Sept. 11, 1956 J. S. CORRAL 2,762,734

PROCESS AND APPARATUS FOR FORMING AND STRESS RELIEVING METAL

Filed Sept. 29, 1952

3 Sheets-Sheet 1

FIG. 1

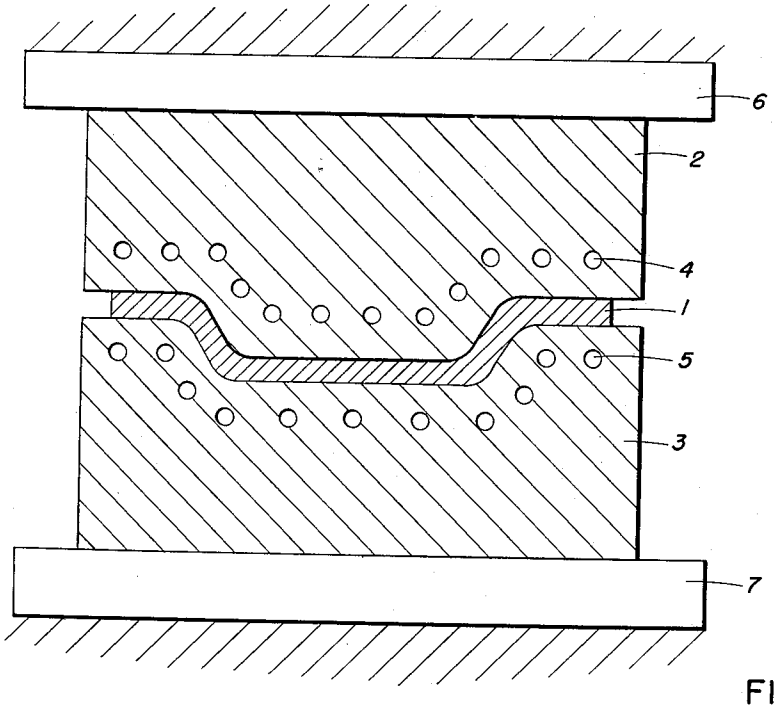


FIG. 2

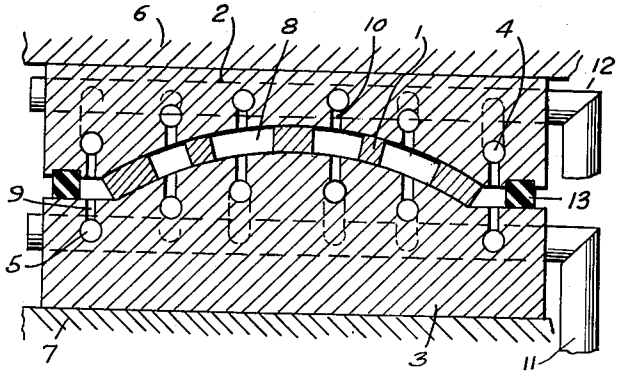
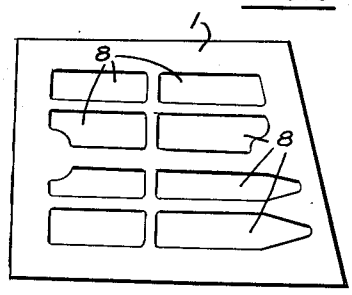


FIG. 3



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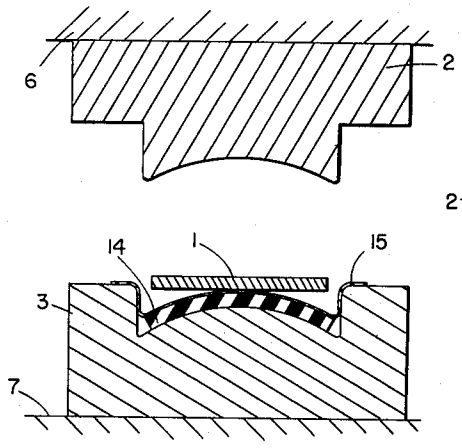


FIG. 4

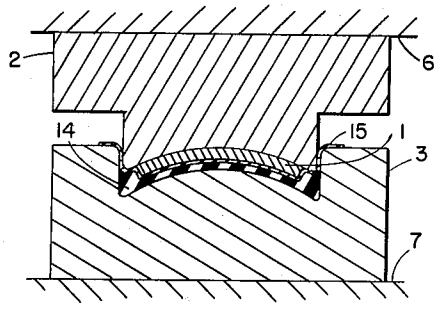


FIG. 5

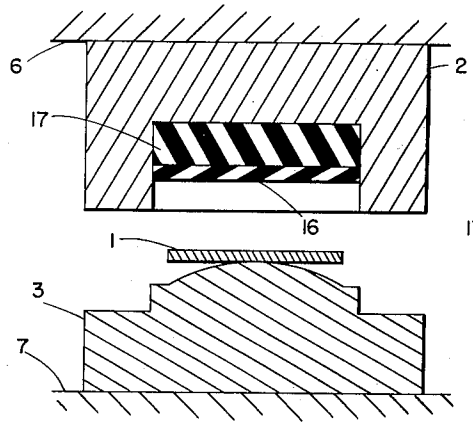


FIG. 6

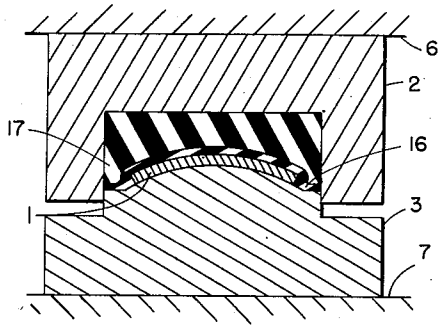


FIG. 7

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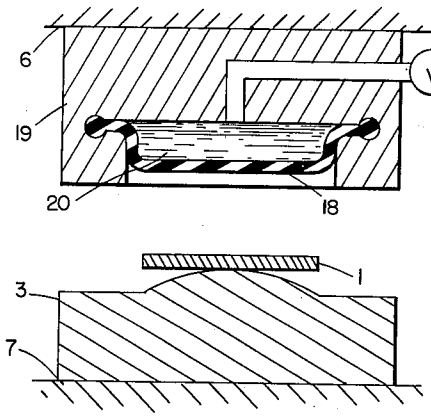


FIG. 8

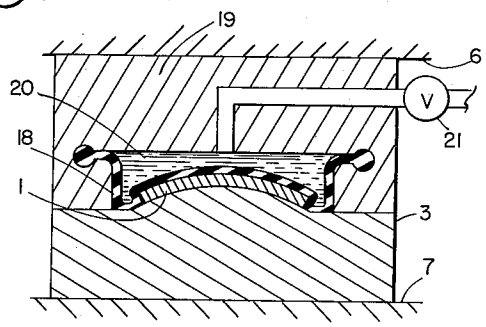


FIG. 9

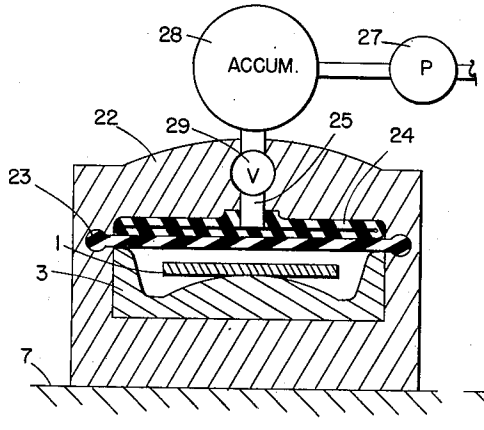


FIG. 10

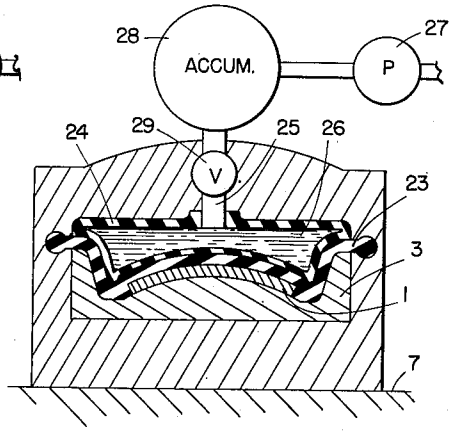


FIG. 11

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2,762,734

PROCESS AND APPARATUS FOR FORMING AND STRESS RELIEVING METAL

Joseph S. Corral, Los Angeles, Calif., assignor to North American Aviation, Inc.

Application September 29, 1952, Serial No. 311,981

4 Claims. (Cl. 148—12.7)

This application is a continuation in part of application Serial No. 98,697, filed June 13, 1949, now abandoned, for Strain Relieving Device, in the name of Joseph S. Corral.

This invention pertains to the elimination of warpage in sheet metal or parts formed therefrom.

In the past parts formed from heat-treatable metal, especially those of aluminum alloy, have undergone serious warpage due to residual strains caused by water-quenching of the material after heat treatment. Heat treatment and subsequent quenching are necessary to develop the full structural strength of the material. As the thickness of the sheet is increased, the effect of surface strains on the flatness of the sheet or the trueness of the contour of parts formed from sheet becomes increasingly difficult of elimination by previously known methods, due to the fact that a greater volume of metal is present to undergo differential strains. It is presently practically impossible to obtain aluminum sheet of a thickness of .375 inch or more which is perfectly flat. Present practice is to mill the tempered sheet to the requisite flatness. This expedient, however, is unsatisfactory because if the sheet is to be used where it needs to be notched or cut to reduced thickness over a limited area, additional warpage will appear near such cuts or grooves due to residual stresses in the metal. Such cuts or grooves serve to relieve the stresses over the limited area of the cut on the one side of the metal but not on the other side of the metal, and to re-establish static equilibrium in the plane of the cross-section of the material a redistribution of stress occurs in the manner required to reduce the internal energy of the member to a minimum.

Additional difficulty is encountered when parts are formed to a predetermined contour by dies or other means. Invariably a certain amount of springback will occur after the dies have been removed from the part so that the finished piece is not of exactly the same contour as that of the dies. Subsequent heat treatment may produce additional warpage and distortion.

The present invention is a process for eliminating the undesirable consequences of heat-treating and water quenching both in flat plates and in parts formed from flat plates. This invention is especially applicable to aluminum alloy sheet of a thickness equal to or greater than .375 inch but can be used to advantage in material having less thickness.

An object of this invention is to provide a method of forming, quenching and stress relieving a workpiece.

Another object of this invention is to provide a method for forming a part to a predetermined contour without springback.

An additional object of this invention is to provide a method for forming a part which will give the part maximum strength properties.

Still another object of this invention is to provide a method of forming a part which will eliminate machining operations.

A further object of this invention is to provide a method and means for eliminating residual stresses in aluminum alloy sheet.

A still further object of this invention is to provide a method for forming and heat-treating aluminum alloy sheets.

Yet another object of this invention is to provide a method for forming residual-stress-free metallic sheet material.

An additional object of this invention is to provide a method and means for simultaneously forming, quenching, and stress-relieving flat aluminum alloy sheet material.

Other objects of invention will become apparent from the following description taken in connection with the accompanying drawings in which:

Fig. 1 is an elevational view of the invention, partly in section,

Fig. 2 is a sectional view of a modification of the invention,

Fig. 3 is a plan view of a part particularly adaptable to the modification of Fig. 2,

Fig. 4 is a sectional view of a modification of the invention, prior to forming,

Fig. 5 is a sectional view of the modification of Fig. 4 during forming,

Fig. 6 is a sectional view of a modification of the invention using rubber pads, prior to forming,

Fig. 7 is a sectional view of the modification of Fig. 6 during forming,

Fig. 8 is a sectional view of a modification of the invention using a fluid filled bag, prior to forming,

Fig. 9 is a sectional view of the modification of Fig. 8 during forming,

Fig. 10 is a sectional view of a modification of the invention using a fluid filled bag without a movable press, prior to forming, and

Fig. 11 is a sectional view of the modification of Fig. 10 during forming.

Referring to Fig. 1 there is shown a formed sheet part **1** between dies **2** and **3** having cooling conduits **4** and **5** respectively. Dies **2** and **3** are brought and held in intimate contact with sheet **1** by pressure exerted by press members **6** and **7**.

In operation the invention may be employed to produce either a flat plate or a formed part free of residual stresses.

If it is required to produce a part which is free of residual stresses and has an accurately defined surface, the aluminum alloy sheet metal is heated in a molten salt bath or oven to the temperature normally used for heat treatment of the particular alloy. In the case of 75–S Alcad material this temperature is 920 degrees Fahrenheit. Referring to Fig. 1, workpiece **1** is heated for a period of one hour, more or less as is required to achieve complete and even heating of the plate, and then is quickly placed between matching Kirksite dies **2** and **3** which are maintained at or below room temperature by the circulation of water through continuous conduits **4** and **5**. Dies **2** and **3** are forced intimately against workpiece **1** under a pressure of the order of magnitude of 100,000 pounds per square inch furnished by press members **6** and **7** for a period approximating three to five minutes during which time workpiece **1** is rapidly quenched.

When dies **2** and **3** are in engagement with the workpiece heat will flow from the heated workpiece to the cooler dies thus quenching the workpiece. This heat transfer may be accomplished simply by the mass of the dies, if preferred, without circulating fluid through coolant ducts. The dies alone will provide a ready medium for

transferring heat from the workpiece for quenching, particularly when the workpiece is relatively thin.

As the workpiece is being cooled and quenched the dies are maintained in firm gripping engagement with the workpiece. This force must be sufficient to substantially restrain movement of the workpiece in all directions preventing its contraction during the quenching. As result, the part is worked evenly throughout as it is quenched thereby entirely relieving it of internal stresses and strains. After the quenching operation is complete and the dies are released for removal of the part, no springback will occur and the finished part will conform exactly to the contour of the dies. If the force exerted by the dies were not great enough to restrain the part during quenching the part would contract along the surface of the dies and would not be worked, thus failing to remove internal stresses. Such a part would be characterized by a marked springback after the dies were released and the finished part would not conform accurately to the configuration of the dies. The exact amount of the force maintained and the period of time for which the force is maintained will vary, of course, with the particular workpiece being formed. Thus a heavy piece might require higher pressures for a longer time in order to adequately quench the part and restrain its movement than would be the case with a relatively small and light article. The important thing is to see that the force is of a magnitude that will restrain the part as the quenching is accomplished.

Of course the finished part when quenched and restrained according to the teachings of this invention will be slightly greater in overall dimensions than was the workpiece prior to the quenching and stress-relieving operation, because it will expand when heated to a heat treating temperature and will be restrained within the dies when it is cooled. Therefore, the unfinished workpiece may be dimensioned slightly smaller than the desired dimensions of the finished part to account for the growth in size resulting from quenching and stress-relieving according to the teachings of this invention.

Following the forming and stress relieving operation the part may be artificially aged at a temperature varying from 250 to 375 degrees Fahrenheit for a period of from ten to twenty-four hours. Plates flattened in this manner have been found to develop approximately full rated strength for the alloy and to be free of warpage and substantially free of all residual stress as can be illustrated by absence of warpage of the surface of the material. The transit time between the oven or salt bath and the die must be kept at a minimum to avoid excess cooling of the part before it is engaged by the dies. It is preferred to keep this time at or under 10 seconds in order to achieve the rapid quench which is required to develop full rated strength for the alloy.

An advantage of this process is that since the material is heated to a semi-plastic state before forming, the dies used need not be of steel or of any other metal which is difficult to cast or machine. On the contrary, the dies may be of Kirksite and may be cast in molds. Kirksite is a zinc base alloy containing 3.5% to 4.5% aluminum, 2.5% to 3.5% copper, and .02% to .10% magnesium, and have a melting point of 717° F. Kirksite is also marketed under the trade name "Zamak II," having the designation SAE 921 or ASTM XXI. The warpage normally present when steel dies are used to form aluminum alloy parts with subsequent heat treatment and water quenching is completely eliminated. Furthermore, the residual stress due to the conventional practice of forming and water quenching are eliminated. The contours of formed parts may be held to much greater accuracy and closer tolerances than was heretofore possible. Note that the two dies which form the part or flatten it, as the case may be, are held in firm clasping engagement with the surface of the plate while it is being quenched or cooled from the semi-plastic state down to a lower temperature. The method of this invention may also be used to strain relieve steel and any other alloys susceptible of heat treatment.

An alternative construction is shown in Fig. 2 which is particularly useful in forming, quenching and stress-relieving parts such as illustrated in Fig. 3. These parts may comprise heavy grids having cutout portions **8** extending through the workpiece, which cutouts may be of an irregular varying contour as shown. Dies **2** and **3** are provided with conduits **4** and **5** of the general type illustrated in Fig. 1 and further have ducts **9** and **10** which have apertures communicating with the surface of each of the dies at a location corresponding to that of cutouts **8** when the workpiece is in the dies. Apertures **9** and **10** also connect with the die surface around the outside of the workpiece. Water or other fluid may then be conducted through inlet pipe **11**, conduits **5**, apertures **9** and **10**, conduits **4**, and out through outlet pipe **12**. In this manner the cooling fluid not only maintains the die at a lowered temperature, but contacts the workpiece within the cutout areas, thereby giving the workpiece a very fast quenching. Seal **13**, of rubber or other suitable construction, is disposed between the two dies surrounding the workpiece so as to circumscribe apertures **9** and **10** and prevent leakage during the quenching operation.

Various other means may be employed to form and quench the workpiece according to the teachings of this invention. It is not necessary in every case to provide matching dies **2** and **3** exactly as illustrated in Fig. 1. For example, in Figs. 4 and 5 a die **2** is provided which may be of Kirksite and correspond very closely to the desired contour of the finished part. Die **3** of this modification may be of lead, Kirksite, or other suitable material and formed to the desired contour of the finished part, but need not be as accurately held as die **2**. A rubber pad **14** is provided on top of die **3** and diaphragm **15** covers the rubber pad. This diaphragm may be made of copper, or other suitable, preferably flexible, heat resistant material. Heated workpiece **1** may then be placed on top of the diaphragm and the dies forced into forming engagement with the workpiece as illustrated in Fig. 5. The dies are held firmly against the workpiece to restrain its movement in exactly the same manner as described above. Heat will flow from the workpiece to the dies as previously noted although a slightly greater amount of heat will be transferred to die **2** than to pad **14** and die **3** because die **2** has a greater ability to transmit heat than does the pad. Diaphragm **15** will serve to protect rubber pad **14** from the heated workpiece so that ordinary forming rubber can be used for the pad. The rubber pad will enable the workpiece to be forced into perfect mating contact with die **2** regardless of any slight irregularity in the surface of die **3**. Diaphragm **15**, being flexible, will not prevent this advantageous fluid forming effect of the rubber pad. The diaphragm and pad further protect die **3** from the heated workpiece which is important where die **3** is made of lead.

Still another manner in which the forming, quenching and stress-relieving may be accomplished is illustrated in Figs. 6 and 7. In this instance only a single die **3** is provided, the top surface of which corresponds to the desired contour of the finished part. The workpiece is placed over die **3** in the usual manner and forced into intimate contact therewith by means of rubber pads **16** and **17**. Pad **16** may comprise a facing of special heat resistant rubber over a second pad **17** of normal metal forming rubber. It is possible of course to make the entire pad out of the same heat resistant rubber as that used for facing pad **16**. Pad **16** is held in firm engagement with the workpiece while the workpiece is quenched in order to restrain any movement thereof. Thus the action of the forming, quenching and stress-relieving is exactly the same as described before, but rubber is used in the forming instead of utilizing a pair of matching metallic dies. The rubber pads will flow around the workpiece as shown

in Fig. 7 exerting a substantially equal pressure on all portions of the part that are in engagement with the rubber. In this manner the rubber acts substantially as a fluid and flows around the part and the die as the part is formed. This type of forming is particularly desirable where flanges or sharp bends are to be provided on the workpiece because of the fluid flow characteristics of the rubber and the substantially equal pressure exerted on all portions of the workpiece. Flange portions can be effectively restrained during quenching because the rubber can exert a high horizontal force as well as a vertical force. The high friction of rubber against the part and the intimate contact with the part that it achieves make it ideal for such forming and quenching.

Still another method of exerting a forming and restraining pressure on the workpiece is illustrated in Figs. 8 and 9. This modification is similar to that shown in Figs. 6 and 7, but a fluid-tight bag **18** is used instead of rubber pads **16** and **17**. This bag may be made of a sheet of heat resistant rubber or other suitable material attached to member **19** carried by the movable ram **6** of the press. A suitable fluid such as oil **20** is contained within bag **18** and is appropriately sealed therein by means such as by valve **21**. When the press members are moved together, bag **18** engages the workpiece. This causes a compressive force on the bag and the fluid therein so that the bag causes the workpiece to assume the contour of the lower die **3**. The bag should be urged against the workpiece with sufficient force so that it will restrain contraction of the workpiece during cooling in the same manner as described above. Quenching will take place by transfer of heat from the workpiece to die **3** and also to the bag and the fluid within the bag. Valve **21** should be a pressure relief type valve to prevent excessive pressures within the bag.

A further means of achieving the forming, quenching, and stress-relieving according to this invention is illustrated in Figs. 10 and 11. This means comprises a rigid housing member **22** into which die **3**, on which workpiece **1** is resting, may be inserted. A pad of heat-resistant rubber **23** may be provided above the die and the workpiece, and a flexible fluid-tight bag **24** provided above the heat-resistant rubber pad. Conduit **25**, communicating with the interior of the bag, contains oil or other suitable fluid **26**. A suitable source of fluid pressure such as pump **27** and accumulator **28** are connected with conduit **25**. A valve **29** may be provided for controlling the pressurized fluid. When the heated workpiece is suitably positioned beneath pad **23** valve **29** may be opened to admit the pressurized fluid into the bag. This will cause the bag and the pad to expand, forcing the pad into engagement with the workpiece and the workpiece in turn in engagement with die **3**, as shown in Fig. 11. The fluid pressure exerted within the bag should be sufficient to restrain the workpiece in its formed position, and prevent any contraction during cooling of the workpice. The workpiece is held so engaged for a length of time sufficient for thorough quenching as heat is transmitted to die **3** and to pad **23**, bag **24** and the fluid within the bag.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by terms of the appended claims.

I claim:

1. A device for forming, quenching, and stress-relieving a heated workpiece having cutout portions therein, said device comprising a pair of matching die members adapted to receive said workpiece, each of said die members

being provided with coolant ducts therein, said ducts having apertures communicating with the surface of said die members at locations corresponding to those of said cutout portions; means for exerting a force urging said die members into engagement with said workpiece, whereby said workpiece is formed and restrained; and means for circulating fluid through said ducts for quenching said workpiece while so engaged, said workpiece being uniformly worked by the restraining action of said dies during said quenching.

2. A device as recited in claim 1 in which said dies are further provided with ducts having apertures communicating with said surfaces thereof outside of the periphery of said workpiece; and including, in addition, sealing means disposed between said dies, circumscribing said apertures, whereby said fluid contacts the edges of said workpiece during said quenching and is contained by said sealing means.

3. The method of forming and stress relieving a workpiece of pressure formable metal material subject to expansion when heated, and provided with cutout portions therethrough, comprising the steps of heating such a workpiece to an elevated temperature; associating said workpiece with matching dies, both of said dies having ducts therein including ducts communicating with the matching surfaces thereof at locations corresponding to the cutouts in said workpiece; urging said dies into forming engagement with said workpiece; and circulating cooling fluid through said ducts from one die to the other via said cutout portions for quenching said workpiece, while maintaining said dies in engagement therewith with sufficient force to substantially preclude contraction of said workpiece during quenching.

4. The method of providing a strengthened contoured finished part of aluminum alloy comprising the steps of providing dies of heat absorbent composition with matching surface portions defining the contour of the part to be produced; providing a workpiece of aluminum alloy with overall dimensions approximating but less than the dimensions of the part to be produced; uniformly heating said workpiece to the solution heat treating range thereof, so as to cause the overall dimensions of said workpiece to increase to those of the part to be produced; associating said workpiece so heated with said matching surface portions of said dies; urging said matching surface portions of said dies against said workpiece to conform the same to the contour defined thereby; and maintaining said workpiece so engaged for a sufficient period of time to quench said workpiece by transfer of heat therefrom to said dies and with sufficient force maintained by said dies on said workpiece to substantially preclude contraction thereof during said quenching, whereby said workpiece retains said increased overall dimensions and provides a uniformly worked and stressed relieved finished part of increased properties, conforming to the contour of said matching surface portions of said dies.

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