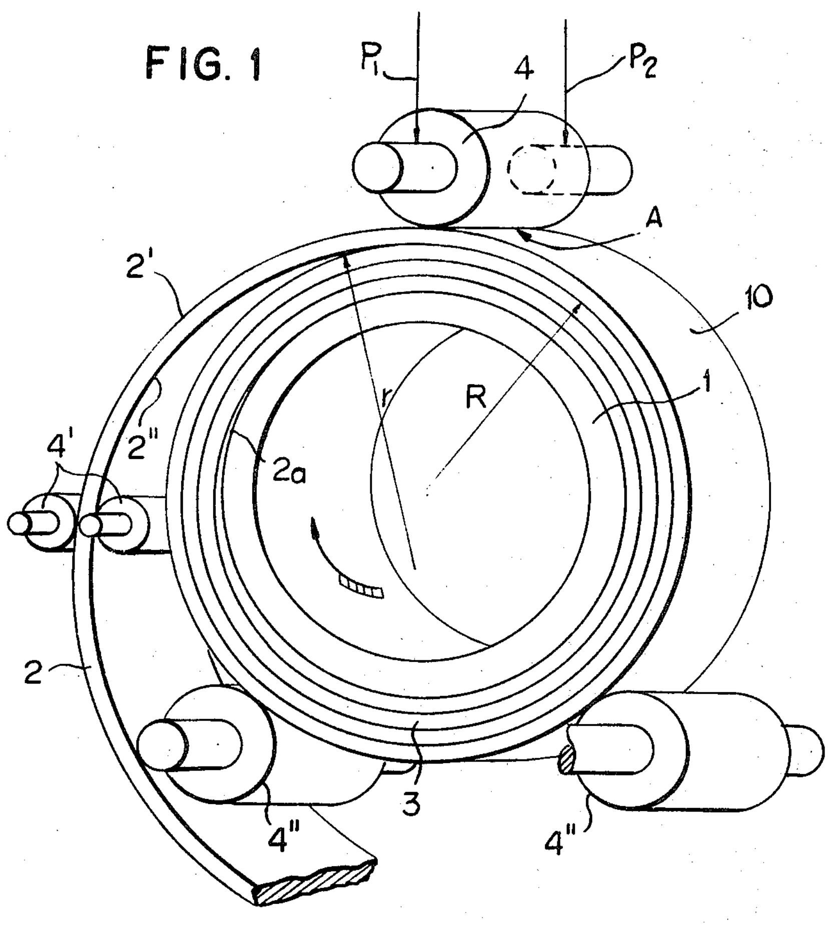
METHOD OF FORMING A WOUND TUBULAR MEMBER

Filed Sept. 13, 1967 3 Sheets-Sheet 1

FIG. 1



INVENTOR.
HIDEO SAGARA
BY
McGlew and Toren
Attorneys

FIG. 2

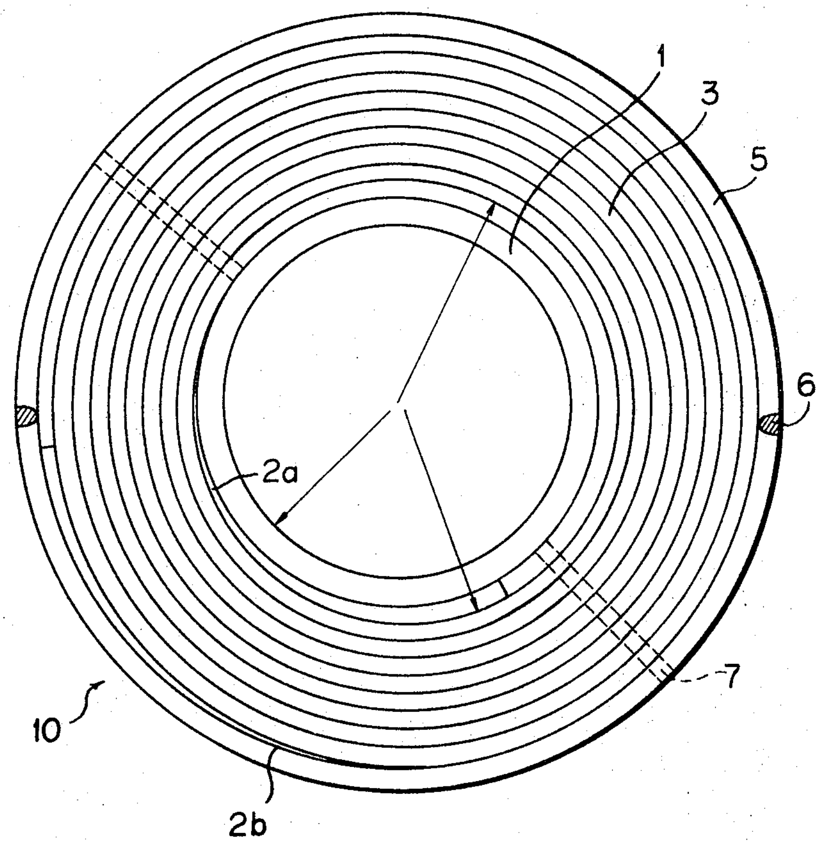
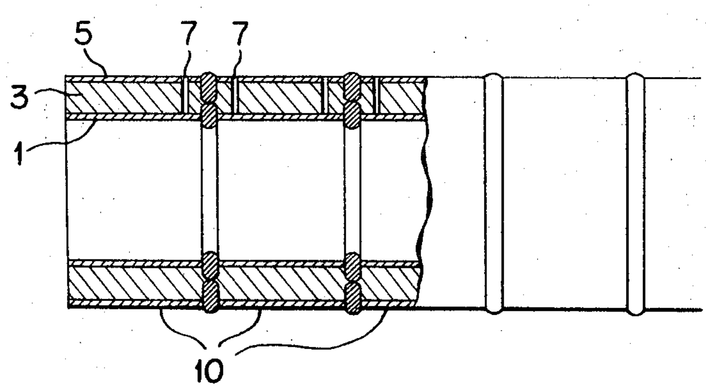


FIG. 3



INVENTOR.
HIDEO SAGARA
BY
Mulglew and Tarew
Attorneys

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Fig. 4

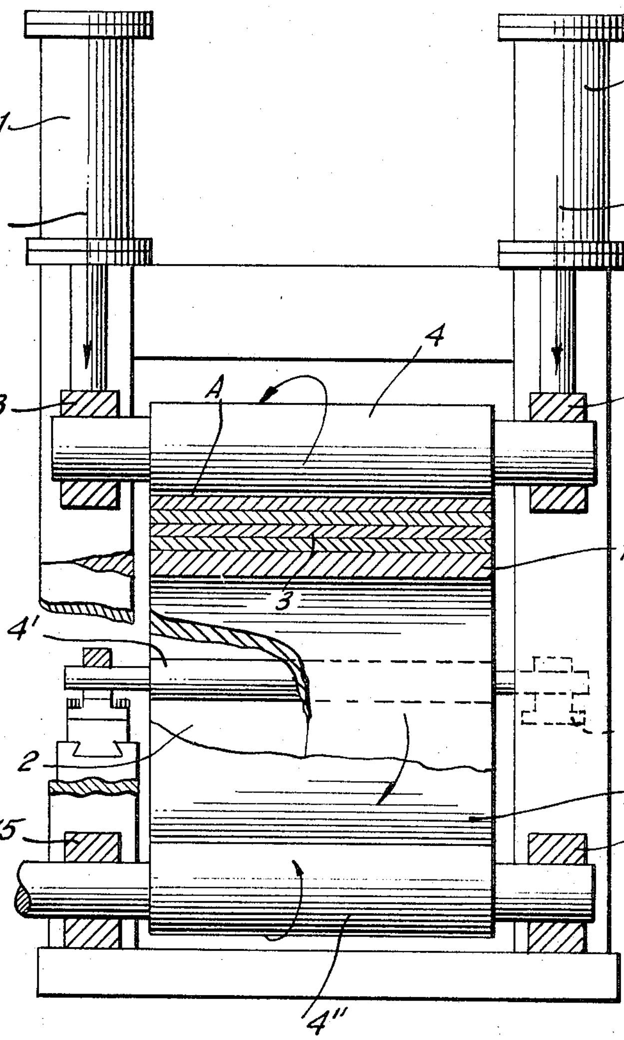
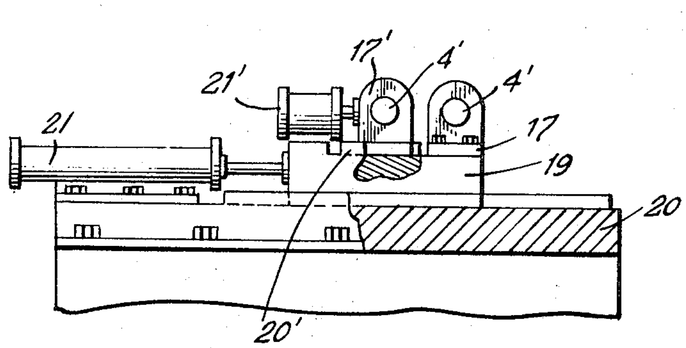


Fig. 5



INVENTOR.
Hideo Sagara

United States Patent Office

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METHOD OF FORMING A WOUND TUBULAR MEMBER

Hideo Sagara, Hiroshima-shi, Japan, assignor to Mitsubishi Jukogyo Kabushiki Kaisha, Tokyo, Japan

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Int. Cl. B21d *39/04*

U.S. Cl. 29—473.9 9 Claims

ABSTRACT OF THE DISCLOSURE

A tubular member adapted to withstand high internal pressure formed of a hollow core member, a continuous strip of metal having a thickness greater than 5 mm. tightly wound in overlapping layers about the core member and an outer cover member disposed about the outer layer of the strip of metal for securing the spirally wound metal in place.

A method of manufacturing multi-layer tubular members comprising feeding metal strip from a coil of wound metal strip to a winding station, continuously spirally winding the metal strip in overlapping layers, applying pressure to the strip at the winding station, and securing the outer edge of the metal strip in place against movement. While feeding the metal strip to the winding station, it is given a radius slightly greater than the radius it had in the coil before delivery to the winding station and the outer surface of the strip is slightly shortened while the inner surface of the strip is slightly elongated at the winding station to assure the proper engagement of the overlapping layers during the winding process.

Apparatus for spirally winding strip metal comprising a pressure roll for urging the strip metal into a coil, feed rolls for feeding the strip material to the pressure roll and combining with the pressure roll to increase the radius of the strip material immediately preceding its application to the coil, and outwardly displaceable means for supporting the coil as it is wound and for maintaining the coil in contact with the pressure roll.

SUMMARY OF THE INVENTION

In recent years there has been an increased use of high pressure processes in industry, particularly in the chemical industry, and these processes have required vessels and pipelines capable of withstanding high internal pressures at increased diameters. As the diameters of vessels and pipelines have increased, it has become increasingly more difficult to form these containers from metal plate. The equipment required to form the walls or shells of these vessels and pipelines from metal plate is quite large and expensive.

It has been considered advantageous to construct high pressure vessels and pipes by spirally winding a strip of high tensile steel approximately three to four mm. in thickness and about 1600 mm. wide about a cylindrical core. After constructing these individual units, they can be joined together by welding to form a high pressure pipeline or by adding closure means to construct a high pressure vessel. Because relatively thin sheet steel can be easily obtained and wound to large diameters, it has provided a simple, safe and effective high pressure tubular

member which does not require any extensive and expensive forming means for shaping the walls of the member as would be the case if relatively thick steel plate were used.

Accordingly, in the construction of chemical plants and other facilities which require high pressure vessels and/or pipes, spirally wound tubular members have become increasingly popular because of the inability to form the required tubular member from a single layer of steel plate because it is difficult to obtain the steel plate in such thicknesses and also because of the size and cost of the facilities required to form such plate into a tubular shape. Another advantage of spirally wound tubular members is that they require no longitudinal seam welding as compared to plate members and therefore the problems involved in heat treating the longitudinal welds is avoided. Because of the problems involved in forming tubular members of thick steel plate, the use of spirally wound multi-layer tubular members has become increasingly popular.

In the manufacture of spirally wound multi-layer tubular members having a considerable length and thickness, if relatively thin sheet metal is used, it must be wound a great number of times to provide the desired thickness and, if necessary, the tubular members must then be buttwelded if a member of increased length is required. When the sheet metal of a thickness of 4 mm. or less is used, padding must be applied to the ends of the multi-layer tubular members before they can be welded together. Because of this characteristic, the welding time needed for joining multi-layer tubular members is considerably longer than is required for spirally winding the members, and, as can be appreciated, the time required to weld the joining pipes will be in inverse proportion to the thickness of the sheet steel employed in winding the pipe. Moreover, when the sheet metal being wound is relatively thin, such as on the order of the size mentioned above, the thermal conductivity of the member is poor because of the great number of interfaces involved. Due to the poor heat conductivity characteristics of thin sheet metal, the heat treatment of the welded points of the members is a very slow process since the tubular members must be heated uniformly at a rather slow speed to avoid the development of any excess internal stress in the spirally wound layers. Further, in heat treating tubular members formed of thin sheet metal, a complete facility must be installed and the operation takes a considerable time during which the surface of the multi-layer sheet metal member becomes oxidized.

The disadvantages just described for thin sheet metal vary directly with the length and, more particularly, with the thickness of the tubular member formed.

These disadvantages which stem from the use of thin sheet metal in spirally wound multi-layer tubular members can be reduced or eliminated when the sheet metal is increased above 5 mm. up to a thickness of about 12 mm. In practice, however, as the thickness of the sheet or plate metal increases, it becomes more difficult to wind or coil it in a multiple number of layers, particularly when it is in a cold condition.

Moreover, it is difficult to obtain from a producer coils of plate metal having a thickness on the order of 12 mm. which has been descaled, smoothed, and heattreated with both edges trimmed to a desired width. For purposes of the invention, the sheet or plate metal must be in the form of a long strip so that it can be wound continuously about a tubular core forming multi-layer member, and when strip material is mentioned herein, it refers to a continuous length of sheet or plate material and is not limited to any specific ranges of thickness. When sheets of steel plate, which have been treated and shaped as mentioned above, are obtained and welded together in the form of a strip, the bending strength and elasticity of the strip is quite high (for example, in the case of a strip of steel having a thickness of 12 mm., the winding force is between 16 to 64 times as great compared with that required for winding similar steel material which is only 3 to 4 mm. in thickness). As a result, when such material is wound, gaps or open spaces are apt to develop between the layers and as the gaps increase in size, excess tensile stress develops about the outer peripheral surface of each layer. If the layers of the tubular member are stressed in the winding process, its ability to withstand tensile stress when exposed to internal pressure will be reduced.

The present invention provides a method of spirally winding a strip of relatively thick steel material in which the disadvantages mentioned above are avoided. In the present invention, the strip of steel material is initially wound in a coil of given curved configuration having a radius approximately equal to the radius of the tubular member to be formed. In spirally winding the tubular member, the steel material is unwound from the supply coil and is pressed forcibly at the winding point or winding station by means of a pressure roller. In the course of winding the steel material onto the tubular member, if it is necessary to do so, the edges of the strip can be displaced laterally by the force exerted by the pressure roller whereby the edges of the strip, in successive layers, can be properly aligned.

The present invention is based on the use of a strip of steel having a thickness greater than 5 mm. and with its leading and trailing edges which contact the core member and the cover plate of the tubular member respectively fashioned in a tapered wedge-shaped configuration to properly contact these respective members and avoid the developement of gaps during the winding operation. When the strip has been completely wound on the core and its outer or trailing edge has been locked in place by means of a cover member, a plurality of bores or openings may be formed through the cover member and the multiple layers terminating at the inner surface of the inner layer. If individual tubular members, constructed according to the present invention, are to be welded together into a composite member for use as a pipe or vessel, the openings through the layers of the tubular member are used for circulating an inert gas through the layers during heat treatment of the welded joints. The circulation of inert gas replaces the air trapped between the layers and prevents oxidation of the contacting surfaces of the layers. Additionally, measuring instruments may be inserted into the openings to determine and maintain the proper temperatures in the various layers.

One of the primary characteristics of the present invention is the use of steel strip which is supplied in a coil having curved configuration similar to that in which the tubular member is to be formed. The coiled shape of the strip permits it to be closely wound about the core requiring a relatively small amount of pressure at the winding station. Due to the curved configuration of the steel strip employed and the manner in which it is fed to the winding station, the outer surface of the steel material is slighly shortened and the inner surface is slightly elongated as it is wound onto the tubular member. In this way the steel strip can be easily wound in the same fashion as if tensile stress were applied to a flat strip of material.

In the event there is any displacement of the edge of the strip being applied, as compared to the edge

already wound on the core, it is possible to exert an increased force on one half of the roller at the winding station and thereby laterally displace the edge as it is wound. In such an arrangement the portion of steel strip receiving the higher pressure will be wound by shorter length and moved into proper alignment with the edge of the underlying layer.

During the winding operation to prevent any slipping between the layers of steel strip and avoid the formation of gaps between adjacent layers, the force provided by the pressure roller is sufficient to develop a frictional force on the steel to avoid any slippage, or, as an alternative, the end edges of the layers may be tack-welded as each layer passes the winding station.

In spirally wound tubular members using relatively thick steel strip according to the present invention, the distance between the abutting surfaces of the layers is increased over that where thinner strip was used. When a plurality of these tubular members are joined end-to-end, a larger diameter welding rod and a continuous welding operation may be employed which provides a considerable advantage over the prior method. During the welding operation when the individual layers are heated and expand, the air between adjacent layers can be discharged through the openings formed in the tubular members. When alloy steel is utilized as the strip material, the inert gases can be introduced between the layers for heat treating the welded joints. Moreover, the temperature of the individual layers can be measured by inserting an instrument into the radial openings in the tubular member to maintain a proper temperature range during the heat treating process. Further, because of the increased thickness of the steel material used, the thermal conductivity of the tubular member is improved and as a result the time for heat treating is decreased. Additionally, the inert gases introduced in the openings of the tubular member displaces any air between the layers and reduces the possibility of oxidation of the abutting surfaces of the layers.

Accordingly, the primary object of the present invention is to form a high pressure tubular member by spirally winding a relatively thick metal strip of steel to form the member.

Another object of the invention is to employ a metal strip having curved configuration or coiled to a radius approximating that of the tubular member prior to its use in forming the member.

Still, another object of the invention is to form a spirally wound tubular member in which the overlapping layers are in close engagement and the layers are locked against sliding or dislacement after the member has been wound.

A further object of the invention is to increase the radius of curvature of the metal strip immediately preceding the winding station.

Another object of the invention is to provide the metal strip with a tapered leading and trailing edge as it is fed onto the tubular member whereby the strip forms a properly cylindrical configuration.

Still, another object of the invention is to provide openings from the exterior of the tubular member through the wound layers for the introduction of inert gas during the heat treating operation.

Another object of the invention is to form a tubular member which can be integrally attached in axial arrangement with similar members to provide either a pipe line or a vessel for high pressure fluids and the like.

A further object of the invention is to produce spirally wound tubular members made of metal strip of an increased thickness as compared to that previously used whereby the cost of forming the members is reduced and the apparatus required for forming the member is also kept to a minimum.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a somewhat schematic illustration of the apparatus employed in forming multi-layer tubular members in accordance with the present invention;

FIG. 2 is a transverse view of a tubular member formed in accordance with the present invention;

FIG. 3 is a longitudinal view, partly in section, of a composite tubular member formed by a number of tubular members illustrated in FIG. 2;

FIG. 4 is a side view partly in section of the apparatus illustrated in FIG. 1; and

FIG. 5 is a side view, partly in section, showing in detail a portion of the apparatus in FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. 1 a tubular member **10** is shown in the process of being formed by a metal strip **2**, such as steel, wound about a core member **1**. The metal strip is 12 mm. in thickness and 1800 mm. in width with a tensile strength of 60 kg. per $mm.^2$ and is supplied in a coil having a radius of curvature approximating that of the tubular member to be formed (the metal strip supply coil is not shown in FIG. 1). From the supply coil the metal strip **2** passes between a pair of rollers **4'** and is fed to a pressure roller **4** which forms the winding station A, that is the position at which the metal strip begins to be coiled onto the core member **1**. The pressure roller **4** exerts an inwardly directed pressure against the metal strip coiled onto the tubular member as indicated by the arrow. Since the metal strip **2** is supplied in a curved configuration when it is fed to the winding station A, a relatively small application of pressure by the roller **4** is required to wrap the material about the core member **1**. At the opposite side of the tubular member **10** from the winding station A, a pair of outwardly displaceable rollers **4''** are located for rotating the tubular member as it is being formed and for keeping the member in contact with the pressure roller **4**.

The position of the rollers **4'** is adjustable so that the metal strip **2**, as it is fed toward the winding station A, can be given a radius of curvature *r* slightly greater than the radius R it is to assume on the tubular member. If, for example, the radius R of the metal strip on the tubular member 10 equals 2000 mm., then the radius *r* equals about 2180 mm. as it is introduced to the winding station A. The increased curvature imparted to the metal strip causes the outer surface **2'** of the steel material to assume a slightly flattened configuration immediately preceding the winding station A and the inner surface **2''** at the same location becomes slightly elongated in the amount of about 0.25/1000 cm./cm. In other words, as the steel material **2** is fed onto the tubular member at winding station A, its outer surface **2'** is shorter relative to its inner surface **2''** by an amount of 0.50/1000 cm./cm. If it is assumed that the modulus of elasticity of the steel material is $E=2\times10^6$ $kg./cm.^2$, then the tensile stress is $E\times0.25/1000$ and equals 500 $kg./cm.^2$ at the inner surface of the metal strip at its point of application to the tubular member, winding station A.

Any tendency for one layer to slip with respect to the other at the winding station A is prevented by the frictional force imparted by the pressure roller **4**, which exerts a force of about 300 tons. Additionally, slipping can also be prevented by tack welding the layers together after they pass the winding station A. After the metal strip **2** passes the winding station A and forms a layer **3** on the tubular member **10**, a stress of 500 $kg./cm.^2$ is developed in the entire section of the strip as it assumes the radius (R) of 2000 mm.

If during the winding process the edge of the metal strip delivered to the winding station A should extend beyond the edge of the layers **3** already wrapped around the core member **1**, the magnitude of the force exerted by the roller **4** can be increased against the extending edge portion so that it will be wound by shorter length and will move in the direction of the edge of the layer which it overlies. In this way it is possible to maintain the edges of the metal strip in alignment with the edges already positioned on the core member during the winding operation.

In FIG. 1 the arrows P_1, P_2 indicates the pressing forces applied at the opposite ends of the roller **4** for adjustably applying pressure across the width of the strip **2** as it is applied to the tubular member **10** at the winding station A. The pressures P_1, P_2 may be maintained at the same level or, as necessary for displacing the strip **2** laterally relative to the underlaying strip the pressure at one edge of the strip can be varied relative to the pressure at the opposite edge of the strip for displacing the strip laterally so that the edges of the overlaying strips are in alignment.

As indicated in FIG. 4, the pressing forces P_1, P_2 are exerted on the bearings **13**, **14** on the opposite ends of the roller **4** by means of hydraulic jacks **11** and **12** respectively.

As illustrated in FIG. 4, the ends of the roller **4''** are supported in the bearings **15** and **16** and the ends of the inside guide roller **4'**, that is relative to the location of the metal strip and the tubular member, are supported in bearings **17** and **18**. The bearing **17** is fixed on a slide shoe **19** which is movable horizontally by means of a hydraulic jack **21** along a guide plate **20** (note FIG. 5.). In addition, the outside guide roller **4'** is supported at its ends by bearings, only the bearing **17'** being shown in FIG. 5. The bearing **17'** is fixed on a slide shoe **19'** and is moved horizontally by means of a hydraulic jack **21** along a guide plate **20'**. Though not shown, a similar arrangement is provided for the bearings **18**, **18'** for properly positioning the rollers **4'** in operation of the apparatus.

Accordingly, the pressing force of the pressure roller **4** can be varied by means of the hydraulic jacks **11** and **12** and as a result the pressing force can be adjustably varied along the axis of the roller **4**. The positions of the guide rollers **4'** can be varied by means of the hydraulic jack **21** and the gripping force of these rollers can be adjusted by means of the hydraulic jack **21'**.

As can be noted in FIGS. 1 and 2, the leading edge **2*a*** of the metal strip **2**, applied to the core member **1** has a tapered wedge-like configuration so that it properly overlies the core member and does not cause any gap between the core member and the overlapping metal strip. For the same reason, the trailing edge **2*b*** of the strip is provided with a similar tapered wedge-like configuration where it contacts the cover members **5**, see FIG. 2. The cover members **5** have a semi-cylindrical shape with an inside diameter substantially equal to the outside diameter of outer layer **3** wound on the core member **1** and are joined by welds **6**.

If the tubular member **10** is to be secured to another similar member in forming a composite pipe or vessel or to a closure member forming the end of a container or vessel it is provided with a number of radially arranged openings **7** which extend from the outer surface of the cover plates **5** interiorly to the inner surface of the innermost layer **3** of the metal strip **2**. The purposes of the openings **7** will be explained hereafter.

The tubular members **10** may be secured together by welding to form an extended pipe member as shown in FIG. 3.

In the spirally wound tubular member **10**, compared to members having a layer thickness of 3 mm., the layer thickness of 12 mm. reduces by one quarter the total number of layers and total length of the strip metal utilized. Because of the increased thickness and the reduced number of interfaces, the thermal conductivity in the radial direction of the layers is better than in a tubular member having a greater number of thinner layers. When a number of tubular members **10** are joined together to form a pipe line, no padding is required at the end faces of the layers as was necessary in the pipes using a much thinner layer and the thicker layers can be joined together in a continuous automatic welding operation.

After individual tubular members **10** are welded together, as shown in FIG. 3, the welded joint is heat treated, especially where alloy steels are employed, by circulating an inert gas through the openings **7**. During the heat treatment operation, temperature measuring instruments can be inserted into the openings **7** so that the temperature distribution in the various layers can be checked and the temperature suitably adjusted, if necessary. Additionally, with the circulation of inert gas through the layers between the tubular member any air which is present is displaced and the possibility of oxidation of the abutting layer surfaces is eliminated. After the heat treatment operation is complete, the openings **7** may be sealed in any suitable manner.

Though the present invention has been described as a method of manufacturing a spirally wound tubular member, it is also possible to employ it in forming the metal strip into a supply coil from which it is unwound in forming the tubular member. In accordance with the present invention, steel strip having a thickness of 12 mm. can then be coiled in the cold rolling process using the general process as indicated in FIG. 1.

Accordingly, a coil of steel strip can be obtained for use in forming tubular members or for other purposes which has been descaled, smoothed, and properly trimmed to size as required.

When the steel material is coiled in this fashion prior to being wound on the tubular member, the end of the steel material will not have a tendency to spring back from its wound position, particularly if in its supply coil it had a radius approximating that of the radius of curvature given it in the winding operation of the tubular member. When using such coiled steel strip, it is not necessary to provide an increased pressure at the winding station or to otherwise tack weld or attach the strip to the core member at the beginning of the winding step. As indicated previously, as the strip is fed to the winding station, the rollers **4'** in conjunction with the roll **4** increase the radius of the steel material and provide it with a slightly flattened configuration at the point of application to the winding station A.

By employing the present invention, a tubular member can be wound from a relatively wide and thick section of metal in a simple, efficient and economical manner. The strip can be prepared by a producer including the required steps of scaling, smoothing, trimming, etc. and can be properly wound to the desired radius of curvature for shipment and use in forming a multi-layer tubular member. As an alternative, the coil may be directly heat treated for the purposes of tempering or normalizing it and shipped in that fashion.

As compared to the thin metal sections previously used, it is possible, by employing a metal strip of 12 mm. in thickness, to obtain an improved thermal conductivity, and the rigidity of the strip due to its thickness is such that it will not be deformed in heat treatment as is more likely to be the case where thin sections are utilized. Moreover, it is easier to normalize the thicker steel section to increase its yield point, and such normalization can be effected while the material is in the form of a coil. When spirally wound metal strip is used in manufacturing tubular members as described above, the bending operation normally employed before the winding operation is eliminated. In other words, if metal plate having a higher yield point and an un-curved configuration is coiled or spirally wound on a core member, extensive facilities and considerable power are required to achieve the bending forces and by utilizing the present invention, such facilities are not required.

While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A method of manufacturing a multi-layer tubular member comprising feeding a continuously curved strip having a thickness between 5 mm. and 12 mm. along a longitudinal path of travel to a winding station from a supply coil having a radius which is within 20 percent of the radius of the tubular member to be formed, continuously winding the curved metal strip at the winding station about a hollow core member into a number of closely engaged superimposed layers, applying pressure across the width of the curved metal strip at the winding station where the strip initially contacts the outer surface of the tubular member being formed, and selectively varying the application of pressure across the width of the curved strip for directing the curved metal strip laterally of its direction of travel for aligning the longitudinally extending edges of the superimposed layers of the metal strip.

2. A method of manufacturing a multi-layer tubular member, as set forth in claim **1**, comprising the step of adjustably positioning the curved metal strip as it is fed to the winding station for increasing its radius so that its radius is slightly greater than the radius it is to assume on the multi-layer tubular member.

3. A method of manufacturing a multi-layer tubular member, as set forth in claim **1**, comprising the step of adjustably positioning the curved metal strip in its path of travel as it approaches the winding station for imparting a slightly flattened configuration to the outer curved surface of the metal strip at a position immediately preceding the winding station so that the inner surface of the metal strip at that location is slightly elongated relative to the oppositely disposed slightly flattened outer surface of the strip.

4. A method of manufacturing a multi-layer tubular member as set forth in claim **1**, comprising the step of forming the leading and the trailing edges of the curved metal strip with a tapered wedge-like configuration so that the leading edge overlying the core member and the trailing edge at the outer periphery of the multi-layer tubular member do not cause gaps at the ends of the metal strip.

5. A method of manufacturing a multi-layer tubular member as set forth in claim **1**, comprising the step of gripping the metal strip at a position preceding the winding station whereby pressure is applied to the strip between the position at which it is gripped and the winding station so that the radius of the strip is increased and the outer surface of the strip immediately preceding the winding station is given a slightly flattened configuration.

6. A method of manufacturing a multi-layer tubular member as set forth in claim **4**, comprising the step of placing cover means on the outer wound surface of the strip and securing the cover means to hold the multiple layers of metal strip in place.

7. A method of manufacturing a multi-layer tubular member as set forth in claim **6**, comprising the step of forming radial openings through the cover means and the multiple layers of metal strip terminating at the inner surface of the inner layer of wound metal strip.

8. A method of manufacturing a multi-layer tubular member as set forth in claim **7**, comprising the step of integrally attaching a plurality of tubular members in end-to-end axial alignment.

9. A method of manufacturing a multi-layer tubular member as set forth in claim 8, comprising the step of heat treating the integrally attached tubular members by circulating an inert gas through the openings formed in the multi-layer tubular member.

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CHARLIE T. MOON, Primary Examiner

R. B. LAZARUS, Assistant Examiner

U.S. Cl. X.R.

29—476.5; 72—148; 113—120