This invention is a continuation of the copending application in the name of the same inventor and bearing the same title, Serial No. 76,572, filed December 19, 1969, now abandoned.

The invention has to do with the annealing of strip metal under circumstances in which the atmosphere of the annealing furnace must have access to the surfaces of the strip. By strip metal is meant metal (usually iron or steel or iron alloys) of sheet gauge, which must be handled in indefinite lengths. The width of the strip material is not a limitation of the invention, although in most instances the strip will be of sheet width. The term "sheet gauge" as used herein is not confined to materials having a finished sheet gauge, since the invention is applicable to the treatment of metal strip material in intermediate hot rolled condition as formed from ingots, billets or slabs, through other intermediate gauges as produced by various stages of hot or cold rolling, wherever the material is of such character as to be most conveniently handled in coiled form.

There are many heat treatments which require that the surfaces of the strip material being treated shall be open to the atmosphere of the furnace. Such treatments include a reduction of the carbon content of the materials through the use of a decarburizing atmosphere. They include controlled oxidation treatments, bright annealing treatments, gas alloying, and, in general, heat treatments at so high a temperature that in tightly wrapped coils the metal convolutions would tend to adhere or fuse together. This is in which it is necessary that evolved gases escape freely from the surfaces of the strip material or from some substance imposed thereon. By way of example, as set forth in United States Patent No. 2,385,332, issued September 25, 1945, to Victor W. Carpenter et al., still another strip material which has been decarburized with the concurrent production of some silica on and in their surfaces, are coated with a slurry of magnesium hydroxide. This slurry is dried so as to eliminate the free water, and the coated materials are then subjected to a high temperature anneal. In this anneal the water of constitution of the magnesium hydroxide is driven off so as to produce magnesium oxide. Thereupon the magnesium oxide or magnesia fuses with the silica on and adjacent the surfaces of the metal strip so as to form a glassy coating thereon which is of utility in providing interlamination resistivity in magnetic cores formed from the silicon-iron sheet materials. It will be evident that the nature of the annealing step and the nature of the atmosphere used in the annealing furnace are not necessary limitations of this invention; and the invention will be described as though the problem were that of access of an annealing atmosphere to the surfaces of the strip material, keeping in mind, however, that the problem also pertains to the escape of gaseous constituents from the surfaces of the strip materials or from substances imposed thereon.

In the recent past, the only way in which this problem could be solved involved the use of a continuous annealing furnace in which the metal could be passed in single strand form. Such annealing furnaces are costly to build and operate; and they do not lend themselves readily to operations in which a long soaking time is a necessary part of the annealing cycle. Treatments in an annealing box or muffle-type furnace are in general less expensive, and impose less serious problems in atmosphere control. However, with tightly wound coils of the strip material, the annealing atmosphere is not generally sufficiently available to all surfaces of the material being treated. Still more recently, it has been suggested that a cord-like material such as a nylon strand be wound with the metal in forming coils for annealing. When the coils are completely formed, the strand is withdrawn by pulling it out of the end of the coil, giving in theory a coil in which the convolutions are spaced from each other. A difficulty here is that after the removal of the strand, the convolutions of the coils do not remain evenly spaced. On the contrary there are likely to be many lines in a single coil in which adjacent convolutions touch each other. Also, it will be evident that the removal of the strand will disturb any coating which may have been imposed upon the surfaces of the strip.

The art has sought means which would not need to be removed from the coil but which would maintain a positive separation of the convolutions therein. Among the suggestions which have been made in this connection are the formation of indentations and corresponding protuberances or other configurations along the edges of the strip material itself, or the winding into the coil of a relatively narrow corrugated strip of metal. These expedients, while operative, have not provided an advantageous solution to the problem, especially since they involve considerable expense. The corrugated strip is not reusable in that the heat treatment acts to soften the strip so that the convolutions will readily flatten if the strip is reused, whereas deforming the edges of the coil or strip would necessitate substantial edge trimming.

It is an object of this invention to provide a means which will maintain a positive non-yielding separation of the convolutions in a coil of metal strip, and which will permit adequate access of the annealing atmosphere to all of the surfaces of the strip, but which do not suffer from any of the above defects.

It is an object of the invention to provide a separator for the convolutions of coils, which separator remains in the coil during treatment and is inexpensive in first cost, readily handled, inexpensive to use, reusable, and highly effective in practice.

These and other objects of the invention which will be set forth hereinafter or will be apparent to one skilled in the art upon reading these specifications, are accomplished by that construction and arrangement of parts of which certain exemplary embodiments will now be described. Reference is made to the accompanying drawings wherein:

FIGURES 1 to 7 inclusive are respectively plan views of separators suitable for the purposes of this invention.

FIGURE 8 is a partial perspective view showing a mode of use of any of the separators of FIGURES 1 to 7.

Briefly, in the practice of the invention, it has been found that the objects above set forth may be attained through the use of heat-resistant stand-like members which are longitudinally flexible or bendable and yet are laterally non-yieldable, and which may with advantage be made entirely or principally of wire. The following constructive features are attained: The winding of a single straight wire element into a coil of metal strip would serve the purpose of maintaining a positive separation of the convolutions in the coil, but it would not permit access of the annealing atmosphere to the surfaces of the metal inside the coil. It has been found, however, that if a wire strand is provided with non-collapsible spacing means which act laterally of the wire element to separate the wire from adjacent convolutions at intervals, and if the amount of separation is great enough, the furnace atmosphere can get to the convolu-
tions adequately, and adequate provision will be made for the escape of gases from the strip stock or from a material imposed thereon. If the wire separator is regarded as comprising a basic strand which must be separated from the convolutions at intervals, it may be pointed out that it need not be separated from both contiguous convolutions at the same point. But, it has been found that when the separation be made between the basic strand, or whether the separation be such that there is a space between the basic strand and both convolutions lying on either side of the basic strand, the total effective separation should be at least 0.030 inch somewhere within the area of separation and preferably but not necessarily throughout that area.

Putting this another way, at an area of separation, if the basic strand lies against one convolution, it should be spaced 0.030 inch at least from the contiguous convolution, or if the basic strand is spaced from both convolutions, the spacing on either side thereof should add up to a total spacing of at least 0.030 inch. The areas of actual separation should be greater in length than the areas between the areas of separation. Thus, along the length of the separator, the areas which are open to the passage of gases should be at least as great as the areas which are not open to the passage of gases. The greater the ratio of areas of passage to areas of non-passage, the more efficient the separator will be providing the areas of separation continue to have a passage width which is effectively 0.030 inch or greater. Again, considering the separator as comprising a basic wire strand with spacing means at intervals to hold the strand away from one or both of two adjacent convolutions, the spacing between the holding means should not be so great as to allow the coiled metal to bend appreciably out of a truly helical conformation so as to narrow the passages for gas. The actual spacing of the holding means may be varied somewhat with the thickness of the strip material being coiled, but in general the holding means should not be spaced from each other by more than 4 to 6 inches; and in many cases a much closer spacing is advisable.

In this case the convolution separating means may be visualized as a longitudinally flexible wire or similar strand having at intervals a laterally or transversely rigid spacing means for holding the wire away from one or both convolutions. In FIGURE 1, one form of separating means is shown as consisting of a wire 1 which carries at intervals nodules 2 which comprise the spacing means. The nodules may be made by swaging or upsetting the material of the wire by means of dies. The nodules may also be formed by depositing on the strand 1 at intervals small bodies of weld material as may be done in an electrical welding operation with molten metallic weld rods. Preferably the nodules extend entirely about the periphery of the wire strand 1 and, as indicated above, they should be of such size as to provide in the interstices between nodules, and taking into account the thickness of the strand 1, a gas passegeway or passageways between adjacent convolutions having a thickness of at least 0.0030 inch.

It is possible to obtain a similar result by flattening the wire strand 1 at intervals, providing the flattened portions have different radial orientations as respects the strand; but this is not preferred for the reason that upon reuse of the strand the flattened portions are likely to come into the same or nearly the same orientation, thus diminishing the effective passageway for gases. It will now be evident that somewhat the same effect may be obtained with a pair of strands twisted together as are the strands 3 and 4 of FIGURE 2. If one of the strands is considered the basic strand, the other acts as the spacing means in that it is juxtaposed to the basic strand and coasts with the basic strand to provide spaced apart areas of rigid non-yielding lateral support having an effective width in excess of the width of the basic strand. The structure illustrated in this figure has an advantage of strength and inexpensive production; but although it is less efficient than other forms of separators in that portions of the strands tend in part at least to diminish the effective size of the passageway for the gases, it has been found to be adequate. In this form of separator, the wires should be from 0.030 inch to 0.1 inch in diameter one side only of about 0.030 inch. The "loop" of the helical wires, i.e., the distance between one convolution and the next, should be about 0.10 inch at least.

FIGURE 3 illustrates another form of the invention which comprises a wire strand 5 with nodules or spacing means formed on it at intervals, or distorted, relatively tight windings 6 of another wire. These windings grip the strand 5 tightly enough to maintain their positions despite normal handling, or they may be attached to the continuous strand by welding or otherwise.

Yet another form of the invention is shown in FIGURE 4 where the separating means comprises in essence a series of wire links 7. At each end of each link the wire is formed into a loop 8 which is interconnected with a loop 9 of the next link. The loops may be formed by bending the wire upon itself and either coiling the bent end about the body of the wire, or welding the bent end to the body as indicated at 11.

Yet another form of the invention is that shown in FIGURE 5 where a wire strand 13 is provided with substantially tubular metal nodules 14 at intervals. Since it is desirable to be able to manufacture the separator in a continuous process, the metallic nodules 14 are preferably formed from spaced pieces of sheet metal wrapped about the strand as at 14a and crimped or welded to the strand so as to maintain their positions thereon.

While the separating means of this invention are designed for reuse, it is nevertheless important that they be made cheaply and on available wire forming equipment so that replacement costs will not be high. One way of making a separator means is to employ apparatus which is the same or similar to that employed in the manufacture of barbed wire. A product suitable for use in the practice of this invention, and so made is illustrated in FIGURE 6. This product comprises wire strands 15 and 16 which are twisted together with the interposition at intervals of other individual wire members 17 which are looped about one or both strands. This product is generally similar to barbed wire excepting that the sharpened ends of the spaced looped members are eliminated. Instead, any projecting wire ends may be cut off or bent over against the twisted strands by means of dies.

The looped members 17 are the holding means in this form of the invention, and they must be made of wire or other strand material of sufficient thickness to provide the required passageway for gases, as will be evident in the light of the teachings above.

Yet another form of spacing structure which may be made in a continuous operation is illustrated in FIGURE 7. Here a single wire or strand 18 is first bent to form a bight as shown at 19. The bight is then twisted to form a loop 20, and the loop is bent over so as to lie against the wire strand; and the side portions of the loop are then bent downwardly about the wire strand giving the configuration shown at 21 in that figure. It will be evident that this is another way of nodulizing a single strand.

The term "strand" as used herein in connection with the spacing means of this invention is inclusive of round wire, flat wire, and other strand forms intended to denote a single wire element. The substance of which the separator means are made will be capable of withstanding the annealing temperatures to be employed. As a consequence, the material will normally be metal; but the nature of the metal may be varied in accordance with the requirements. It will be made of iron or steel and should be soft enough so that the coil is not scratched. Stainless steel or other alloys
resistant to oxidation may be employed where the furnace atmosphere is oxidizing toward iron. Where the furnace atmosphere is decarburizing in nature, low carbon metals will be suitable.

In practice, coils are prepared for annealing, preferably but not necessarily by winding them on vertical mandrels such as that shown at 22 in FIGURE 8, while the coils are resting upon a flange or plate-like support 23. The separating means, indicated in FIGURE 8 at 24, may be used adjacent one or both edges of the strip 25 which is being formed into the coil 26. The separating means is kept as close to the coil edge as is feasible; and if the coil has a delicate coating, it may be kept within 1/4 inch of the edge of the strip, as can readily be effected by the use of guides (not shown). The strip and the separating means at one or both edges are coiled together under conditions of sufficient tension to form a stable coil. Depending somewhat upon the nature of the strip being coiled, the spacing means on the separating strand, i.e., the nodules or the additional wire thickness, should be from about 1/4 inch to 6 inches apart. A standard spacing of about 2 inches for the spacing means will be found to take care of most materials.

When the winding of the coil has been finished, the end of the strip 25 will be tucked to the next convolution as by spot welding, or if desired, the coil can be banded. During the annealing operation, which will be carried on in a muffle furnace or annealing box, the coil or coils will be placed in upright position on their ends. Usually there is provided within the muffle or box one or more stools on which the coils rest; and these stools should have their tops grooved or perforated to permit the exit and entry of gases between the convolutions of the coils at the bottoms thereof. Within the limitations set forth above, the spacing means of this invention will provide adequately for access of the annealing atmosphere to the surfaces of the stock throughout the convolutions thereof as well as for the escape of gases from these surfaces or from materials imposed thereon. In some furnaces or in some parts of annealing cycles, the gases may move into or out of contact with the convolutions by convection or diffusion; but the invention is especially applicable to annealing operations in furnaces of such type that entering gases, recirculated gases or gases within the muffle or box are blown directly against the ends of the coils.

It has been found that a single separator such as taught herein wound into a coil close to an edge of the strip being coiled will maintain the convolutions in a state of positive separation. At the same time the separating means of this invention will not disturb any coating already on the surfaces of the strip.

In starting a cooling operation such as that shown in FIGURE 8, the separating means may, if desired, be attached to the leading end of the strip as by a spot weld. After the coil has been wound and fastened, any excess length of the separating means may simply be wound loosely about the coil to facilitate reuse. After the annealing treatment, and when the coil has cooled, the strip will be unwound from it and recoiled for use or for a subsequent manufacturing operation, while the separating means will be withdrawn simultaneously and separately coiled for employment in the next annealing operation.

Modifications may be made in the invention without departing from the spirit of it, and it is not intended that the invention be limited other than in the manner set forth in the claims which follow.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a method of annealing coils of strip in an open coil annealing operation, which comprises coiling a length of metallic strip and simultaneously during the formation of the coil winding a separator between the convolutions thereof, and thereafter passing an annealing atmosphere between the separated convolutions of the coil while the separator is maintained between the said convolutions, the improvement which comprises utilizing a separator comprising a longitudinally flexible metallic wire strand having spacing means juxtaposed thereto throughout the effective length of the strand, the said spacing means being formed from metal and coating with the said strand to define spaced apart, laterally rigid and non-collapsible spacers which separate adjoining convolutions of the coil by a distance of at least about 0.030 inch greater than the thickness of the said strand, thereby providing sufficient space between said strand and the adjoining convolutions of the coil for the flow of the annealing atmosphere therebetween.

2. The method claimed in claim 1 wherein said spacing means contact at least one of the adjoining convolutions at intervals not less than about 1/4 inch apart and not more than about 6 inches apart.

3. The method claimed in claim 2 wherein said spacing means comprise a second metallic wire strand twisted with the first named wire strand.

4. The method claimed in claim 2 wherein said spacing means comprises spaced windings of wire surrounding said strand.

5. The method claimed in claim 2 wherein said wire strand is composed of separate link members, said link members having interengaging loops at their ends, which loops define said spacing means.

6. The method claimed in claim 2 wherein said spacing means comprise sleeve-like members surrounding said wire strand.

7. The method claimed in claim 2 wherein said wire strand is formed into twisted loops at spaced apart intervals, which loops are bent over and conform to said strand to define said spacing means.

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