

[54] APPARATUS AND METHOD FOR SIZING HOLES

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[22] Filed: Jan. 17, 1973

[21] Appl. No.: 324,485

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 268,478, July 3, 1972, which is a continuation-in-part of Ser. No. 33,281, April 30, 1970, abandoned, which is a continuation-in-part of Ser. No. 711,368, March 7, 1968, abandoned.

[52] U.S. Cl. 72/370, 72/391, 29/446, 29/523

[51] Int. Cl. B21j 15/04

[58] Field of Search 72/370, 391; 29/446, 523

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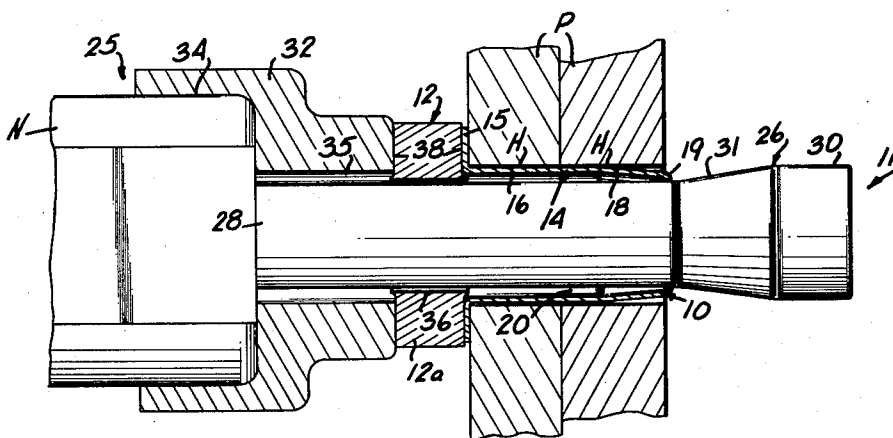
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[57] ABSTRACT

A method of sizing holes by enlarging holes through a workpieces with a mandrel and working through a seamless tubular member to enlarge the holes. The rebound of the tubular member upon enlargement is less than the material of the workpieces and is left in the holes to limit the rebound of the holes. Also disclosed is the joint produced by the above method.

A device for sizing holes is disclosed which includes a mandrel with an expansion section which is forced through a seamless tubular member while held in the holes to enlarge both the tubular member and the holes. A backup member is provided with an aperture therethrough of a diameter smaller than the inside diameter of the tubular member and which is enlarged by the mandrel simultaneously with the enlargement of the sleeve member. By providing different outside diameters and a constant inside diameter on the seamless tubular member, the workpieces may be enlarged different amounts.

20 Claims, 22 Drawing Figures



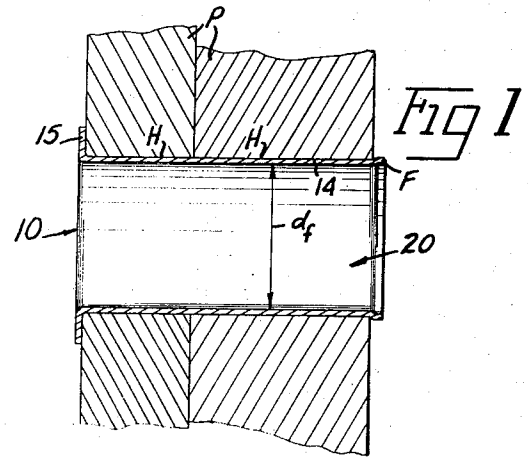
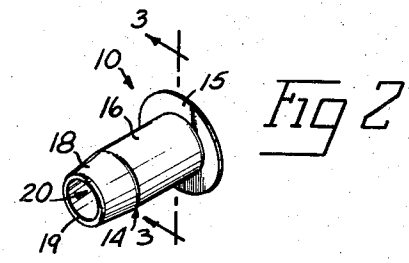
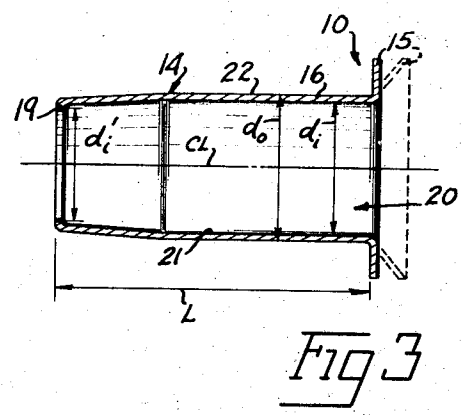
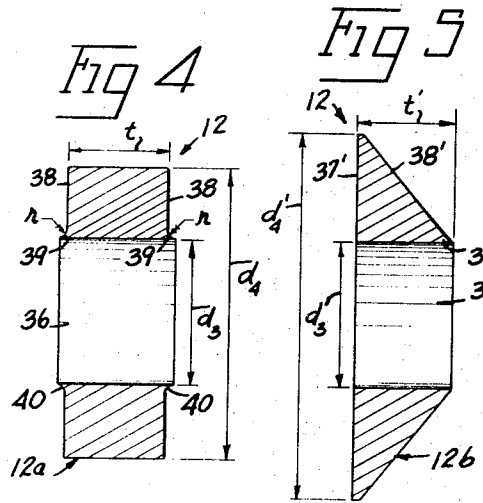
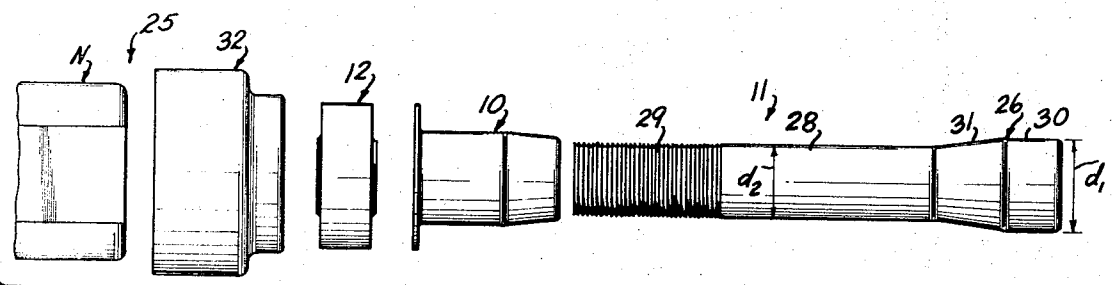
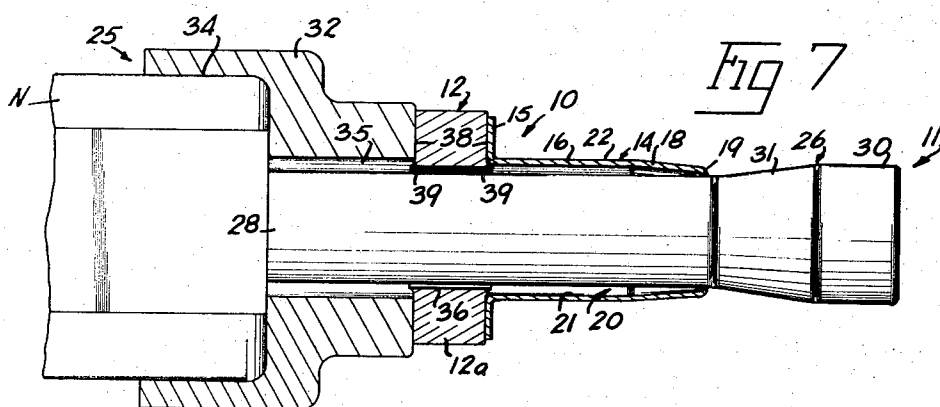
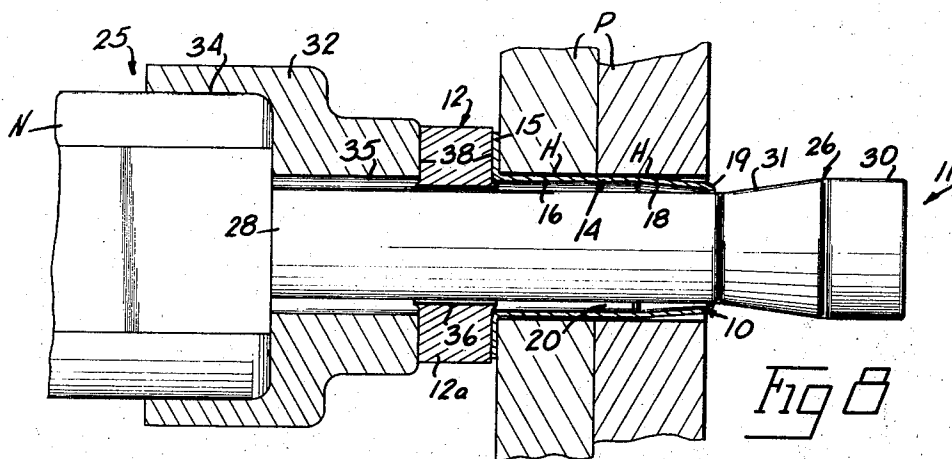
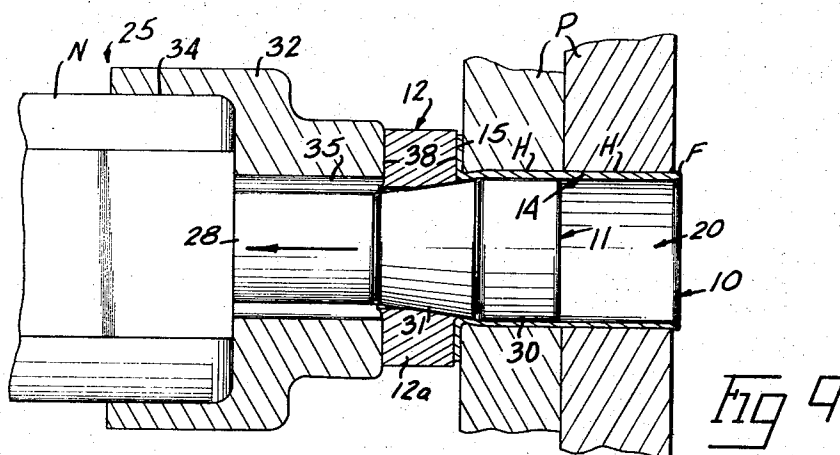
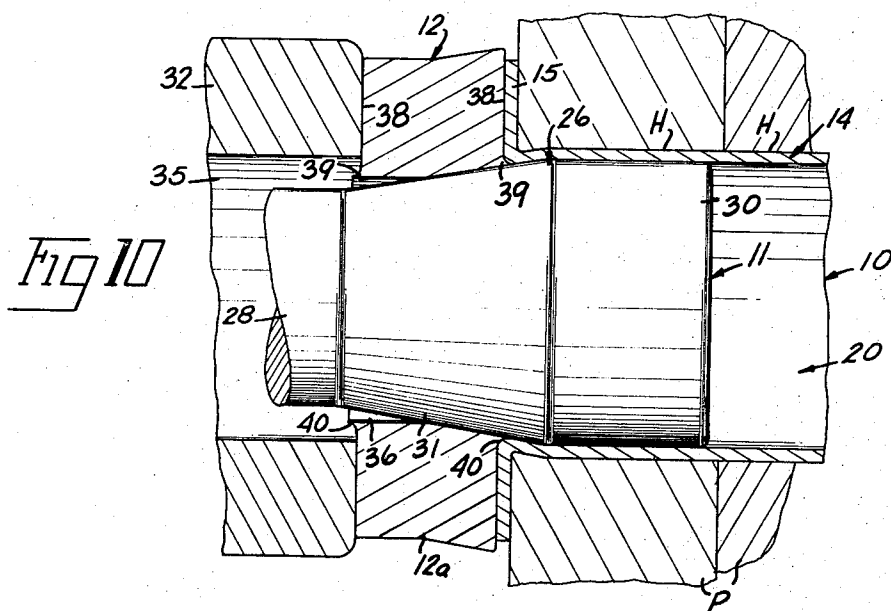
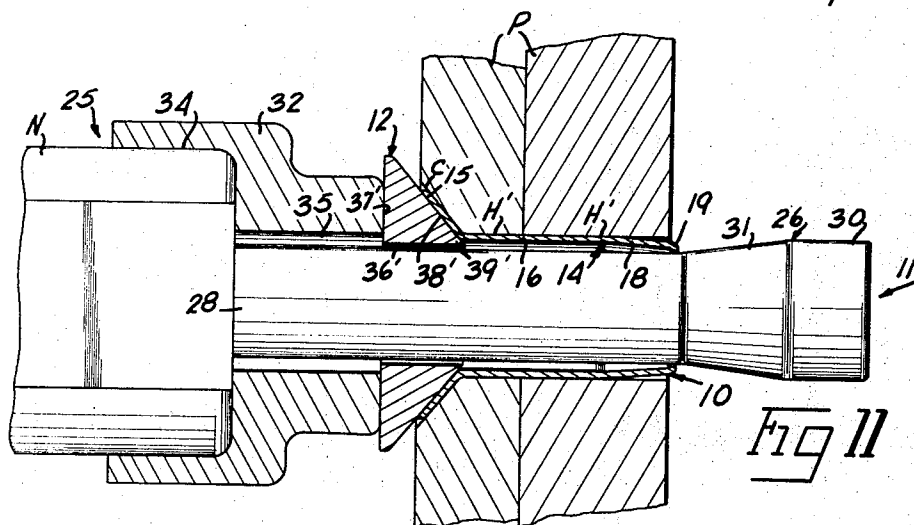
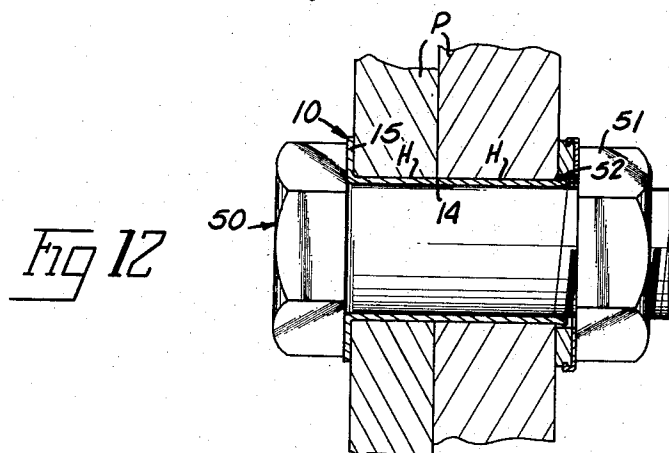
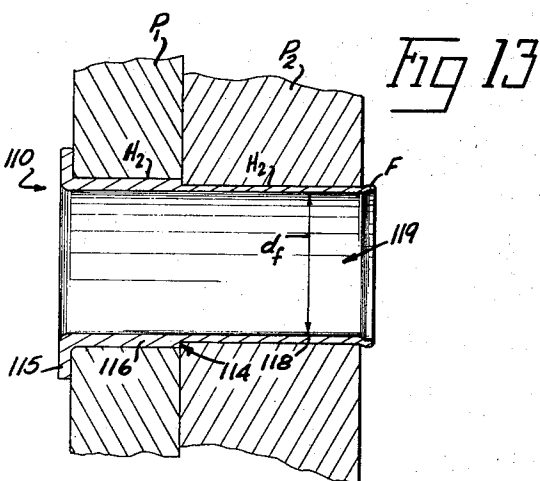
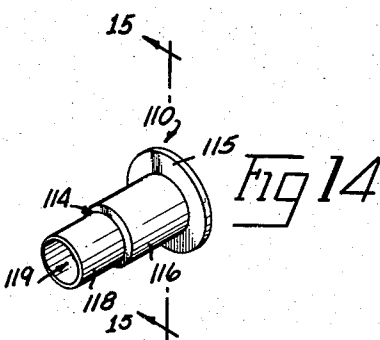
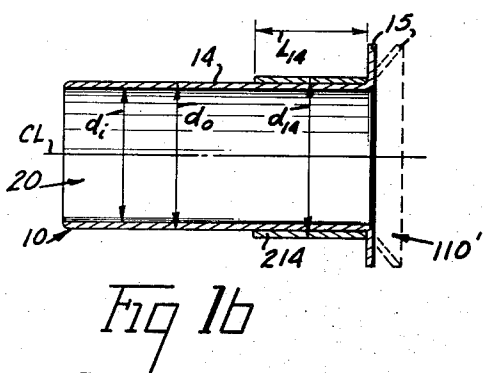
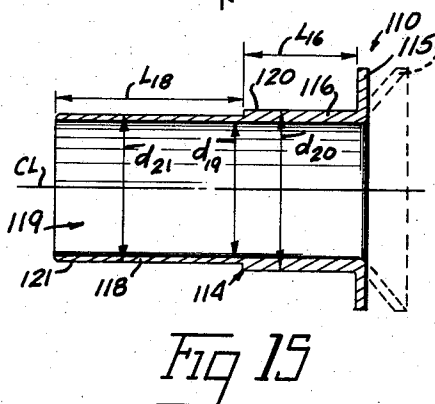
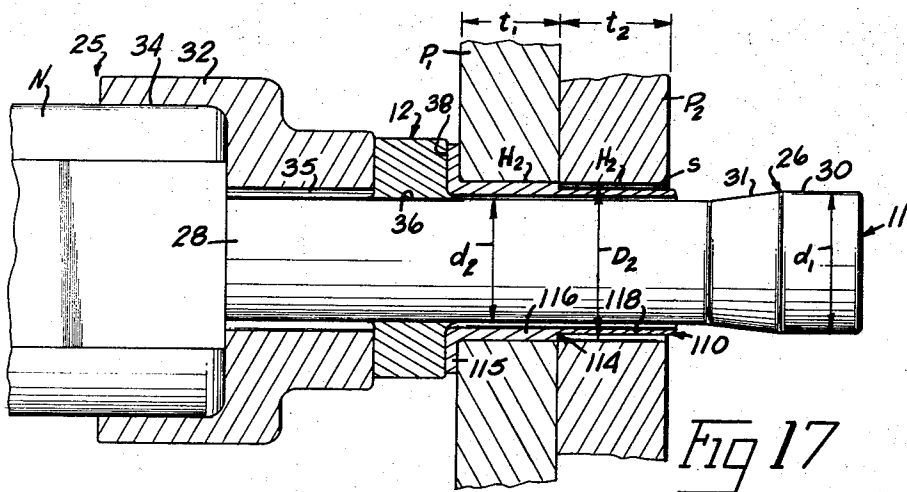
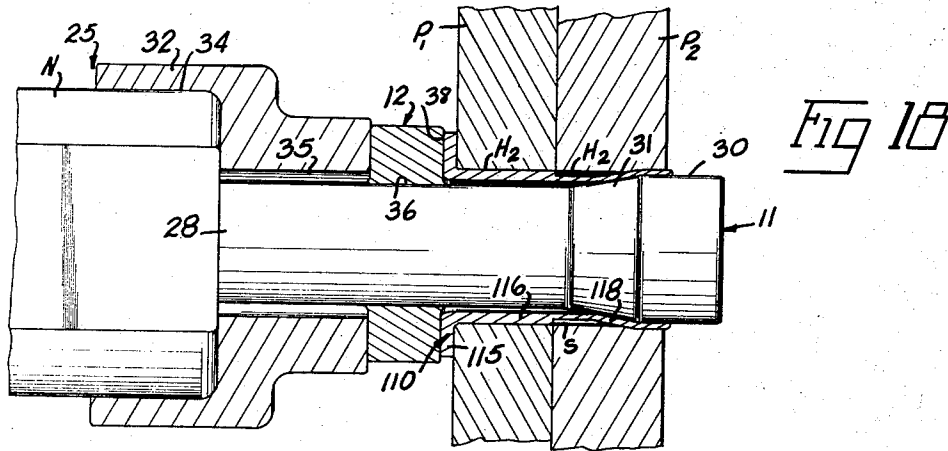
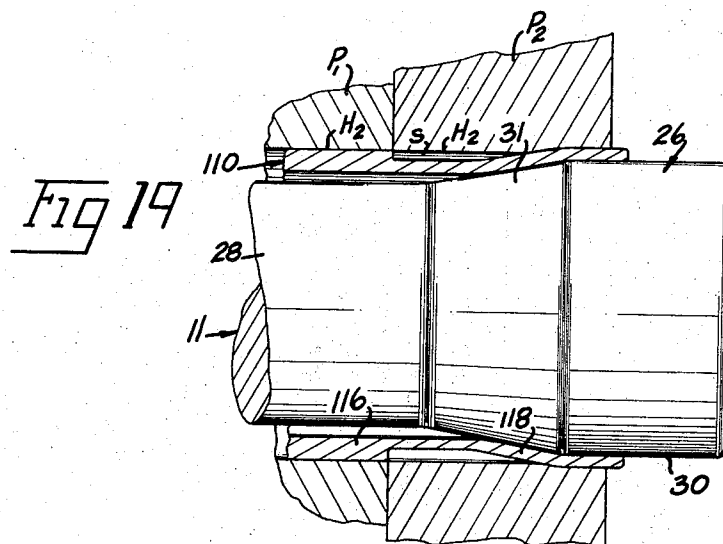
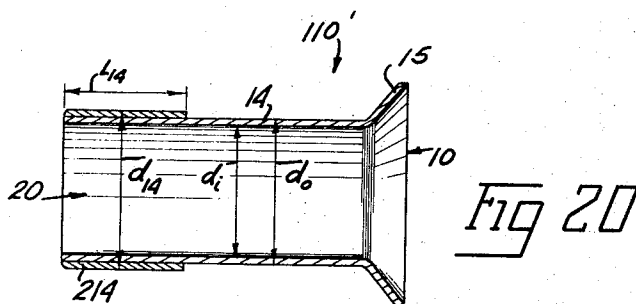


Fig 6









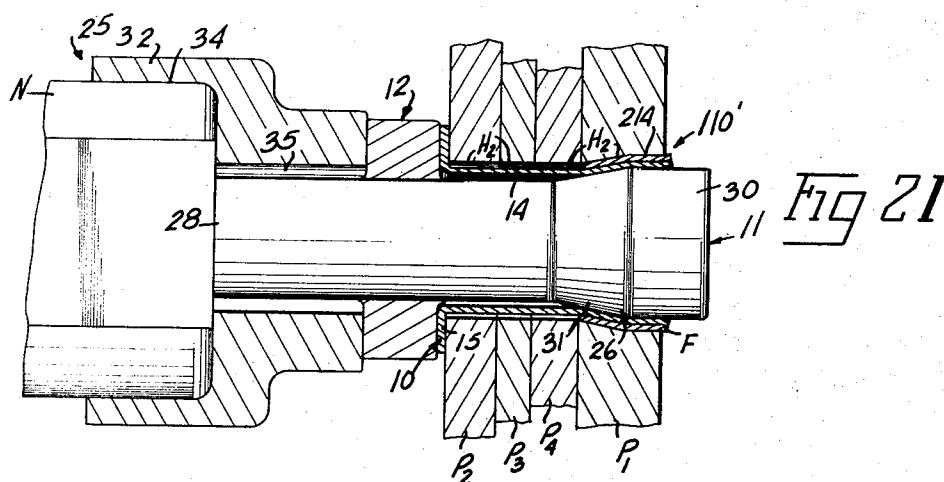
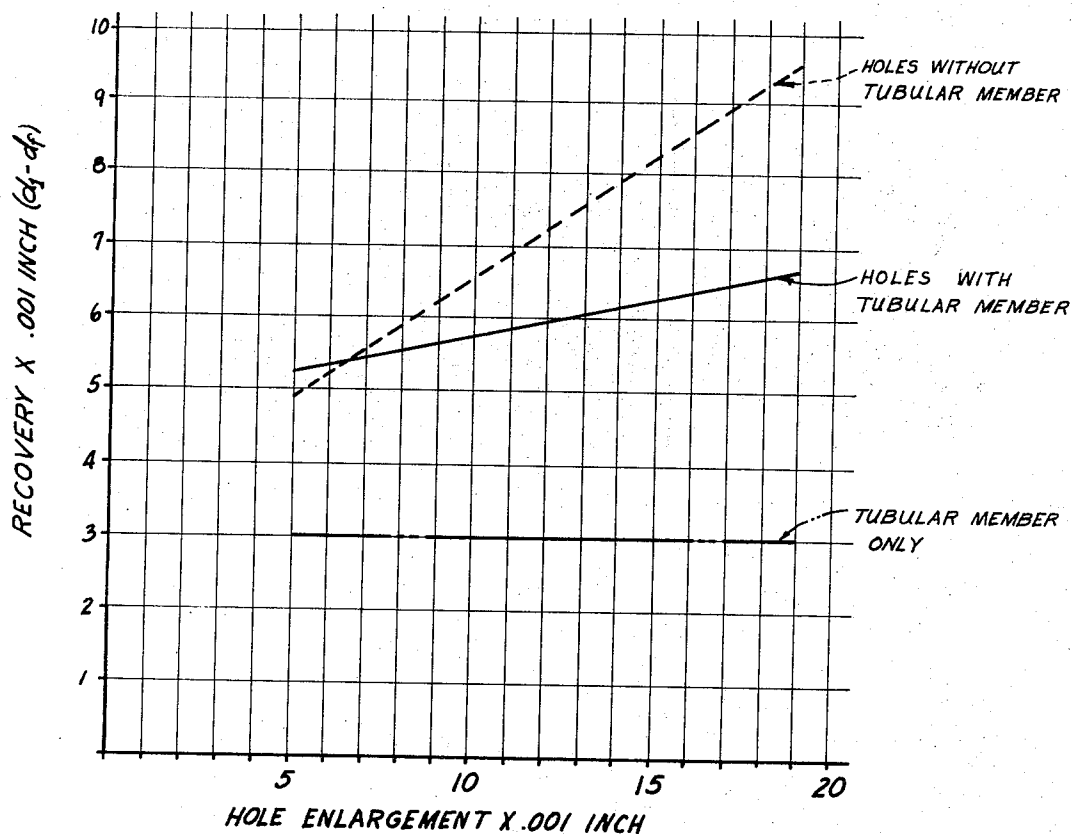


Fig 22

APPARATUS AND METHOD FOR SIZING HOLES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of my co-pending application Ser. No. 268,478, filed July 3, 1972 which is in turn a continuation-in-part of my earlier filed application Ser. No. 33,281, filed Apr. 30, 1970, now abandoned which was in turn a continuation-in-part of my earlier filed application Ser. No. 711,368 filed Mar. 7, 1968, now abandoned.

BACKGROUND OF THE INVENTION

Various methods and techniques are available on the market today for accurately sizing holes in work pieces for the installation of fasteners therein. The most commonly used technique is to drill a pilot hole through the workpieces and then ream this pilot hole to final size with a reamer. While drilling and reaming can be satisfactorily used in a laboratory or machine shop environment where sufficient equipment is available to both accurately drill and ream the holes, this technique has been unsatisfactory when the operation must be performed using manually held tools even though elaborate guides have been devised. This has been especially true in the aerospace industry where the use of compound surfaces and the necessity of field repair have required widespread use of manually held tools. As a result of the use of such manually held tools, widespread use of nonstandard sizes of fasteners have been required to correct improperly sized holes.

Another hole sizing technique that has been attempted is to drill a pilot hole and then pull a mandrel with an expansion section thereon through the pilot hole to finally size same. Because the material of the workpieces rebounds after the passage of the mandrel through the holes and the amount of rebound is a function of the amount the pilot hole is enlarged, it is necessary to accurately size the holes either before or after the enlarging operation with a tool such as a reamer in order to accurately determine the final hole size. Thus, because of the inability to accurately control the reaming operation when using manually held tools, this technique has been unable to accurately size holes.

SUMMARY OF THE INVENTION

These and other problems and disadvantages of the prior art are overcome by the invention disclosed herein by providing a seamless tubular member within the holes to be sized which rebounds less than the material of the work pieces when it is enlarged. A mandrel with an expansion section is passed through the seamless tubular member to enlarge same into contact with the holes and enlarge the holes through the tubular member. Because the seamless tubular member is left in the holes and rebounds less than the amount the material about the holes would normally rebound, the tubular member limits the rebound to such an extent that the final size of the passage through the tubular member is substantially constant even though the amount of enlargement of the holes through the workpieces may vary from hole to hole. Thus, the invention is able to accurately size holes where the pilot hole tolerance is greater than that allowed in the prior art. Because the final size of the passage through the seamless tubular member is substantially constant where the amount of

enlargement of the holes vary, the holes through different workpieces at the same joint may be enlarged different amounts using a seamless tubular member with a constant inside diameter and a multiple outside diameter while the final size of the passage remains substantially constant.

The seamless tubular member is prevented from being stripped from the holes by a washer shaped backup member which has an aperture therethrough which is at least as small in diameter as the initial inside diameter of the seamless tubular member. As the mandrel passes out of the seamless tubular member during the enlargement thereof, the aperture through the backup member is enlarged simultaneously with the tubular member so that the tubular member is always supported against stripping out of the holes during the expansion operation.

The apparatus of the invention includes generally a seamless tubular member positionable in the pilot holes through the workpieces to be enlarged, and a mandrel with a support section slidably receivable through the tubular member and an expansion section of a prescribed diameter larger than the inside diameter of the tubular member. The backup member has an aperture therethrough at least as small as the inside diameter of the tubular member prior to enlargement and is positioned on the support section of the mandrel in opposition to the expansion section. The backup member is sufficiently strong in compression to prevent its collapse during the withdrawing of the expansion section through the tubular member, but is sufficiently weak in radial expansion to allow the expansion section of the mandrel to pass therethrough and enlarge the aperture simultaneously with the enlargement of the tubular member.

When it is desirable to enlarge the holes a substantially constant amount, the sidewall of the seamless tubular member has a substantially constant thickness along its length with substantially constant inside and outside diameters. On the other hand, when it is desirable to enlarge the holes in the different work pieces of the same joint different amounts, the sidewall of the seamless tubular member has different thicknesses along its length with a substantially constant inside diameter and multiple outside diameters.

The method of the invention includes positioning a seamless tubular member having a rebound that is less than that of the material of the workpieces in holes through the workpieces and enlarging the tubular member and the holes of the workpieces through the tubular member. This causes the tubular member to limit the amount of rebound of the material of the workpieces so that the final size of the inside of the tubular member is relatively constant even though the amount of enlargement of the holes may vary.

These and other features and advantages of the invention will become more fully understood upon consideration of the following specification and accompanying drawings wherein like characters of reference designate corresponding parts throughout the several views and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a joint in which the holes through the workpieces have been sized in accordance with the invention;

FIG. 2 is a perspective view of the tubular member for use with the invention;

FIG. 3 is an enlarged cross-sectional view taken along line 3—3 in FIG. 2;

FIG. 4 is an enlarged cross-sectional view of one embodiment of the backup member of the invention;

FIG. 5 is an enlarged cross-sectional view of another embodiment of the backup member of the invention;

FIG. 6 is an exploded view illustrating the assembly of the invention;

FIG. 7 is a cross-sectional view of the invention assembled for use;

FIG. 8 is a cross-sectional view of the invention in position for sizing a hole in workpieces;

FIG. 9 is a view similar to FIG. 8 showing the mandrel being withdrawn;

FIG. 10 is an enlarged portion of FIG. 9;

FIG. 11 is a view similar to FIG. 8 for countersunk holes;

FIG. 12 is a view showing a fastener installed in the joint after the holes have been sized;

FIG. 13 is a cross-sectional view of a joint in which the holes through the workpieces have been sized in accordance with an alternate embodiment of the invention;

FIG. 14 is a perspective view of an alternate embodiment of the tubular member for use with the invention;

FIG. 15 is an enlarged cross-sectional view taken along line 15—15 in FIG. 14;

FIG. 16 is a cross-sectional view similar to FIG. 15 showing an alternate form of the tubular member of FIG. 14;

FIG. 17 is a cross-sectional view of the invention using the alternate embodiment of the tubular member ready for use;

FIG. 18 is a view similar to FIG. 17 showing the mandrel being withdrawn;

FIG. 19 is an enlarged portion of FIG. 18;

FIG. 20 is a cross-sectional view similar to FIG. 16 showing an alternate location for the major expansion section on the tubular member;

FIG. 21 is a cross-sectional view showing the tubular member of FIG. 20 in use; and,

FIG. 22 is a graph illustrating the effect of the invention on hole sizing operations.

These figures and the following detailed description disclose specific embodiments of the invention, however, the inventive concept is not limited thereto since it may be embodied in other forms.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Referring to the figures, it will be seen that the apparatus of the invention includes generally a seamless tubular member 10, an expansion mandrel 11 and a backup member 12. The tubular member 10 is held within pilot holes H through workpieces P by the backup member 12 while the mandrel 11 is withdrawn through the tubular member 10 to enlarge the tubular member into engagement with the workpieces and enlarge the pilot holes H. After the mandrel is withdrawn through the tubular member, the tubular member limits the rebound of the material of the workpieces to determine the final hole size independently of the amount of enlargement of the pilot holes.

It is known that if holes through workpieces are enlarged by moving a mandrel therethrough, the material of the workpieces about the holes rebounds or recovers for a certain percentage of the enlargement. This makes the holes after passage of the mandrel therethrough smaller than the largest diameter of the mandrel. The amount of material recovers depends on several factors including the type of the material of the workpieces, the mass of the material about the holes, the initial diameter of the pilot holes and the amount the holes are enlarged. Because these factors vary, it is difficult to predict what the amount of recovery will be. This is especially true if the amount of enlargement of the holes is not accurately controlled.

It has been found, however, that if the holes are enlarged through a seamless member which has less of a tendency to recover than the material of the workpieces and this member left in the holes after the holes have been enlarged, the size of the resulting hole or passage through the seamless member is substantially constant. This is true even though the amount of enlargement of the initial pilot holes through the workpieces varies. This is the basic invention disclosed in this application.

Referring now to FIGS. 2 and 3, the seamless tubular member 10 is that member used to limit the amount of rebound of the pilot holes H in the workpieces P upon enlargement. The tubular member 10 includes a sidewall 14 with a head flange 15 at one end thereof. The head flange 15 may be normal to the centerline CL of the tubular member as shown in solid lines in FIG. 3 if the resulting joint is to include an exposed head fastener or at an angle as shown by dashed lines in FIG. 3 if the resulting joint is to include a countersunk head fastener. The sidewall 14 includes a constant diameter cylindrical section 16 adjacent the head flange 15 with a tapered section 18 integral with that end of the cylindrical section 16 opposite the head flange 15. An inwardly directed lip 19 may be provided on the free end of the tapered section 18. Thus, the sidewall 14 defines a passage 20 therethrough along centerline CL. The tapered section 18 and lip 19 are provided to facilitate insertion of the member 10 into the pilot holes H and to prevent damage to the inside of the holes H during insertion. It is to be further understood that the entire sidewall 14 may be of constant diameter without departing from the scope of the invention.

It will further be noted that the thickness of sidewall 14 is substantially constant along its length so as to define concentric inner and outer surfaces 21 and 22. The material and the thickness of the sidewall 14 are such that the amount of rebound or recovery upon expansion is very small. One such material that has been found satisfactory is stainless steel when the thickness of sidewall 14 is approximately 0.008–0.016 inch where the workpieces are of a material such as an aluminum alloy. It is to be understood that different materials and thicknesses may be used without departing from the scope of the invention. The sidewall 14 has a major outside diameter d_o , a major inside diameter d_i and a length L prior to enlargement as will be more fully explained.

The mandrel 11 is designed for use with a driving unit 25 for forcing the mandrel through the tubular member 10. As seen in FIGS. 7–9, the mandrel 11 has an expansion section 26 at one end, a central support section 28, and a gripping section 29 at the opposite end thereof.

The expansion section 26 defines a cylindrical sizing surface 30 at its free end with a tapered expansion surface 31 connecting the surface 30 with the support section 28. The diameter d_1 of the sizing surface 30 is larger than the major inside diameter d_i of the member 10 and the diameter d_2 of the support section 28 is smaller than the diameter d_i' of the hole through the lip 19. The gripping section 29 is adapted to be gripped by the unit 25 as will be explained.

The driving unit 25 includes an adapter 32 and a commercially available lockbolt installation tool (not shown) with a self-releasing pulling nose assembly N (partly shown). The gripping section 29 is provided with grooves and ridges to be engaged by the nose assembly N. The adapter 32 has a large diameter recess 34 receivable over the end of the nose assembly N with a passage 35 through the end thereof aligned with the hole in the end of nose assembly N when the adapter is in position as shown in FIG. 7. The passage 35 has a diameter such that the sizing surface 30 will just slidably pass therethrough. The adapter 34 serves as a spacer to prevent the expansion section 26 of mandrel 11 from being caught in the nose assembly N since this section is normally larger in diameter than the opening in the end of the nose assembly. The adapter 32 is also removable from the nose assembly N so that the mandrel 11 can be easily removed from the nose assembly manually after each use.

The backup member 12 is best seen in FIGS. 4 and 5. The member 12a in FIG. 4 is for use when enlarging the member 10 for exposed head fasteners and the member 12b in FIG. 5 is for use when enlarging the member 10 for countersunk head fasteners. Member 12a is washer shaped and defines a central aperture 36 therethrough with a diameter d_3 at least as small as the diameter d_i but larger than the diameter d_2 so that the member 12a can be slipped onto the support section 28 of the mandrel. Member 12a has opposed working faces 38, each of which is adapted to face the head flange 15 of the member 10. Faces 38 are normal to the aperture 36 and parallel. A protruding lip 39 is provided about the aperture 36 on each face 38. This lip 39 has an outer surface 40 with a concave cross-section of a radius r that conforms to the radius between the head flange 15 and sidewall 14 at passage 20.

The backup member 12a has a thickness t and an outside diameter d_4 such that the member is sufficiently strong in compression through its thickness to not collapse as the mandrel 11 is being withdrawn to enlarge the member 10 but sufficiently weak in a radial direction to allow the expansion section 26 to expand same and enlarge the aperture 36 so that section 26 can pass therethrough as seen in FIG. 9. Because the tapered expansion surface 31 of the section 26 expands the aperture 36 at the same rate the sidewall 14 adjacent the aperture 36 is being expanded, the sidewall of the member 10 is supported to prevent the sidewall from being stripped from the holes H during enlargement. This is best seen in FIG. 10. Thus, the radius between the head flange 15 and sidewall 14 is maintained.

The member 12b shown in FIG. 5 is also generally washer shaped with a central aperture 36' like aperture 36 in member 12a. Aperture 36' has a diameter d_3 like that of aperture 36 so that the member 12b can be slipped onto the support section 28 of the mandrel 11. Unlike the member 12a, member 12b has a working face 38' which is tapered to conform to that of counter-

sunk head flange of member 10. Member 12b has an opposite face 37' which is normal to aperture 36' like face 38 of member 12a. Because the intersection of the tapered face 38' with the aperture 36' forms a lip 39', there is no need for the additional lip required as with the member 12a. The member 12b has a maximum thickness t' and an outside diameter d_4' such that the member will not collapse as the mandrel is being withdrawn to enlarge member 10 but will allow the aperture 36' to be expanded as the expansion section 26 passes therethrough simultaneously enlarging the member 10 immediately adjacent the member 12b.

The diameter d_1 of the sizing surface 30 is usually larger than the major inside diameter d_i of member 10 in the range of 0.005–0.030 inch, depending on the desired amount the passage 20 in the seamless member 10 is to be enlarged to final diameter d_f seen in FIG. 1. The diameter d_2 of the support section 28 is usually smaller than the initial diameter d_i' of the opening in lip 19 so that the section 28 can be easily inserted into the member 10. The diameter d_3 of the aperture 36 through backup member 12 is usually equal to or slightly smaller than the major inside diameter d_i in the order of 0.001 inch to insure that the sidewall 14 of member 10 will be adequately supported during the enlargement of the member 10 to prevent the member 10 from being stripped from the holes. The thicknesses t and t' may be varied as long as the above criteria is met, however, it has been found that a thickness in the order of 1/16–1/8 inch is sufficient for both members 12a and 12b. The diameters d_4 and d_4' may also be varied, however, it has been found that a diameter d_4 in the order of 1/8 – 1/4 inch larger than diameter d_3 is sufficient and a diameter d_4' in the order of 1/4 – 3/8 inch larger than diameter d_3' is sufficient. While various materials may be used for members 14, it has been found a mild annealed steel performs satisfactorily using the dimensions set forth above. Of course, it is to be understood that different diameters d_1 , d_2 , d_3 and d_3' will be used for different diameters of members 10.

OPERATION

In operation, the pilot holes H are drilled through the workpieces P with a conventional drill. Because the invention is able to accept a hole tolerance greater than that presently associated with precision hole preparation, it is not necessary to ream the pilot holes to their final size as is presently done. The drill size for the holes H is selected so that the amount the holes will be enlarged while the expansion section 26 is within the holes H is in the order of 0.005 to 0.020 inch. Because holes can be drilled conventionally within a 0.005 inch tolerance range, this range will usually be acceptable within the overall hole enlargement range set forth above. Previously, the holes tolerance range was 0.003 inch which required the reaming operation.

If the diameter d_1 of the cylindrical sizing surface 30 is smaller than the major outside diameter d_o of the tubular member 10 as is usually the case, the mandrel 11, member 10 and member 12 can be assembled prior to insertion of the unit into the holes H as seen in FIG. 7. This is accomplished by sliding the tubular member 10 onto the support section 28 with the tapered section 18 and lip 19 facing the expansion section 26 of mandrel 11. Next, the backup member 14 is slipped onto the support section 28 so that its working face 38 faces the head flange 15 of member 10. Next, the gripping sec-

tion 29 of mandrel 10 is inserted through the passage 35 in adapter 32 until the gripping section 29 is engaged by the nose assembly N as seen in FIG. 7.

The operator can then insert the tubular member 10 and mandrel 11 through the holes H until the head flange 15 rests against the workpieces P as seen in FIG. 8. It will be noted that the length L of the sidewall 14 is slightly greater than the combined thickness of the workpieces P so that the end of the wall 14 protrudes from the off side of the workpieces. This amount of protrusion is usually less than 1/16 inch. The driving unit 25 is then actuated to cause the nose assembly N to pull the mandrel 11 toward it while bearing against the backup member 12 to hold it and the head flange 15 against the work pieces P in opposition to the expansion section 26 of mandrel 11.

As the tapered expansion surface 31 enters the member 10, the tapered section 18 and lip 19 are first straightened and that portion protruding beyond the workpieces P is then flared outwardly as indicated at F in FIGS. 1 and 9. This serves to assist in retaining the member 10 properly located within the holes H as the section 26 passes therethrough. The section 26 continues to move through the member 10 enlarging the sidewall 14 into contact with the side of the holes H and then enlarging the holes H.

As the tapered surface 31 passes out of member 10, it engages the member 12 as best seen in FIGS. 9 and 10 to expand the aperture 36 therethrough simultaneously with the expansion of the member 10 immediately adjacent the member 12. Thus, that end of member 10 on the near side of the workpieces P is supported at all times during the passage of the expansion section 26 through member 10 to prevent the member 10 from being stripped out of the holes. A lip may be extruded on the member 12 about the aperture 36 on that side of member 12 from which the section 26 exits. The lip, however, has no detrimental effect on the workpieces P since the member 12 is discarded after the expansion of aperture 36. The member 12 cannot be reused in subsequent hole enlarging operations since the enlarged aperture 36 would not adequately support the member 10 to prevent it from being stripped out of the holes of the workpieces.

Because the tubular member 10 is left in the holes after they are enlarged, an added benefit is achieved in that a hard durable surface is provided within the holes that resists damage as the fastener is installed. This surface on the inside of the member 10 further allows the fastener to be driven into interference if it is desirable. Even if the member 10 is scratched or otherwise damaged during the placement of the fastener therethrough, the fatigue life of the workpieces is extended because the damage is segregated from the holes.

When a countersunk fastener is to be used in the joint as illustrated in FIG. 11, countersunk pilot holes H' are formed with a countersink C. The head flange 15 of member 10 fits within the countersink C and is supported by the tapered work face 38' of the backup member 12b. As the mandrel 11 is withdrawn through the member 10, a sufficient force is exerted on the countersink C through member 12b and head flange 15 to work the countersink C. Previously, the countersink C had to be formed after the mandrel had passed through the holes.

To facilitate the placement of the tubular member 10 and backup member 12 onto the mandrel 11, the work-

ing face of the backup member may be bonded to the head flange 15 of the tubular member so that members 10 and 12 come as a unit. The relative movement between the backup member 12 and the head flange 15 as the mandrel 11 is pulled therethrough breaks the bond to separate the backup member 12 from the tubular member 10 as an incident to the enlarging operation. The bonding agent should be easily cleanable so that any residue left on the head flange 15 after the bond is broken can be easily removed.

Because galvanic corrosion may be encountered between the material of the workpieces and the tubular member when the joint is in use, a protective coating may be applied to the outside surface of the tubular member. Because the tubular member is not moved longitudinally during enlargement, this coating will remain in place as the tubular member is installed. One suggested coating is a zinc chromate primer.

Also, because of the high friction forces involved, it may be desirable to lubricate the interface between the tubular member and the mandrel. While various lubricants may be used, a dry film lubricant that is commercially available has been used satisfactorily. This dry film lubricant is usually applied to the inner surface of the tubular member so that the mandrel does not have to be recoated before each use.

When a conventional fastener 50 is installed through the joint as seen in FIG. 12, an appropriate nut or washer nut 51 is used which defines a cutout 52 therein as is known in the art to fit over the protruding end of the tubular member 10. Because of the superior quality of the inner surface of the member 10 through which the fastener is installed, it will be seen that the fastener may be driven into interference without damaging the joint.

FIG. 22 is a graph resulting from a series of test conducted by applicant to determine the effectiveness of the invention. First, a series of holes in the same diameter range where enlarged in different amounts using the invention. The diameter d_f of the enlarged resulting passage 20 through the tubular member 10 was measured and compared with the always larger diameter d_i of the sizing surface 30 of mandrel 11. The difference between diameter d_i and diameter d_f is commonly referred to as the rebound or recovery after enlargement. The rebound was then plotted against the amount of enlargement to produce the solid line in FIG. 22. Next, the test was repeated except that no member was left in the holes to limit the amount of rebound. The plot of the rebound versus enlargement is shown by a dashed line in FIG. 22. Next, the member 10 was enlarged out of the holes in the work pieces and the amount of rebound plotted against enlargement is shown by a phantom line in FIG. 22. Based on this chart then, it will be seen that the rebound using the invention is substantially constant even though the amount of enlargement varies. This means that the size of mandrel 11 determines the final size of the passage through the workpieces. Referring to FIG. 22, it will be seen that the amount of change in the rebound as the enlargement varies is well within the allowable 0.003 inch range generally permissible for hole tolerance in the aerospace industry when the invention is used, whereas such is not the case when the prior art techniques are used in which rebound is not limited. Thus, because the amount of rebound or recovery is predictable when the invention is used, the workman prepares

the pilot holes with a standard drill without having to very accurately size the pilot holes. He then selects the mandrel size for the particular desired final diameter without having to consider the amount of enlargement to the extent required by the prior art. The above tests were made in 7075 aluminum alloy.

ALTERNATE EMBODIMENT OF TUBULAR MEMBER

Referring now to FIGS 13-15 and 17-19, an alternate embodiment of the seamless tubular member is illustrated and designated 110. The member 110 is used when it is desirable to enlarge the holes through different workpieces at the same joint different amounts while providing a constant diameter fastener receiving passage in the enlarged holes. The member 110 is best seen in FIGS. 14 and 15 prior to use and is used to limit the amount of rebound of the pilot holes H_2 in the workpieces P_1 and P_2 upon enlargement. The tubular member 110 includes a sidewall 114 with a head flange 115 at one end thereof. The head flange 115 may be normal to the centerline CL of the tubular member as seen in solid lines in FIG. 15 if the resulting joint is to receive an exposed head fastener or at an angle as shown by dashed lines in FIG. 15 if the resulting joint is to receive a countersunk head fastener.

The side wall 114 includes a major expansion, constant outside diameter cylindrical section 116 adjacent head flange 115 and a minor expansion, constant outside diameter, cylindrical section 118 integral with section 116 opposite head flange 115. The sections 116 and 118 define a common constant diameter cylindrical passage 119 therethrough. The projecting end of section 118 may be tapered and have a lip as disclosed for member 10. It will be seen that section 115 defines an outer surface 120 concentric with passage 119 with a major diameter d_{20} prior to use while section 118 defines an outer surface 121 concentric with passage 119 with a minor diameter d_{21} prior to use smaller than diameter d_{20} . The common passage 119 has a diameter d_{19} prior to use smaller than diameter d_{21} . Section 116 has a length L_{16} substantially equal to the thickness t_1 of the workpiece P_1 that is to be enlarged the larger amount while the section 118 has a length L_{18} slightly greater than the thickness t_2 of the workpiece P_2 which is to be enlarged the smaller amount as will become more apparent.

The material of tubular member 110 is the same as that of member 10 and has the same characteristic of rebounding less than the material of the workpieces P_1 and P_2 upon enlargement. The thickness of the thinner section 118 is substantially the same as that of the sidewall 14 of member 10 while the thickness of section 116 is thicker than section 118 by an amount equal to that amount the workpiece P_1 is to be enlarged greater than workpiece P_2 . This amount ranges from 0-0.020 inch is usually about 0.008 inch.

The member 110 uses the same mandrel 11, backup member 12 and driving unit 25 as the member 10 for installation. The pilot holes H_2 are made through the workpieces P_1 and P_2 just as holes H for using member 10. The holes H_2 , however, are made with a constant diameter D_2 sufficient to receive the thicker section 116 of member 110. The tubular member 110 is loaded onto the mandrel 11 followed by backup member 12 similarly to that of member 10. The unit is inserted through the holes H_2 in the workpiece P_1 first so that

the thicker section 116 lies within the workpiece P_1 while the thinner section 118 lies within the workpiece P_2 as seen in FIG. 17. It will be noted that an annular space s is now around the outside of the thinner section 118.

The driving unit 25 is then actuated to cause the nose assembly N to pull the mandrel 11 toward it while bearing against the backup member 12 to hold it and the head flange 115 against the workpiece P_1 in opposition to the expansion section 26 of mandrel 11. As the tapered expansion surface 31 enters the projecting end of section 118 protruding beyond the workpiece P_2 , it flares the section 118 outwardly to first form the flange F seen in FIG. 13 to assist in retaining the member 110 in holes H_2 . The surface 31 continues to move through the member 110 first expanding the section 118 across the space s into contact with the workpiece P_2 and then expands the hole H_2 in workpiece P_2 a first amount as seen in FIGS. 18 and 19. When the surface 31 reaches the thicker section 116, it expands the inside thereof to the same diameter as the inside of section 118. Because section 118 is thicker, this expands the hole H_2 in workpiece P_1 a greater amount than the hole H_2 in workpiece P_2 , however, because the member 110 limits the rebound of the workpieces P_1 and P_2 , the enlarged common passage 119 through sidewall 114 has a substantially constant resulting diameter d_r along its length as seen in FIG. 13. The backup member 12 serves the same function as described above. A fastener such as that shown in FIG. 12 can then be installed through the tubular member 110 to complete the joint.

An alternate form of the tubular member is shown in FIG. 16 and is designated 110'. The member 110' includes the tubular member 10 described above with an additional seamless tubular cylindrical section 214 around a portion of the outside of sidewall 14. The member 10 shown in FIG. 16 does not have the tapered section 18 or lip 19 although they may be used. The section 214 has an inside diameter just sufficient to be forced onto the sidewall 14 to the position shown in FIG. 16. The outside diameter d_{14} of section 214 and the length L_{14} thereof corresponds to the outside diameter d_{20} and length L_{16} of section 116. The member 110' is installed in the same manner as member 110 and performs the same.

FIG. 20 shows a tubular member 110' in which the major expansion section 214 is located on the distal end of the member 10 rather than adjacent the head flange 15. With section 214 on the distal end of sidewall 14, the holes H_2 of the underlying workpiece can be enlarged a greater amount than the exposed workpiece. The member 110' shown in FIG. 20 is illustrated in use in FIG. 21. The flange F' formed when the mandrel 11 initially engages the sidewall 14 and section 214 prevents the section 214 from slipping as the mandrel continues to move through member 110'. Thus, it will be seen that the holding member 12 prevents the shifting of section 214 along the member 10 when it is located adjacent head flange 15 as seen in FIG. 16 while the flange F' prevents it from shifting when it is located on the distal end of sidewall 14. It is to be understood that member 110 may have the major expansion section 116 located like that of sleeve 110' in FIG. 20 and perform in the same way. Also, FIG. 21 illustrates the use of the invention on more than two workpieces, here designated as P_1 - P_4 .

Another advantage that has been found when using the invention is that the fatigue life of the workpieces is usually increased when the holes are enlarged without removing any material. It is to be further understood that full use of modifications, substitutions and equivalents may be made without departing from the scope of the invention.

I claim:

1. A method of sizing holes through workpieces comprising the steps of:

forming pilot holes through the workpieces;

placing a seamless tubular member within the pilot holes which rebounds less than the workpieces upon enlargement beyond the elastic limit of the material of the workpieces; and

uniformly enlarging the tubular member throughout its length and the pilot holes through the tubular member with the tubular member serving to limit the amount of rebound of the resulting substantially constant diameter hole through the tubular member.

2. The method of claim 1 wherein the step of enlarging includes passing a mandrel axially through the tubular member to uniformly enlarge the tubular member throughout its length.

3. A method of sizing holes through workpieces comprising the steps of:

forming pilot holes through the workpieces;

placing a seamless tubular member within the pilot holes which rebounds less than the workpieces upon enlargement;

enlarging the tubular member and the pilot holes through the tubular member by passing a mandrel through the tubular member with the tubular member serving to limit the amount of rebound of the resulting hole through the tubular member; and,

supporting the tubular member in opposition to the movement of the mandrel with a backup member having aperture therethrough at least as small as the hole through the tubular member prior to enlargement, and wherein the step of enlarging further includes passing the mandrel through the aperture to enlarge same simultaneously with the enlargement of the tubular member immediately adjacent the backup member.

4. A method of enlarging a tubular member within holes through workpieces comprising the steps of:

a. forcing a mandrel having an expansion section of a diameter larger than the inside diameter of the tubular member through the tubular member to enlarge same; and,

b. supporting the end of the tubular member toward which the mandrel is moving with a back-up member having an aperture therethrough at least as small as the inside diameter of the tubular member prior to enlargement which is aligned with the inside of the tubular member and through which the expansion section passes to enlarge same simultaneously with the enlargement of the tubular member immediately adjacent the back-up member.

5. A device for sizing holes through workpieces including:

a seamless tubular member having an outside diameter smaller than the initial diameter than the holes through the workpieces and defining a passage therethrough;

a mandrel having an outside larger and an outside smaller diameter, said larger diameter larger than the inside diameter of said tubular member and said smaller diameter smaller than the inside diameter of said tubular member; and

a backup member having an aperture therethrough at least as small as the inside diameter of said tubular member and larger than said smaller diameter of said mandrel so that when said smaller diameter is inserted through said passage of said tubular member and said backup member positioned on said smaller diameter in opposition with said larger diameter across said tubular member, said larger diameter and said backup member can be forced toward each other to cause said larger diameter to pass through said passage and said aperture to enlarge the diameter of said tubular member and the holes through said tubular member.

6. The device of claim 5 wherein said tubular member has less rebound than the work pieces upon enlargement so that the tubular member limits the amount of rebound at the holes when said larger diameter has been forced through said tubular member.

7. The device of claim 5 wherein said backup member is washer shaped and defines a supporting surface for supporting said tubular member immediately adjacent said backup member to prevent said tubular member from being stripped from the holes as said mandrel is forced therethrough.

8. The device of claim 7 wherein said supporting surface is normal to said aperture and wherein said backup member further includes a supporting lip protruding from said supporting surface about said aperture and facing said tubular member, said lip having a concave outside surface.

9. The device of claim 7 wherein the hole through the workpieces is countersunk and wherein said tubular member includes a countersunk head flange at one end thereof adapted to fit within the countersink of the holes.

10. The device of claim 9 wherein said supporting surface is tapered to fit within said countersunk head flange.

11. The device of claim 5 wherein said aperture has a diameter a prescribed amount smaller than inside diameter of said tubular member.

12. A device for sizing holes through workpieces including:

a seamless tubular member having an outside diameter smaller than the initial diameter of the holes through the workpieces and defining a passage therethrough, said tubular member having less rebound upon enlargement than the material of the workpieces when the enlargement of said tubular member exceeds the elastic limit of the material of the workpieces; and,

a mandrel having an outside larger diameter and an outside smaller diameter, said outside larger diameter larger than the inside diameter of said tubular member and said smaller diameter smaller than the inside diameter of said tubular member so that when said smaller diameter is inserted through said passage in said tubular member and said larger diameter is forced axially through said tubular member while said tubular member is held within the holes, said larger diameter will enlarge said tubular member uniformly throughout its length and en-

large the workpieces about the holes beyond the elastic limit of the workpieces, and said tubular member will limit the amount of rebound of the holes.

13. A tool for enlarging holes through workpieces including:

a tubular member receivable through said holes and having a tubular sidewall defining a central passage therethrough;

a mandrel having an expansion section of a diameter a prescribed amount larger than the inside diameter of said tubular member;

a backup member defining an aperture therethrough of a diameter at least as small as the inside diameter of said tubular member; and,

drive means for forcing said expansion section of said mandrel through said tubular member to expand said sidewall and said holes while holding said tubular member within said holes and said backup member against said tubular member in opposition to said expansion section of said mandrel, said backup member being made out of a material that allows said expansion section of said mandrel to be forced therethrough to enlarge said aperture.

14. A device for use with a lockbolt installation tool to size holes through workpieces including:

a tubular member including a seamless sidewall defining a passage therethrough and a head flange at one end of said sidewall, said sidewall defining a cylindrical section adjacent said head flange, an inwardly tapered section joined with said cylindrical section opposite said head flange, and an inwardly directed lip joined to said tapered section opposite said cylindrical section, said seamless sidewall having less rebound than the material of the workpieces;

an elongate mandrel comprising an expansion section at one end thereof; a central support section integral with said expansion section at one of its ends, and a gripping section integral with said support section opposite said expansion section; said support section having a diameter smaller than the initial smallest inside diameter of said sidewall so as to be slidably received therethrough, said expansion section including a cylindrical portion of a diameter larger than the largest inside diameter of said sidewall and a tapered portion connecting said cylindrical portion with said support section; and said gripping section adapted to be engaged by the lockbolt installation tool to pull said expansion section through said sidewall to enlarge same;

a backup member having a washer shape and defining an aperture therethrough of a diameter larger than the diameter of said support section and smaller than the initial largest inside diameter of said sidewall slidably receivable over said support section; said backup member defining a working face adapted to engage and support said head flange and an opposite face normal to said aperture, said backup member being made of a material that is sufficiently weak in radial tension to allow said expansion section to be forced through said aperture to enlarge same but sufficiently strong in compression to prevent the collapse thereof; and,

an adapter constructed and arranged to be removably mounted on the operating end of the lockbolt

installation tool and defining a central passage therethrough of a diameter sufficiently large to slidably receive said cylindrical portion of said mandrel therethrough, so that when said support section is inserted through said sidewall and said backup member placed on said support section with said working face facing head flange in opposition to said expansion section, said lockbolt installation tool can engage said gripping section after passage through said adapter to pull said expansion section through said wall while forcing said backup member toward the workpieces to enlarge said tubular member, the holes through the workpieces and said aperture through said backup member and said tubular member will limit the rebound of the holes through the workpieces.

15. The device of claim 5 wherein said tubular member includes a seamless cylindrical sidewall comprising a major expansion section and a minor expansion section positioned end-to-end with said major section, said passage being a common passage through both said major section and said minor section with a substantially constant diameter along its length, said minor section having a minor outside diameter a prescribed amount larger than that of said passage, and said major section having a major outside diameter a prescribed amount larger than said minor outside diameter but at least as small as said holes in said workpieces.

16. The device of claim 15 wherein said major expansion section is positionable on one of said workpieces and has a length corresponding to the thickness of said one of said workpieces and wherein said minor expansion section is positionable in another of said workpieces when said major section is positioned in one of said workpieces and has a length corresponding to the thickness of said another of said workpieces to enlarge the holes through said workpieces different amounts when said larger diameter of said mandrel is forced through said passage in said tubular member.

17. The device of claim 12 wherein said tubular member includes a seamless cylindrical sidewall comprising a major expansion section and a minor expansion section positioned end-to-end with said major section, said passage being a common passage through both said major section and said minor section with a substantially constant diameter along its length, said minor section having a minor outside diameter a prescribed amount larger than that of said passage, and said major section having a major outside diameter a prescribed amount larger than said minor outside diameter but at least as small as said holes in said workpieces.

18. The device of claim 17 wherein said major expansion section is positionable in one of said workpieces and has a length corresponding to the thickness of said one of said workpieces and wherein said minor expansion section is positionable in another of said workpieces when said major section is positioned in one of said workpieces and has a length corresponding to the thickness of said another of said workpieces to enlarge the holes through said workpieces different amounts when said larger diameter of said mandrel is forced through said passage in said tubular member.

19. The method of claim 1 wherein said tubular member includes a seamless sidewall having a major expansion section and a minor expansion section positioned end-to-end with said major expansion section,

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said major section having an outside diameter a prescribed amount larger than the outside diameter of said minor section, and said major and minor sections defining a common passage therethrough of a prescribed diameter; wherein the step of placing said tubular member in said pilot holes includes positioning said major section within that workpiece to be enlarged the greater amount and said minor section within that workpiece to be enlarged the lesser amount; and, wherein the step of enlarging the tubular member in-

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cludes enlarging said passage a substantially constant amount along its length to enlarge the pilot holes through the workpieces different amounts.

20. The method of claim 1 further including the step of leaving the enlarged tubular member within the holes during subsequent use so that the tubular member continues to limit the amount of rebound of the material of the workpieces about the holes during such subsequent use.

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