

July 13, 1965

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3,194,275

SPIRALLY WOUND PAPER TUBE

Filed Jan. 15, 1963

2 Sheets-Sheet 1

FIG-1

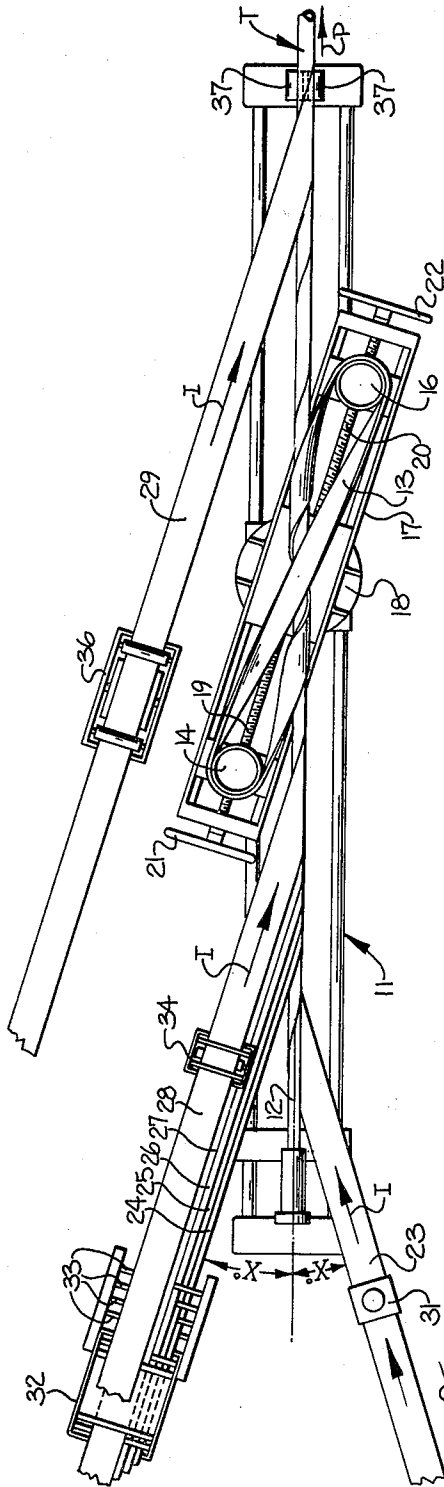
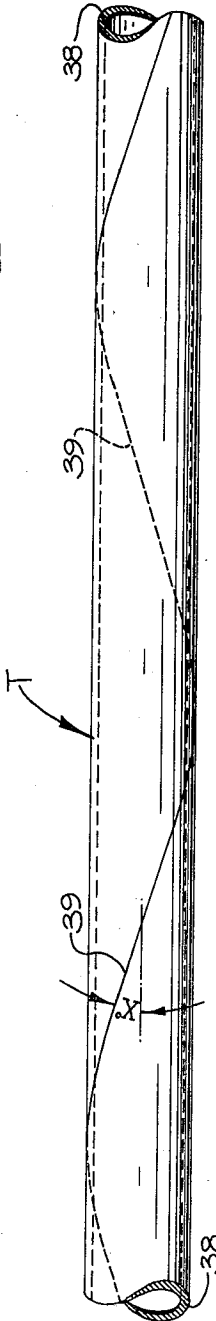


FIG-2



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2 Sheets-Sheet 2

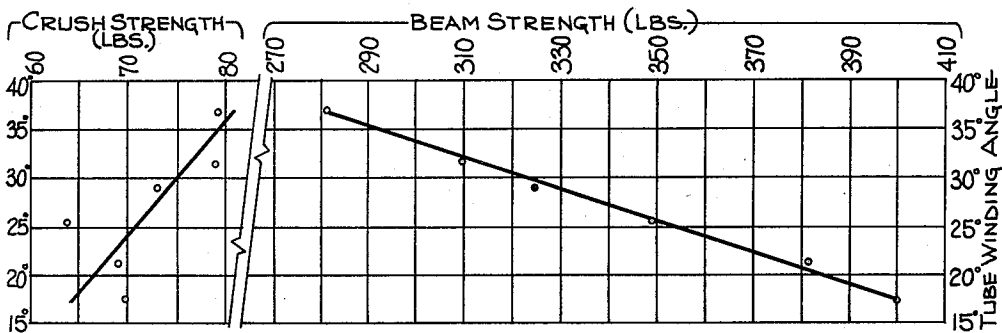


Fig-3

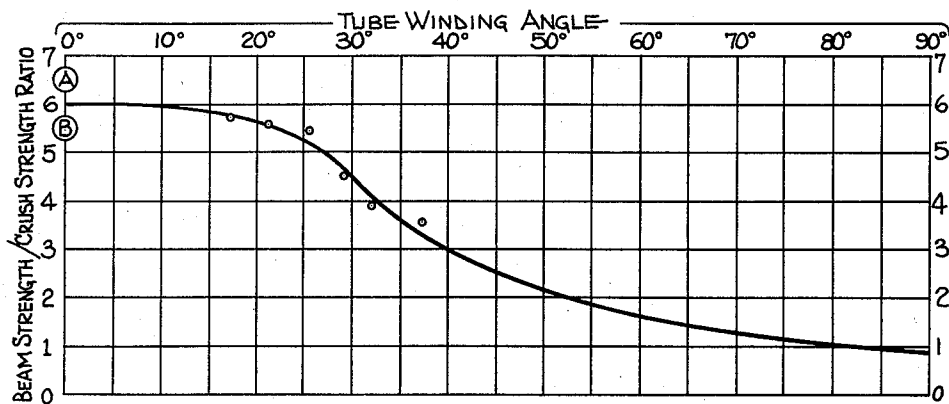


Fig-4

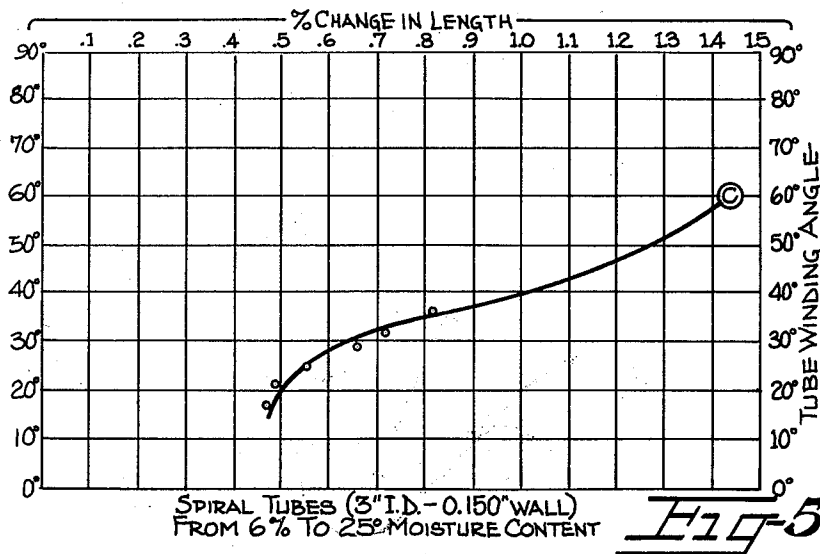


Fig-5

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SPIRALLY WOUND PAPER TUBE

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ville, S.C., assignors to Sonoco Products Company,
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3 Claims. (Cl. 138—144)

This invention relates to paper tubes and more particu-
larly to a spirally wound paper tube for the winding of
sheet material such as textile material and the like.

It is a common practice today to utilize wound, multi-
ply paper tubes as carriers or cores for sheet material
such as paper, cloth, carpet material and the like. Such
tubes or cores used for the winding of heavy sheet mate-
rial such as carpet material are required to be of high
strength to resist crushing and buckling when subjected
to the forces generally encountered when wound with
such carpet material and the like. Carpet material is
generally wound in long lengths on its tubular carrier
producing a very heavy load and although the spiral tube
of the invention may be used for the winding of any
material where a strong carrier is desired, it is particu-
larly useful for the winding of such heavy carpet material.

Paper tubes in use today as a carrier for long lengths of
carpet material are required to have both a high resistance
to radial crushing and a high beam strength which, as is
well known, is measured by the ability of the tube to with-
stand a centrally positioned load with the tube supported
only at its ends. Such present day tubes or cores are
generally made by convolutely winding a paper web into
a tube as a convolutely wound tube has by its nature a
beam strength greatly in excess of a spirally wound tube
together with a satisfactory degree of crush strength.
Furthermore, the convolute tube when subjected to a
beam load fails by a buckling or pleating of its walls
whereas the spiral tube fails by splitting along its spiral
tube seam or what is known as "seam splitting." Such
seam splitting is highly undesirable in that it pinches the
material wound on the core with resulting damage to the
material.

Primarily because of its lower cost of production, there
has been a continuous search for a spiral tube which will
provide the beam and crush strength of the convolutely
wound tube for use in such areas of use as described
above. While spirally wound tubes have been well known
from the earliest times, a suitable spiral tube for such a
use has not heretofore been obtained. In addition to the
high radial crushing strength of spiral tubes in compari-
son with convolute tubes, their uniform concentricity and
radial dimensional stability, the low production costs com-
mon to the spiral tube has intensified the search all to no
avail. Some progress has been made in increasing the
beam strength of such spiral tubes by increasing the wall
thickness of the tube and with the use of stronger paper
but the resulting tubes still have far less than the desired
strength and the slight strength increase obtained is offset
by the high cost and increased bulkiness of the tubes.

Accordingly, a primary object of this invention is to
provide a new and novel spiral tube having a high beam
strength and high crush strength.

Another object of this invention is to provide a new and
novel spiral tube for use as a core or carrier for heavy
sheet material such as carpet material and the like.

A further object of this invention is to provide a new
and novel spiral tube for use as a core for heavy sheet
material which tube has a beam strength and crush
strength substantially the same as a corresponding con-
volutely wound tube and which fails by buckling rather
than by seam splitting so as to avoid damage to the mate-
rial wound on the tube.

Still another object of this invention is to provide a

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new and novel spiral tube having a high degree of dimen-
sional stability so as to remain substantially constant in
length throughout changes in moisture content.

This invention further contemplates the provision of
a new and novel spiral tube wound at a winding angle
not heretofore considered possible which is characterized
by a beam strength and crush strength substantially equiv-
alent to that of a corresponding convolutely wound tube,
which utilizes spiral tube winding equipment presently
available and which may be manufactured from readily
available inexpensive materials at a relatively low produc-
tion cost.

Other objects and advantages of the invention will be-
come apparent from the following description taken in
connection with the accompanying drawings.

In general, the objects of the invention and related ob-
jects are accomplished by providing a plurality of strips of
paper which are spirally wound in overlapping relation-
ship with adhesive therebetween to form a spiral tube.

The paper strips which contain fibers common to paper
have the fibers extending lengthwise in the direction of the
longitudinal axis of the paper strips or what is generally
referred to as the "paper machine direction." The wind-
ing angle of the paper strips is within the range of be-
tween 15 to 27 degrees and preferably an angle of ap-
proximately 17 degrees so that the long axis of the strips
and consequently the fibers in the strips approach closely
a parallel relationship with the axis of the tube to provide
a tube of high beam strength and high crush strength
together with a high degree of dimensional stability.

The novel features which are believed to be character-
istic of the invention are set forth with particularity in the
appended claims. The invention itself, however, both as
to its organization and method of operation may be best
understood by reference to the following description taken
in conjunction with the accompanying drawings in which:

FIGURE 1 is a plan view of a spiral tube winding ap-
paratus illustrating the winding of the tube of the inven-
tion;

FIGURE 2 is a side view of a tube constructed in ac-
cordance with the invention;

FIGURE 3 is a graph illustrating the relationship be-
tween tube beam and crush strength and tube winding
angle;

FIGURE 4 is a graph illustrating the relationship be-
tween the ratio of tube beam and crush strength with tube
winding angle; and

FIGURE 5 is a graph illustrating the relationship be-
tween tube length change under varying moisture condi-
tions with tube winding angle.

Referring now to the drawings and to FIGURES 1, 2
in particular, there is shown in FIGURE 2 a spiral tube
designated generally by the letter T which is constructed
in accordance with the invention. The spiral tube T is
wound on slightly modified conventional spiral tube wind-
ing apparatus portions of which are shown in FIGURE 1.
The apparatus of FIGURE 1 includes a frame designated
generally by the numeral 11 arranged to support a wind-
ing mandrel 12 around which a continuous belt 13 is
looped in the conventional manner for advancing the tube
T in the direction of the arrow P. The belt 13 is mounted
in the conventional manner on drums or pulleys 14, 16
at least one of which is rotatable by suitable driving means
and the pulleys 14, 16 are arranged for adjustable sliding
movement on a frame 17 positioned for angular adjust-
ment on a base 18. The spacing between the drums 14,
16 is adjusted by means of threaded shafts 19, 20 arranged
to be manually rotated by means of hand wheels 21, 22
respectively for belt tensioning purposes.

The spiral tube T of the invention is wound from a plu-
rality of plies or strips of paper containing fibers common
to paper and, in the specific embodiment illustrated, the

paper strips are seven in number including an inner strip 23, intermediate strips 24, 25, 26, 27, 28 and outer strip 29. The paper strips 23 through 29 are formed in a conventional manner on a paper making machine but all of the strips employed in the construction of the tube T of the invention are made by the well-known technique wherein the fibers of the strips lie substantially parallel with the longitudinal axis of the strips or in the direction of the arrows I. In other words, the paper strips 23 to 29 have their longitudinal axis parallel to what is referred to as the "paper making machine direction." This is accomplished by cutting the paper web parallel to the direction the web travels during its formation on the paper machine to form the strips 23-29.

In the manufacture of spiral tubes under present day practice, the winding angle, identified in FIGURES 1, 2 as X° , is generally within the range of 50 to 80 degrees and as has been explained tubes made at a winding angle within this range do not have the desired beam strength. In accordance with the invention, the winding angle X° at which the strips 23 to 29 are wound on the winding mandrel 12 is within the range of 15 to 27 degrees preferably within the range of 17 to 22 degrees. In the specific embodiment illustrated, the winding angle X° is approximately 17 degrees as it has been found that an angle of approximately 17 degrees produces the novel high strength characteristic desired in the tube T. This high strength is expressed as a beam strength to crush strength ratio as shown in the graph of FIGURE 4 and as will be explained hereinafter.

As shown in FIGURE 1, the inner paper strip 23 which forms the inner ply of the tube is wound on the mandrel 12 being brought in from one side of the spiral tube winding machine and has a suitable lubricant applied thereto by a suitable lubricating device 31. Paper strips 24 through 27 which are preferably wound onto the mandrel from the side opposite the inner strip 23 as shown are immersed in a glue bath contained in a glue pot 32 which is provided with scrapers 33 for removing excess glue from the strips as shown in FIGURE 1. Glue is not applied to the intermediate strip 28 and it is brought in dry over a set of guide rolls 34.

The top paper strip 29 is brought in from the same side of the mandrel as the intermediate strips and is advanced over a glue applicator 36. Strip 29 is then wound together with the other strips on the mandrel below the belt 13 as shown. Suitable support rollers 37 are provided on the spiral tube winder as shown in FIGURE 1 which not only aid in compressing the wound paper strips together for increased adherence but additionally serve to prevent the mandrel 12 from moving out of alignment as a result of the winding forces exerted by the belt 13 on the mandrel.

The paper strips 23 through 29 therefore form the tube T having a multi-ply side wall 38 and on its outer surface, a spiral seam 39 which as a result of the selected winding angle X° lies at an angle of approximately 17 degrees relative to the longitudinal axis of the tube as shown in FIGURE 2.

The novel results accomplished with the spiral tube of the invention are shown clearly in FIGURES 3-5 and in Table I below:

TABLE I

Paper Strip Width (inches)	Winding Angle (degrees)	Crush Strength (lbs.)	Beam Strength (lbs.)	Beam Strength/ Crush Strength Ratio
7½	37¼	79	281	3.55
8	32	79	310	3.93
8¼	29	73	325	4.45
8½	25½	64	349	5.45
8¾	21¾	69	382	5.54
9	17¾	70	400	5.70

The results shown in Table I were obtained by winding multi-ply spiral tubes having a 3" inner diameter and a 0.150" wall thickness at winding angles ranging from a maximum of 37¼° to a minimum of 17¼°. The paper strip widths, of course, vary in accordance with the winding angle. The physical limitations of the spiral tube winding machine would not permit the winding angle to be reduced below approximately 15 degrees as at this point the length of the winding belt and the spacing of the belt drums for winding a tube at this winding angle became prohibitively large. In addition to the beam strength test as described above, a crush strength test was conducted on specimens of these various tubes both of which tests are considered in the industry as standard. As is well known, the crush strength test is carried out by loading a standard 3" length of tube between flat platens until failure.

The results of the beam strength and crush tests are tabulated in Table I and are plotted on the graph shown in FIGURE 3. It will be noted that throughout the winding angle range of approximately 37 to 17 degrees there was a 43% increase in beam strength with an accompanying crush strength decrease with only about 12%.

A ratio of beam strength to crush strength was utilized as representative of both of the desirable strength factors in a tube of the invention and FIGURE 4 shows the various ratios plotted on a graph. As explained above, the last beam strength to crush strength ratio obtained was at the 17 degree angle approximately as the physical limitations of the spiral tube winding machine militates against the winding of spiral tubes to any substantial degree below this winding angle. Points A and B plotted at the zero winding angle position of the graph of FIGURE 4 are strength ratio figures for two convolutely wound tubes of the same diameter and wall thickness on which the same tests were run and the strength ratios obtained can be considered to be those corresponding to a theoretical spiral tube having a zero degree winding angle.

It will be noted that throughout the winding angle range of approximately 17 to 27 degrees the beam strength/crush strength ratio was substantially the same and approaches substantially that of the convolute tube samples A and B. The beam strength/crush strength ratio dropped off sharply above a winding angle of approximately 27 degrees and has been explained above, a winding angle below approximately 17 degrees could not for all practical purposes be measured. It will also be noted that the beam strength/crush strength ratio of the tubes appeared to be at a maximum at a winding angle of between 17 and 22 degrees.

In addition to the high strength characteristics obtained at the low winding angles of the tubes of the invention, it was noted that the seam splitting upon failure common to spirally wound tubes subjected to a beam test did not occur but rather that the tube buckled as in the convolutely wound tube thereby avoiding the possibility of injury to material wound on the tube. This is considered to be a completely new and unexpected result and considerably enhances the commercial appeal of the tubes.

The novel results of the invention are believed to be obtained as a result of the close approach of the fibers in the paper strips used to wind the tube T to a parallel relationship with the longitudinal axis of the tube T. As a result of this positioning of the fibers of the strips forming the tube, a high resistance is offered to collapse of the tube under a beam load such as the beam strength of a convolutely wound tube which is wound with the fibers extending transversely of the "cross wound" paper sheet or, in other words, parallel to the longitudinal axis of the convolute tube. The tube T of the invention can be said to have strength characteristics closely approximating those of a convolutely wound tube.

Other new and unexpected results developed when spirally wound paper tubes wound at low winding angles

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in accordance with the invention were subjected to dimensional stability tests. In conducting one such dimensional stability test on the tubes of the invention, six spiral tubes having an inner diameter of 3", a 0.150" wall thickness and a length of 30" were wound at winding angles of 36°16'; 31°55'; 28°54'; 25°36'; 21°49'; and 17°16' using seven plies of paper. In the test, the moisture content of these tubes was changed from 6% to 25% as the change in tube length resulting from this moisture content change was measured.

The resulting percent changes in length of these tubes are plotted on the graph of FIGURE 5 and it will be noted that the percent change in tube length varies from a figure of 0.82 at the higher tube winding angle of 37°16' to a percent change in length figure of 0.47 at the lower winding angle of 17°16'. Here again as in the beam strength/crush strength ratio graph the reduction in the percent change in tube length becomes increasingly small as the tube winding angle falls within the 15 to 27 degree range so that, as shown in FIGURE 5, a curve drawn through the plotted points indicates a gradual decrease in curve slope at these lower tube winding angles.

Point C in the graph of FIGURE 5 indicates the percent change in length under the same moisture content change specified above in a spirally wound tube having an inner diameter of 3½", an outer diameter of 4" and a length of 30" but wound at a winding angle of 59 degrees. It will be noted that the length change with moisture content change at the higher winding angle far exceeds that of the winding angle range of the invention. The graph of FIGURE 5 thus reveals clearly that a substantial increase in dimensional stability is obtained at the lower angles of wind and the maximum dimensional stability is obtained within the range of winding angles comprising the invention.

It can be seen with the novel construction of this invention that a multi-ply spirally wound paper tube wound at winding angles not heretofore considered possible or contemplated produces completely new and unexpected results in that a spiral tube is provided having strength characteristics heretofore unobtainable in a spiral tube and obtainable only with a convolutely wound paper tube. This strength increase in the tube of the invention does not require an increase in paper nor in paper strength but is due primarily to the unusually low tube winding angle together with the use of paper strips having their fibers oriented so as to approach closely a parallel relationship with the longitudinal axis of a tube wound therefrom. The range of winding angles contemplated by the invention appear to provide the maximum strength improvement desired for spiral tubes and at the same time are within the practical considerations involved in the manufacture of such tubes.

Not only does the low angle of wind spiral tube of the invention have improved strength characteristics but seam splitting common to spiral tubes occurring upon tube

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failure which is generally injurious to material wound thereon is eliminated and the tube buckles in the nature of a convolute tube. Furthermore, unusually high dimensional stability is obtained in the spiral tube of the invention in that changes in moisture content produce only very small length changes far less than those common to spiral tubes wound at the higher winding angles considerably widening the application for such spiral tubes wherein length changes must be held to a minimum.

While there has been described what at present is considered to be the preferred embodiment of the invention, it will be understood by those skilled in the art that various changes and modifications may be made therein without departing from the invention and, therefore, it is the aim of the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

Having thus described the invention, what is claimed is:

1. A spirally wound paper tube comprising, a plurality of fiber containing paper strips spirally wound in overlapping relationship with adhesive therebetween to form a spiral tube, each of said paper strips having its fibers lying generally in the direction of the longitudinal axis of said strips, said strips being wound at a winding angle of between about 15 to 25 degrees thereby providing a dimensionally stable tube of high beam strength and crush strength.

2. A spirally wound paper tube comprising, a plurality of fiber containing paper strips spirally wound in overlapping relationship with adhesive therebetween to form a spiral tube, each of said paper strips having its fibers lying generally in the direction of the longitudinal axis of said strips, said strips being wound at a winding angle of between 17 to 22 degrees thereby providing a dimensionally stable tube of high beam strength and crush strength.

3. A spirally wound paper tube comprising, a plurality of fiber containing paper strips spirally wound in overlapping relationship with adhesive therebetween to form a spiral tube, each of said paper strips having its fibers lying generally in the direction of the longitudinal axis of said strips, said strips being wound at a winding angle of approximately 17 degrees thereby providing a dimensionally stable tube of high beam and crush strength.

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