. 3) |
|---|---|---|---|
| X | GB-A-1 309 197 (INTERNATIONAL STANDARD ELECTRIC CORP.)<br>* Claims 1-2 * | 1,3 | H 01 H 1/02<br>C 22 C 9/00 |
| A | DE-B-2 124 707 (SIEMENS AG)<br>* Claims 1-4; columns 2-3 * | 1,3 | |
| A | US-A-3 551 622 (H. TAKEUCHI et al.)<br>* Claim 1 * | 2 | |

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)

H 01 H 1/00
H 01 H 33/00
C 22 C 9/00

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| BERLIN | 26-08-1983 | RUPPERT W |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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