Oct. 3, 1944. A. W. SPAULDING ET AL 2,359,450

CULVERT

Filed Feb. 26, 1942 2 Sheets-Sheet 1

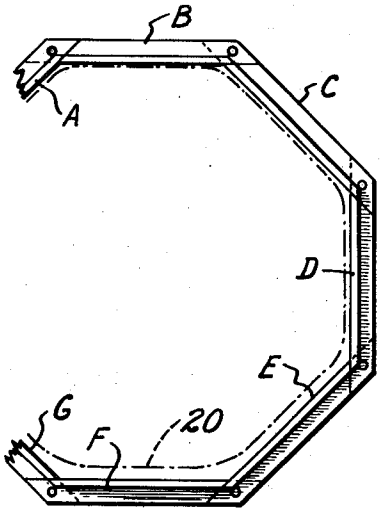



FIG. 1.

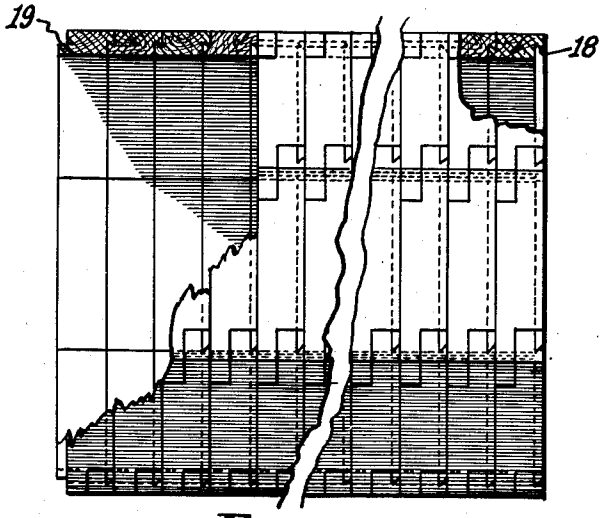



FIG. 2.

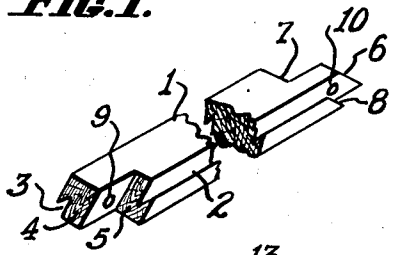



FIG. 3.

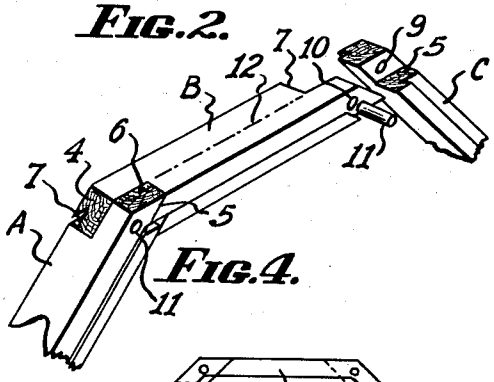



FIG. 4.

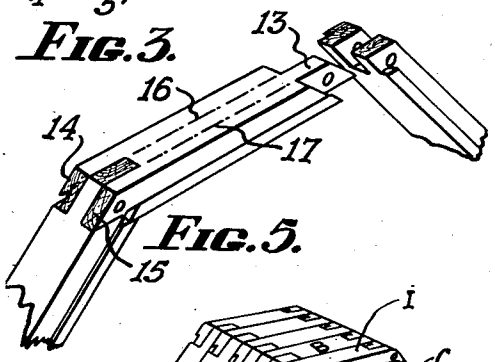



FIG. 5.

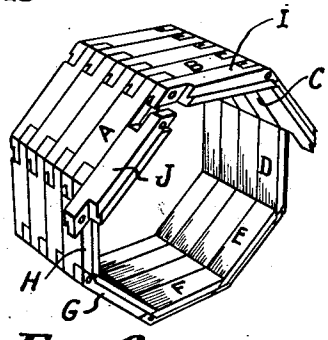



FIG. 6.

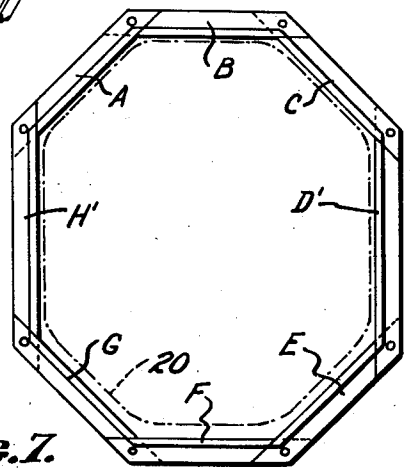



FIG. 7.

INVENTOR.

BY ARCH W. SPAULDING AND JOHN M. ROBERTSON.

Allen & Allen

ATTORNEYS.

Oct. 3, 1944. A. W. SPAULDING ET AL 2,359,450

CULVERT

Filed Feb. 26, 1942 2 Sheets-Sheet 2

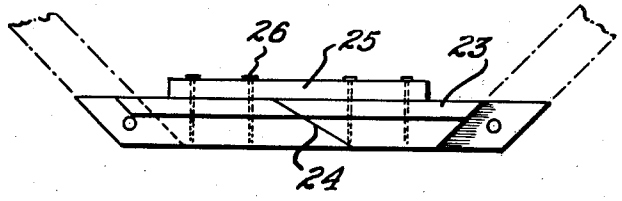



FIG. 8.

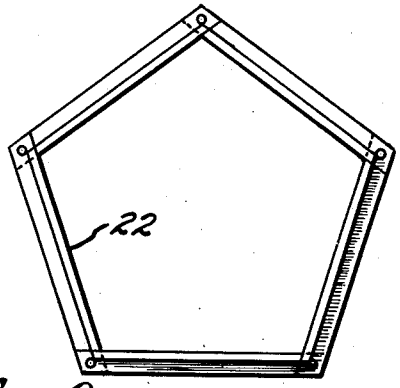



FIG. 9.

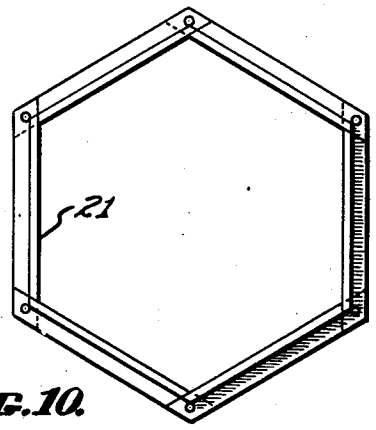



FIG. 10.

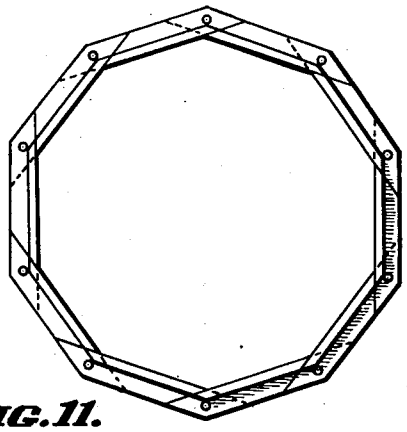


FIG. 11.

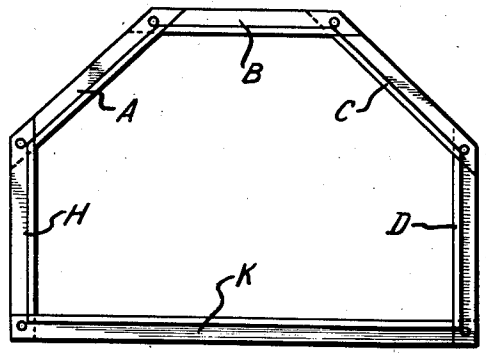



FIG. 13.

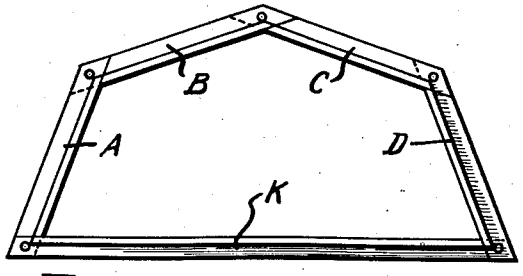



FIG. 12.

BY

INVENTOR.
ARCH W. SPAULDING
AND JOHN M. ROBERTSON.
Allen & Allen
ATTORNEYS.

Patented Oct. 3, 1944

2,359,450

# UNITED STATES PATENT OFFICE

2,359,450

## CULVERT

Arch W. Spaulding and John M. Robertson, Middletown, Ohio, assignors to The American Rolling Mill Company, Middletown, Ohio, a corporation of Ohio

Application February 26, 1942, Serial No. 432,434

18 Claims. (Cl. 138—79)

As is well known, the great strength of the corrugated iron culvert, compared with the weight of the structure itself, is due not alone to the fact that the corrugations in the metal form truss-like structures in both directions, but also to the general resilience of the structure, and its ability to deflect under dead and live loads. The corrugated iron culvert, when buried in the earth, is capable of deflecting to the point where the pressure against the sides of the culvert equals the vertical pressure, at which point the resistance of the culvert to loads increases very greatly. This is illustrated in laboratory methods of testing culverts. If a culvert section be placed in a press and subjected to vertical pressure, without side support, to the point where a constant pressure produces a continual bending, a certain value will be attained. But if while the culvert section is being tested, rigid members are brought against its sides, or its sides are tied across to prevent expansion, the pressure necessary to produce a continual bending will usually be found to have been more than doubled.

With increasing shortages of metal, attention is being turned to the possibility of making culverts and similar structures of other materials, of which wood is an example. Conduit structures have hitherto been designed to employ wood; but so far as we are aware, the wooden structures which have come to any commercial use, have either been of longitudinal wood-stave-and-hoop construction, of a square or rectangular cross section having thick and heavy wooden beams, or of true arch block construction as in the voussoirs of wooden tunnel lining. The first and last of these structures are not available for ordinary culvert uses. In the rectangular structures, strength is attained solely through the beam action of the several members. The cross sectional shape of the structures requires that these members be of considerable length; and in turn, strength considerations require that they be of considerable depth. Hence, the quantity of wood required for a structure having a given flow capacity and given strength requirements has been excessive, and the cost of the structures proportionately high. Moreover, the structures have not been capable of acting in use like the corrugated metal culvert, but have relied on rigidity for sustaining the loads encountered in use. It may be noted that any deflection of the top beams due to load tends to draw in the side members, instead of causing them to expand and seek side support.

It is an object of our invention to provide a structure which, although not made of corrugated sheet metal, is capable of acting in use as the corrugated sheet metal culvert acts. The particular material of which our structure is made, is not a necessary limitation on our invention, since it can be any suitable substance including metal; but it is a special utility of our invention that it enables very strong but relatively cheap structures to be made of non-metallic materials such, for example, as wood, compositions or plastics. It is an object of our invention to provide a structure for culverts or comparable uses which may deflect in use to seek side support, and which gains the strength advantage of such resilience. It is an object of our invention to provide a structure in which strength is attained not alone by the longitudinal stiffness of elongated members acting as beams. It is an object of our invention to provide a structure which can if desired be fabricated from a plurality of identical, relatively short sections to provide a culvert of large diameter as compared with the length of the sections. As applied to the manufacture of culverts from wood, it is an object of our invention to provide a structure which can be readily and cheaply fabricated from wooden pieces, otherwise classifiable as scrap, and having relatively little utility or market value as such. It is an object of our invention to provide a structure which does not require long lengths of prime lumber. It is an object of our invention to provide a structure in which, if one member is defective, the strength and continuity of the remainder of the structure is not lost. It is an object of our invention to provide a culvert which may be made in a wide variety of sizes merely by varying the length of the parts employed, the parts otherwise being identical. It is an object of our invention to provide a structure which can be made cheaply, as compared with a corrugated metal culvert of the proper gauge for the diameter of the culvert, but which will be equally strong in service. It is an object of our invention to provide a culvert structure which may be fabricated in the manufacturing plant in convenient lengths the same as, or comparable to, the lengths in which corrugated culvert is fabricated, which will not be heavier length for length than corrugated culvert of the same diameter and proper gauge, which may be handled and shipped like corrugated culvert is handled and shipped, and which may be installed in substantially the same manner.

These and other objects of our invention which

will be set forth hereinafter or will be apparent to one skilled in the art upon reading this specification, we accomplish by that certain construction and arrangement of parts of which we shall now describe an exemplary embodiment. Reference is made to the drawings wherein:

Figure 1 is a partial elevational view of an exemplary form of our structure.

Figure 2 is a side elevation thereof with parts cut away.

Figure 3 is a perspective view of a single member or part of the structure of the preceding figures.

Figure 4 is a perspective view showing how the individual members fit together.

Figure 5 is a view similar to Figure 4, but showing a modified form of the member.

Figure 6 is a perspective view showing how the members are fitted together to form a long culvert section.

Figure 7 is an elevational view of a modified culvert shape.

Figure 8 is a plan view of a member prepared to permit the erection of the structure from the inside.

Figure 9 is an elevational view of a pentagonal culvert.

Figure 10 is an elevational view of a hexagonal culvert showing a preferred mode of laying it.

Figure 11 is an elevational view of a ten-sided structure.

Figures 12 and 13 are elevational views of various arch-shaped structures.

In the practice of our invention, we provide a standard member having on its sides and ends configurations suitable for interfitting or interengagement. These members are fitted together end to end to make a culvert portion of the proper diameter and of a length equivalent to the width of one such member. Hereinafter we shall refer to the structure so produced as a "ring." By building up additional members on a ring or rings previously formed, a culvert structure of the required length may be produced. We shall hereinafter refer to such a structure as a culvert "section." Sections may be joined in the field to provide a completed culvert of the required length. In the manufacture of corrugated metal culverts, standard sections usually have a length of twenty feet, shorter sections being also made where the length requirements of the completed culvert demand them. In the practice of our invention, we make up sections of similar length in the fabricating plant and ship, handle and install them as corrugated culverts have hitherto been shipped, handled and installed.

In our drawings we have illustrated our culverts in the form of polygons. The number of sides in the polygons is not a limitation on our invention. We do, however, contemplate that our culverts shall not be rectangular, and that they should be made up of more than four members in each ring, where the completed structure is a regular polygon, since if this is not done, one of the advantages of our structure is lost. A rectangular structure must of necessity, operate as a rigid structure, relying on the longitudinal stiffness of the various members as plain beams; and when this is done, the deflection under load of the structure as a whole, which we contemplate in our invention, is not attained. Deflection may be attained, however, together with a concurrent lightening of the several members, in the formation of structures having a regular polygonal cross section of more than four sides.

Referring to Figure 3, we shall first describe one of the members of which our rings are formed. This member is shown as having a body 1, of a required length to form a desired side of the polygonal figure. The sides of the body are rabbeted as at 2 to form an interlock groove which faces outwardly. On the other side, the body is rabbeted as at 3 to form an interlock groove which faces inwardly. The exact shape of these grooves and of the interlock members formed thereby is not a limitation on our invention. We prefer to make them as shown in the form of angular grooves and members since this involves a simple cutting problem and a simple type of cutting tool. The width of the body section may be as desired or as permitted by the available lumber or other material. However, for reasons hereinafter clarified in connection with a description of the operation of our structure, we prefer not to have the members too wide in proportion to their depth, and in practice, the width of the bodies of our members is usually approximately twice or three times the depth of the bodies of the members.

The ends of the members are beveled or cut slantwise in several planes, the angularity of these planes to the body of the member being preferably the angularity of the sides of the chosen polygonal figure to each other. In Figure 3, it will be noted, that the extreme left hand end of the member is so beveled as at 4, but that the member at approximately its mid-section is cut back, and the cut-back portion is beveled as at 5 to the same angularity. The displacement between planes 4 and 5 is equivalent to the thickness of the body 1. At the other end of the member shown in Figure 3, there is an opposite bevel at 6, and the member is cut back at its mid-section with the cut-back portion beveled as at 7. Again the displacement between planes 6 and 7 is equivalent to the thickness of the body of the member. Planes 4 and 5 are, of course, parallel to each other and planes 6 and 7 are likewise parallel to each other. It will further be noticed in Figure 3, that the interlock member formed by the rabbet 2 is cut away as at 8 substantially in the plane 7.

It will now be seen that our members are provided with opposed interlock means at each side, and at their ends they have tongues disposed in off-set relation to each other.

In forming a ring from members such as illustrated in Figure 3, the members are interfitted angularly, as shown in Figure 4. Here we have shown three members indicated respectively at A, B and C. The interlock has already been effected as between members A and B. It will be noted that the members are angularly related; that the tongues of the two members lie side by side; that the plane 4, of member B, is coincident with the top surface of member A; that the plane 6, of member A, is coincident with the top surface of member B; that the under-surface of member B lies against and conforms to the plane 7 of member A; and that the under-surface of member A lies against and conforms to the plane 5 of member B. A similar association of parts will be formed, as is evident, when member C is interlocked with member B in Figure 4.

In Figure 3, we have indicated holes 9 and 10 extending through the tongues at each end of the member. In Figure 4, it will be seen how, when the members are interengaged, these holes come into alignment. The members may then be fastened together by a pin 11 passed through

the holes. When the structure is made of wood, these pins may conveniently be wooden dowel sticks; although pins or rods of any other suitable material may be employed. As will be hereinafter explained, there is no great shearing stress imposed upon these pins or dowels, and it may be pointed out in this connection that our entire section may be of wood, not requiring the use of any metal. The pins or dowels may, of course, be common to a plurality of rings and may, if desired, extend the full length of each section. Where the pins are of wood and the sections twenty feet long, this is not ordinarily feasible and shorter pin sections may advantageously be employed. Where pins come together it is well to have the break line within some one tongue rather than at the meeting planes of tongues, but this again is not of paramount importance. While we have just descrbied a preferred form of our individual members, modifications may be made in them. We think it both simpler and cheaper in construction to fix the planes **6** and **7** and the planes **4** and **5** at the particular angular relationships outlined above. It will be clear, however, that they could have other angularities. If the underside of the end portions of the members are cut or beveled to correspond, equally tight joints will be produced. If the contacting surfaces do not correspond as to angularity there will be a certain play, or resiliency in the joints.

It will be evident from Figures 1, 2 and 6, how an entire ring may be formed by interengaging a plurality of the members after the manner just described in connection with Figure 4. It will also be apparent from Figure 6, how additional rings may be built up on the first ring. Each ring, regarded alone, presents at its sides the interengagement members heretofore described. In Figure 6, considering a previously formed ring to comprise members A to H, it will be seen how an additional member I may be put in place parallel to member B, with the side interengagement means interlocked. Another member J may be interengaged with member A, and then slid into position in its own plane so as to effect the interlocking of the end tongues as has heretofore been described. In the same manner, about the periphery of the structure, the various members may be placed and interlocked in position. In inserting the final member, it will be necessary to dispose the adjacent two outwardly at their free ends in order to facilitate their interengagement with the last member, after which all members are brought to their ultimate position, giving a second ring interengaged with the ring comprising members A to H. When suitable pins are passed through the holes in the ends of the members, the two rings will be locked together and cannot be separated. Similarly, by building member on member and ring on ring, a culvert section of the required length may be formed. Such a culvert section is illustrated in Figure 2, and is shown in partial end elevation in Figure 1.

The structure so formed is very strong considering the weight of material therein. By way of illustration we have subjected to comparative tests a wooden culvert structure like that shown in Figures 1 and 2 and a corrugated iron culvert of standard characteristics for a pipe of the same diameter. Our wooden culvert had a diameter, i. e., a distance between B and F in Figure 1, of 24 inches. The members were 13 inches in extreme length, 4 inches in extreme width and 2 inches in thickness. They were made of yellow pine wood. The wooden culvert weighed 34 pounds per foot of length. The corrugated iron culvert of the same diameter was made of 1A gauge metal (which is the standard gauge for that diameter), and it had the standard corrugations, namely a pitch of 2⅔ inches and a depth of ½ inch. It weighed 25.2 pounds per foot of length.

When the wooden culvert was subjected to crushing force, i. e., a force exerted between B and F in Figure 1, the force necessary to produce failure was 2400 pounds per linear foot. When the corrugated iron culvert was subjected to similar crushing force, the force required to produce failure was 1900 pounds. When the wooden culvert was given side support as at D and H in Figure 6, the crushing force necessary to produce failure was 12,250 pounds. When the corrugated iron culvert was given the same side support, the force necessary to produce failure was 4700 pounds.

In the above test, the point of failure was taken (as in usual practice) as the point at which a given force produced a continuing and progressive distortion such that, if the force had been continued the structure would have collapsed.

The manner in which failure manifests itself in our culvert is important as illustrating the mode of operation of our culvert. Referring to Figure 4 and the relationship of parts there most clearly shown, at the point of failure, in the test outlined above, there occurred a splitting of the members along a line indicated at **12**. The reason for this will be understood when the relationship of parts is considered. The various members are angularly related to each other. Any deflection which cannot be absorbed by the resiliency of the members themselves, tends to widen the angle at which the members engage each other. In Figure 4, the part of the member B which lies closest to the observer tends to rotate in a counterclockwise manner while the part on the side of the line **12** furthest from the observer, tends to rotate in a clockwise direction. The surface **5** of member C will be pressing upwardly on the under side of the extreme end of member B. At the same time, the under side of the extreme end of member C will be pressing downwardly on plane **7** of member B. At the other end of member B a similar action occurs. The under side of the extreme end of the member A will be pressing downwardly on plane **5** of member B, while plane **7** of member A will be pressing upwardly on the extreme end of member B. Consequently, the strength and stiffness of the structure in this test depended not on the inherent stiffness of the several members alone, but much more importantly, upon the resistance of the members themselves to shearing along a longitudinal plane. Thus the most important action of the members was not that of an ordinary beam. Of course, the resistance of the members to shearing and splitting, as described, is very great indeed; and considering the ability of our structure to deflect under load, it enables our structure to sustain tremendous weights. The greater the number of shear planes per unit length, the greater is the strength of the structure. Hence, individual members such as that shown in Figure 3, are preferably not made too wide.

Considering the possible modes of failure in a structure of our type, in the light of what we have taught above, it will be seen that these fac-

tors only need be considered: (1) The members might break transversely, (2) the ends of the members, where they are interengaged might break off, (3) the wood itself under these tremendous pressures might crush, and (4) the members might split as described above.

While the transverse breaking strength of our members can readily be calculated on the known physical qualities of the materials from which they are made, it may be noted that, as compared with a square or rectangular structure, we have greatly increased the load carrying capacity of our individual members (regarding them as beams) by greatly shortening them. The tongues or ends of the members are likewise strong in proportion to the thickness of the members; and they should in most structures be made so strong that they do not tend to break off before failure occurs elsewhere. Since the planes of the interfitting parts are preferably made to correspond, as indicated above, the pressure is well distributed, and there is little tendency for the wood or other material to crush; and this is true in spite of very considerable deflection of the structure under load. Hence the structures we prefer are those in which longitudinal splitting is the manifestation of failure. Such structures maintain their shape very well, even after splitting occurs, and even after the splitting of one or more members are still capable of sustaining very large loads, due to the arch-like action of the structure. However, the various factors may be modified, if desired, to secure other results.

It is also possible to design our members in such fashion that the load will be applied against a plurality of shear planes instead of against a single shear plane in each member. An exemplary structure of this type is shown in Figure 5, where the essential difference between the members, and the members heretofore described, is that each member has at least one tongue **13** on one end and at least a pair of tongues **14** and **15** on the other end. The last mentioned tongues are interspaced the width of the first mentioned tongue or tongues so that the tongue on an adjacent member can slip between them. In the light of what has been explained above, it will be clear that the same action will occur; but the number of shear planes has been multiplied. Thus, when stressed to failure the ring of Figure 5 will fail because one or more of its members have sheared or split on planes **16** and **17**; and since the force per unit length of the culvert section is divided between these two planes, it will be seen that the ability of the structure to withstand crushing forces has been increased.

We have indicated above that in service our culvert structures act like corrugated iron culverts in that they seek side support by deflecting. In the test outlined above, by way of example, the top of the structure, when there was no side support, deflected 2.0 inches prior to failure. Proportionately less deflections, of course, occurred with lesser forces; and when such lesser forces were removed, the structure resumed its original shape. Repeated deflections produce very minor wear, and do not significantly tend to produce a loosening of the structure. Moreover, there is very little shearing force on the pins **11**, and in none of the tests which we have made have these pins sheared or broken.

Our structure thus is characterized by surprising resiliency. Some of the ability of the structure to deflect under stresses may occur at the actual joints, and we have indicated above how, by causing the planes at the joints not to correspond, further deflection may be permitted at the joints. But since structures made as hereinabove taught can deflect and when the pressure is removed return to their original conditions with apparently tight joints, we believe that much of the ability of the structure to deflect resides in the resilience of the members. Those forces which tend to produce that splitting of the individual members which has been referred to hereinabove in connection with failure, also to some degree at least subject the members to torsion in structures such as illustrated in Figures 3 and 4 and it is possible that this accounts for some of the resiliency.

It will be noted that the several rings going to make up such sections as are illustrated in Figures 2 and 6, are immovably locked together and can neither be shifted with respect to each other in the plane of any ring nor can they be shifted with respect to each other along the axis of the section. Likewise, because of the polygonal character of the structure, the rings cannot be rotated as respects each other in any given section.

Different sections may be joined to each other in the field, when laying the culvert, in a variety of ways. They may be joined by bands, cleats or nails if desired. Since we contemplate making our sections up of rings formed from identical members, a convenient way of treating the ends of each formed section is by planing off the angular part of the interengagement members on the first and last rings. This is illustrated in Figure 2, and results in the provision of a female member at **18** on one end of the section and a male member at **19** on the other end of the section. In joining sections, the male member on the end of one section is caused to enter the female member on the end of the adjacent section. This assures alignment; and further fastening means may frequently be dispensed with. However, where desired, cleats or the like may be employed. Also it is possible to leave the pins **11** projecting somewhat at one end of each section and recessed at the other end, for interengagement, as will be evident.

Corrugated iron culverts are normally designed for a given service with a safety factor contemplating a 5% deflection. We have indicated that our culvert when made of wood is capable of greater deflections with safety. In the installation of corrugated iron culverts, it has frequently been the practice initially to force the culverts out of round and to cause them to assume an elliptical shape with the longer axis vertical. After installation in the trench, and when the earth has been tamped about the sides of the culvert and the top earth applied, it is the practice to remove the jacks. The expected deflections in the culvert, under these circumstances, will tend to cause it to assume a more nearly circular shape rather than to depart from a circular shape by the elongation of the horizontal axis at the expense of the vertical axis. The same treatment cannot literally be applied to our culverts except to a very limited extent; but the same effect can be achieved by a modified procedure. Remembering that the effective pressure depends not alone on the force exerted but also on the area over which the force is distributed, it will be found possible to provide a structure which, upon initial installation, will encounter equivalent forces about its periphery with a minimum of deflection. This can be ac-

complished by elongating the side elements of the structure in the position in which it will be installed. This is illustrated in Figure 7 where like indicia have been given to like parts. Here, however, the members D' and H' are longer than the members A, B, C or E, F, G. The structure thus becomes elongated as to its vertical axis and the side portions represented by D' and H' are of greater area. Thus the side pressures on the structure become more nearly equivalent to the vertical pressures with very slight deflection.

In Figure 10 we have shown in elevation a hexagonal culvert **21**. This culvert if laid in the position shown in that figure, has a vertical inside diameter greater than its horizontal inside diameter; and in such a structure it is advantageous to lay it as shown. The same effect can be secured to some lesser degree in any polygonal figure having a greater, even number of sides.

In Figure 9 at **22** we have illustrated in elevation a pentagonal culvert. This culvert is an excellent shape for small sizes. It is advantageous in that it may be made up of a fewer number of members, while in the smaller sizes these members remain of relatively short length. Yet the structure is capable of acting as the structures hereinabove described and is capable of resisting very heavy loads in spite of the fact that the individual members may be thin.

It will be noted that a culvert structure of any given polygonal shape is made up of a plurality of identical members. The construction of these members thus becomes a quantity production manufacturing operation, using identical tools and equipment whether the members be made by cutting wood, molding plastic, casting metal or otherwise. Moreover, for any other diameter of culvert of the same polygonal cross section, the only difference between the members need be in their length. It is, of course, clear that for wide diameter differences, differences in the thickness of the members may be desired; but in working with wood, thicker materials may be handled using the same tools. And the strength of our structure is such that, for size differences over a very considerable range, the length of the members only need be varied. Moreover, the members themselves are not of great length, being by way of example 13 inches over all, for an octagonal culvert of 24 inches diameter. Hence, where the members are made of wood, scrap lumber and short lengths of material may be employed which either would have no other utility or would be of very slight commercial value. When working with wood, the members of the sections should be treated, unless they are made of some wood which is naturally resistant to underground conditions and to the ravages of insects. Various treatment substances may be employed in the nature of wood preservatives, fungicides and insecticides. The wood members may be treated with creosote as is done with railroad ties, or they may be impregnated with resins. However, individual treatment of the members is not usually necessary. It is frequently sufficient merely to dip the entire formed section into a tank of suitable coating or impregnating substance. The construction is such that a reasonably fluid impregnating agent will pass into the interstices between rings and between members with ease. Thus, in practice, we may form culvert sections and then dip them in a bath of creosote or some insecticide or fungicide, or an asphalt or bitumen cut back with a solvent, and, after drying (where that is necessary) we may dip the entire section into a heat liquefied bitumen such as asphalt. This bitumen should preferably be of such character as to be inert, non-brittle and plastic at ordinary temperatures. It will penetrate fissures of the structure and seal any leaks therein and, if desired, may be so applied as to be thicker along the bottom of the structure, hence to provide an asphaltic floor which will largely prevent that erosion and wear which arises from sand or other abrasive materials propelled through the culvert by water. The bitumen elsewhere may act as a thin coating over the walls of the structure. This condition is diagrammatically indicated by the dotted lines **20** in Figures 1 and 7.

It will be understood that we are not limited as to the sizes in which our structure may be made. The thickness and rigidity of the individual members may be controlled in accordance with good practice in the light of the diameter of the structure and the pressures which it will have to sustain. Our structure, thus, may be employed as tunnel lining and is of such character that the individual members may be assembled together as the excavation progresses.

In order to facilitate this where a tunnel lining is being erected in a bore or excavation which does not leave much room for the toothing of the individual members, we may employ the expedient illustrated in Figure 8. Here, one of our individual members **23** has been cut apart diagonally along a line indicated at **24**. The two parts of the individual member may thus be successively inserted in place without bending outwardly the two adjacent members with which they are interengaged. Then when the parts of the member **23** have been brought together as illustrated in this figure, they may be held together by means of a cleat **25** of wood, metal or other substance fastened to the member by means of nails **26**, screws, bolts or other suitable fastening means.

As we have hereinabove indicated, we may make our culverts, conduits, pipes or tubes to any polygonal figure having more than four sides, and have illustrated in Figure 11 at **27** a 10-sided figure whereby a culvert of larger diameter may be made of members having no greater individual lengths; but we are also not limited either to polygons having equal sides or to regular polygons. Arch shape structures may be made by using our members in combination with a suitable base. In Figures 12 and 13 we have illustrated exemplary arches. By the term "arch-shaped" culvert we mean, of course, a culvert in which primarily the upper portion of a complete culvert of regular polygonal shape is joined to a base. As has been understood in connection with corrugated metal culverts, the structure under top loads forms in essence two opposed arches, the bases of which are held from spreading by the side support furnished by the fill, in addition, of course, to the natural stiffness of the structure. Arch type culverts have heretofore been made of corrugated metal. They may comprise a single arch supported on suitable footings in the earth or they may comprise a single arch having a flat or slightly outwardly convex metallic base. Arches may be formed in accordance with the teachings of the present application and may similarly be supported. The ends of the arch may be mounted on concrete footings or entire arch structures may be made as we have shown. In Figure 12 sections A, B, C

and D similar to the sections of the culvert of Figure 1 have been joined to a base K. The members A, B, C and D form an arch. A slightly different arch is shown in Figure 13 comprising the members H, A, B, C and D again with a tie member K. Where the arch portions join the base, joints may be made as hereinabove taught or otherwise as may be desired. One advantage of arch-shaped structures is that they may be constructed to provide maximum flow capacity with minimum head room.

Modifications may be made in our invention without departing from the spirit of it. Having thus described our invention, what we claim as new and desire to secure by Letters Patent is:

1. A tubular article designed to withstand external compressive forces and formed of a sidewise juxtaposed series of polygonal, circumferential assemblies, each of which assemblies in turn is formed of interengaged, substantially straight individual members, said members having at their ends interengaging projections and recesses, the tops and bottoms of said projections and recesses being formed in planes having the same angularity to the bodies of the members as the angularity of the members to each other when interengaged in said assemblies, the projections of said members crossing each other in said assemblies, and the interengagement being such as to resist forces tending to increase the angularity of the members to each other by producing in said members forces tending to shear them longitudinally, there being in each assembly more than four of such members.

2. A tubular article designed to withstand external compressive forces and formed of a sidewise juxtaposed series of polygonal, circumferential assemblies, each of which assemblies in turn is formed of interengaged, substantially straight individual members, said members having at their ends projections and recesses, the tops and bottoms of said projections and recesses being formed respectively in parallel planes, angularly related to the surface planes of said members, as the members are related angularly to each other in said assemblies, the projections of one member crossing and interengaging with projections of adjacent members and the interengagement being such as to resist forces tending to increase the angularity of the members to each other, there being in each assembly more than four such members.

3. A tubular article designed to deflect in withstanding external compressive forces and formed of a sidewise juxtaposed series of polygonal, circumferential assemblies, each of which in turn is formed of substantially straight individual members extending in the directions of the sides of said polygonal assemblies, said members having at their ends projections and recesses, the projections of one such member interengaging with and lying alongside in the direction of the axis of said tubular article of the projections of adjacent members in said assemblies the interengagement being such as to resist forces tending to increase the angularity of the members to each other while permitting resilient deflection in response to said forces, there being in each assembly more than four of such members.

4. A tubular article designed to withstand external compressive forces and formed of a sidewise juxtaposed series of polygonal, circumferential assemblies, each of which in turn is formed of substantially straight individual members extending in the directions of the sides of said polygonal assemblies, said members having at their ends projections and recesses, the projections of one such member interengaging with and lying alongside in the direction of the axis of said tubular article of the projections of adjacent members in said assemblies the tops and bottoms of said projections and recesses being formed in planes having the same angularity to the bodies of the members as the angularity of the members to each other when interengaged, and the interengagement being such as to resist forces tending to increase the angularity of the members to each other by producing in said members forces tending to shear them longitudinally, there being in each assembly more than four of such members, said members having at their sides means for interengagement with similar members whereby the several assemblies are held together.

5. An elongated arch-shaped structure formed of a series of interengaged arches, each of which is in the shape of a portion of a polygonal figure and is formed substantially straight individual members, said members having at their ends projections and recesses, the projections at the ends of one such member being in crossing interengagement with projections of adjacent members in said arches, the projections of such members being offset from each other in the direction of the axis of said structure, the interengagement being such as to resist forces tending to increase the angularity of said members to each other, said members forming the sides of a regular polygon which, if complete, would have more than four sides.

6. A tubular article designed to withstand external compressive forces and formed of a sidewise juxtaposed series of polygonal, circumferential assemblies, each of which in turn is formed of interengaged, substantially straight individual members, said members having at their ends interengaging projections and recesses, the tops and bottoms of said projections and recesses being formed in planes having the same angularity to the bodies of the members as the angularity of the members to each other when interengaged, and the interengagement being such as to resist forces tending to increase the angularity of the members to each other by producing in said members forces tending to shear them longitudinally, there being in each assembly more than four of such members, said members having at their sides means for interengagement with similar members whereby the several assemblies are held together, the interengaged portions of said members being perforated, and pins inserted in said perforations to hold said members together.

7. A member for forming a culvert or like construction by interfitting with other similar members, said member having an elongated body, interengagement means at each side of said body comprising an interengagement part demarked by an oppositely extending groove, said member having at each end, at least one projection of lesser cross section than the member, the projections at each end being staggered with respect to each other, the outer end of each projection and the inner end of each portion of the member cut away to form such projection being located aslant to the plane of the top surface of the body, and having an angular relationship thereto such that when the projection of one member is engaged in the cut away portion of another member, the members will be so related to each other

as to constitute sides of a polygonal figure which, if complete, would have more than four sides, the interengagement being such that a force tending to increase the angularity between such interengaged members tends to split such members longitudinally by forcing different parts thereof in different rotative directions.

8. A member as claimed in claim 7 in which there are a plurality of projections at one end and a lesser number of off-set projections at the opposite end, such that forces tending to vary the angularity between interengaged members will tend to shear any one member along a plurality of longitudinal lines.

9. A culvert structure formed at least in part of a plurality of interengaged individual members, said members being of elongated shape and having at each end at least one projection and recess of such character and so located that the projection of one member will engage in the recess of another member interengaged therewith, the configuration of the projections and recesses being such that the said members will interengage with each other at an internal angle greater than 90°, the bottom planes of the recesses corresponding to the bottom planes of interengaged projections, whereby forces tending to vary the angularity between members tend to shear said members along longitudinal lines.

10. A culvert structure formed at least in part of a plurality of interengaged individual members, said members being of elongated shape and having at each end at least one projection and recess of such character and so located that the projection of one member will engage in the recess of another member interengaged therewith, the configuration of the projections and recesses being such that the said members will interengage with each other at an internal angle greater than 90°, the bottom planes of the recesses corresponding to the bottom planes of interengaged projections, whereby forces tending to vary the angularity between members tend to shear said members along longitudinal lines, similar members being interengaged to form circumferential structures of polygonal cross section, said structures being assembled together to form an elongated conduit.

11. A culvert formed of wood in a plurality of interengaged individual members, each of said members being of elongated shape and having at each end at least one projection and recess of such character and so located that the projection of one member will engage in the recess of another member interengaged therewith, the configuration of the projections and recesses being such that the members will interengage with each other at an internal angle greater than 90° the bottom planes of the recesses corresponding to the bottom planes of interengaged projections, whereby forces tending to vary the angularity between members tend to shear said members along longitudinal lines, similar members being interengaged to form circumferential structures of polygonal cross section, said structures being assembled together to form an elongated conduit, said members having at opposite sides, oppositely directed interengagement means whereby said circumferential structures are locked together, the interengaging portions of the members in each circumferential structure having perforations and pins engaged in said perforation to hold said members together.

12. A culvert formed of wood in a plurality of interengaged individual members, each of said members being of elongated shape and having at each end at least one projection and recess of such character and so located that the projection of one member will engage in the recess of another member interengaged therewith, the configuration of the projections and recesses being such that the members will interengage with each other at an internal angle greater than 90° the bottom planes of the recesses corresponding to the bottom planes of interengaged projections, whereby forces tending to increase the angularity between members tend to shear said members along longitudinal lines, similar members being interengaged to form circumferential structures of polygonal cross section, said structures being assembled together to form an elongated conduit, said members having at opposite sides, oppositely directed interengagement means whereby said circumferential structures are locked together, the interengaging portions of the members in each circumferential structure having perforations, and pins engaged in said perforation to hold said members together, said members being treated to increase their resistance to conditions encountered when buried in earth.

13. A culvert formed of wood in a plurality of interengaged individual members, each of said members being of elongated shape and having at each end at least one projection and recess of such character and so located that the projection of one member will engage in the recess of another member interengaged therewith, the configuration of the projections and recesses being such that the members will interengage with each other at an internal angle greater than 90°, the bottom planes of the recesses corresponding to the bottom planes of interengaged projections, whereby forces tending to increase the angularity between members tend to shear said members along longitudinal lines, similar members being interengaged to form circumferential structures of polygonal cross section, said structures being assembled together to form an elongated conduit, said members having at opposite sides, oppositely directed interengagement means whereby said circumferential structures are locked together, the interengaging portions of the members in each circumferential structure having perforations, and pins engaged in said perforations to hold said members together, said members being treated to increase their resistance to conditions encountered when buried in earth, and the combined structure so formed having a coating on at least the interior surfaces thereof of a bitumen, non-brittle at ordinary temperatures.

14. A structure as claimed in claim 2, in which one opposite pair of the members in each circumferential structure are of a length differing from the other members in said structure whereby to provide a structure which in cross section is of greater diameter in one direction than in another direction normal to the first.

15. A structure as claimed in claim 2, in which the section on one of its ends has a female portion and on the other of its ends a male portion whereby adjacent sections may be interfitted.

16. A culvert or like article having a polygonal cross section of more than five sides, said sides being formed of non-metallic members having projections and recesses at their ends, adjacent members being interfitted as to their projections and recesses with the projections of circumferentially adjacent members lying sidewise of each

other in the direction of the axis of the article so that forces tending to increase the angularity between members tend to cause said members to split or shear longitudinally, and whereby the resistance of the structure to external crushing forces is dependent upon the resistance of the individual members to shearing and splitting longitudinally, the entire structure being capable of deflection under top loads with consequent widening at the sides, whereby the structure, like a corrugated metal culvert, can expand laterally under top load until all circumferential pressures are substantially equalized.

17. A wooden culvert structure of polygonal cross section, made up of individual wooden pieces extending circumferentially of the structure and interengaged at their ends by means of projections engaging within recesses, the projections of circumferentially adjacent members lying sidewise of each other in the direction of the axis of the culvert and crossing each other, said members being of lesser length than any diameter of the structure, the said interengagement resisting variation in their angularity to each other, the entire structure being capable of deflecting under load, and the individual members being interengaged with each other in a direction longitudinal of the structure.

18. A member for forming a culvert or like construction by interfitting with other similar members, said member having an elongated body, and at each end, at least, one projection of lesser cross-section than the member, the inner end of each portion of the member cut away to form such projection being located aslant to the plane of the top surface of the body and having an angular relationship thereto such that when the projection of one member is engaged in the cut-away portion of another member, the members will be so related to each other as to constitute sides of a polygonal figure which, if completed, would have more than four sides, the interengagement being such that force tending to increase the angularity between such interengaged members tends to split such members longitudinally by forcing different parts thereof in different relative directions.

ARCH W. SPAULDING.
JOHN M. ROBERTSON.