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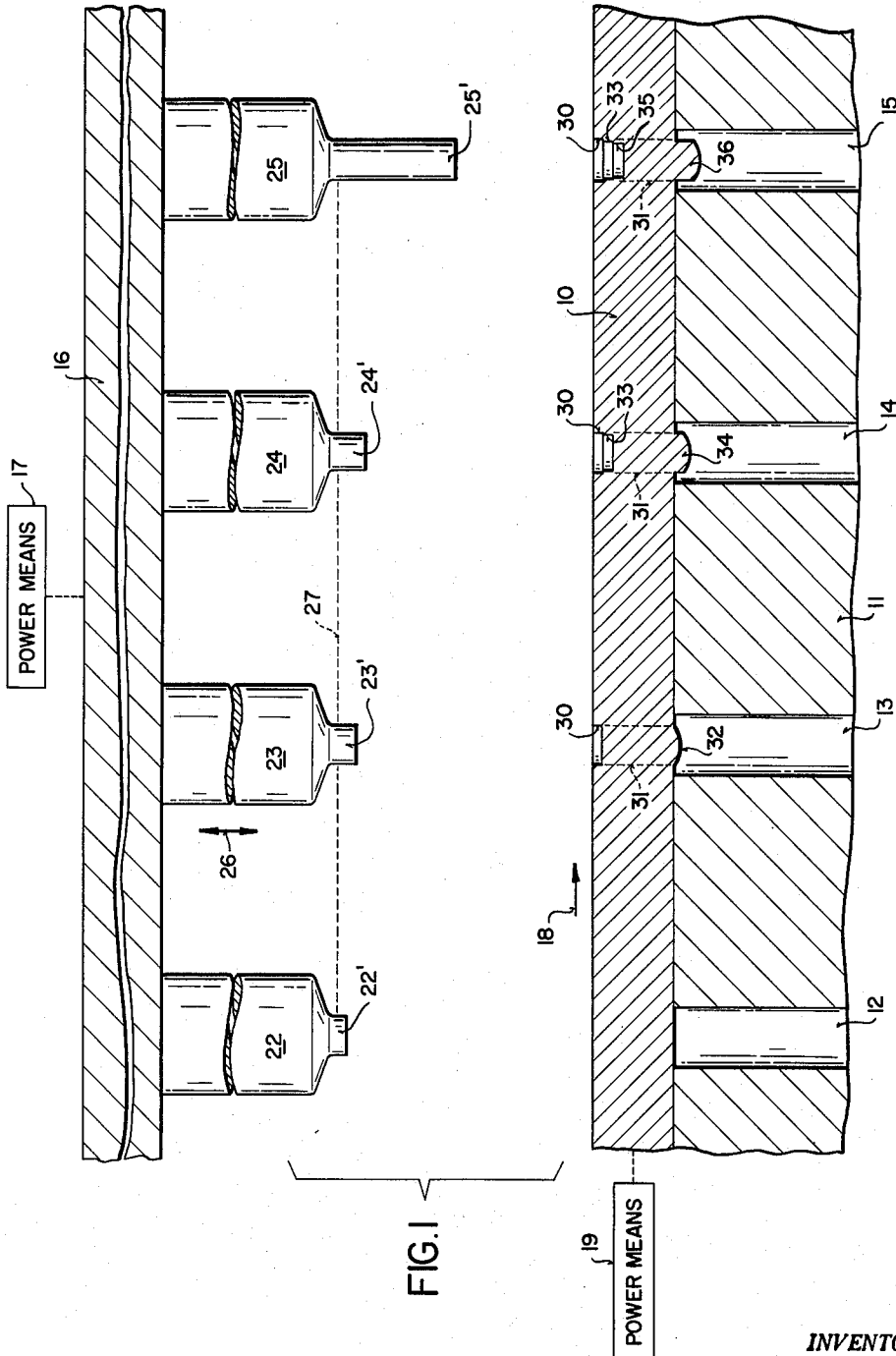
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3,232,156

MULTIPLE STEP PERFORATING OF SHEET METAL

Filed Dec. 26, 1963

2 Sheets-Sheet 1



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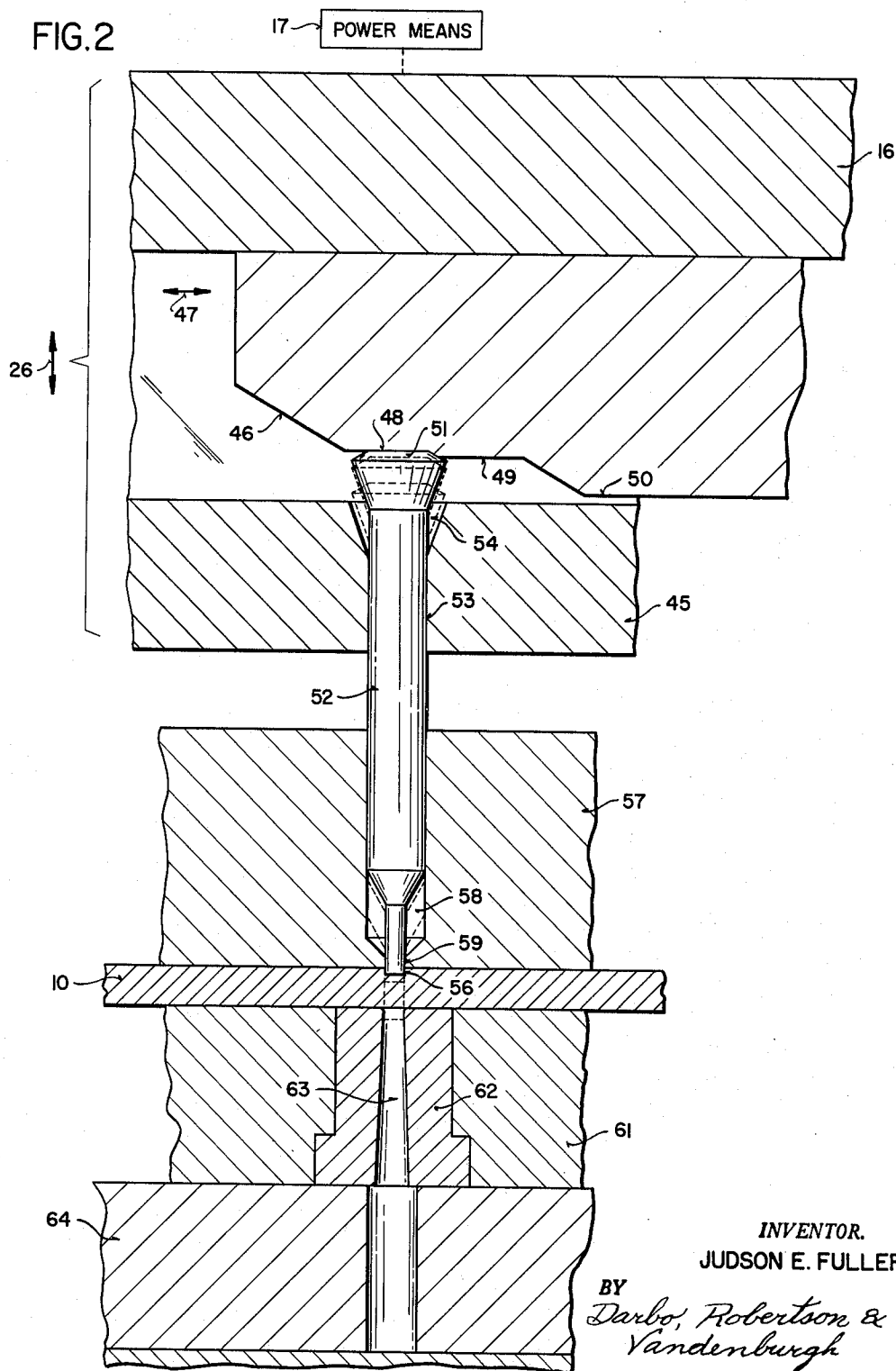
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2 Sheets-Sheet 2

FIG. 2



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MULTIPLE STEP PERFORATING OF SHEET METAL

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The present invention relates to a method and apparatus for the perforation of sheet metal or the like, and the following disclosure thereof is offered for public dissemination upon the grant of a patent therefor.

One of the common methods for producing perforations or openings in sheet metal is that of punching, sometimes referred to as blanking. While punching is a convenient and inexpensive method of producing openings, there is one important limitation on its use under present commercial practices. This limitation pertains to the size of the opening that can be produced in relationship to the thickness of the metal being punched. When the opening is relatively small in cross section, as related to the thickness of the metal being punched, it is very possible that the punch will break. Of course, punch breakage is undesirable because there is the loss of the value of the punch, the work and progress may be damaged by the breaking of the punch, and the perforating equipment must be shut down and the punch replaced. Thus, even though upon occasion one can punch openings smaller than the generally accepted limits, a manufacturer of perforated metal ordinarily will not attempt to do so on a production basis.

In present commercial practices of punching a hole in cold rolled steel, it is generally considered that the smallest cross sectional dimension of the hole can be no smaller than the thickness of the metal. In the case of a round hole this means that the diameter can be no smaller than the thickness of the metal. When punching metals having a greater tensile strength, the cross sectional size of the hole must be increased as compared to the thickness of the metal to maintain the same safety against punch breakage. For example, in punching stainless steel the general practice is to make the diameter of the hole no smaller than twice the thickness of the metal.

Where it is necessary to have openings in sheet metal that are smaller, in relation to the thickness of the metal, than the foregoing limits, other procedures are employed to produce those openings. Round holes may be drilled. Where slotted openings are required, these may be produced by milling. However, the cost of drilling, milling, etc., is extremely high as compared to the cost of perforating by punching.

The principal object of the present invention is to provide a method and apparatus for punching holes in sheet metal or the like, which holes are smaller in relation to the thickness of the metal than those that can be produced using present commercial practices. For example, the present invention can be employed to produce holes in a sheet of stainless steel with the holes being half the thickness of the metal. Viewed in the light of present commercial practices, this is an outstanding breakthrough in the perforating of metal.

Although the following disclosure offered for public dissemination is detailed to ensure adequacy and aid understanding, this is not intended to prejudice that purpose of a patent which is to cover each new inventive concept therein no matter how others may later disguise it by variations in form or additions or further improvements. The claims at the end thereof are intended as the chief aid toward this purpose; as it is these that meet the requirement of pointing out the parts, improvements, or combinations in which the inventive concepts are found.

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In the punching of metal the sheet to be punched is placed on a platen or die having an opening at least equal in size to the diameter of the hole to be punched. The punch is then pressed against the opposite face of the metal in alignment with the die opening. Pressure is applied between the punch and the die. A slug corresponding to the shape of the punch is pushed out of the metal sheet and into the die opening. Pressure usually is applied by having the die or platen fixed in position and the punch mounted on a ram actuated by a crank, toggle, hydraulic cylinder, etc. However, either part may be movable toward and away from the other.

The present invention is based on the discovery that by the time that the punch has penetrated a part of the thickness or depth of the metal, which part is substantially less than said thickness, the slug, ultimately extracted, is substantially broken loose in the sense that comparatively little force (as compared to that necessary to achieve the penetration of the first part) is required to push the slug the remainder of the way out of the metal sheet. This discovery is utilized by prepunching approximately the first part of the depth of the metal with a punch having an effective unsupported length not substantially greater than said part of the thickness of the metal. To state it another way, an effective punch portion is employed for part or all of the first part of thickness of the metal and is supported about the sides thereof immediately adjacent the end of the effective portion of the punch. In some instances this first part is punched in a plurality of steps with the opening increasing in depth with each successive step. In such practices the unsupported length of the punch is increased for each successive punching step. After the opening made by the punching has a depth approximately equal to said part the thickness of the metal, there need only be one final punching step forming the finished opening in the metal. Since the power required to push out the slug and complete the opening is relatively small for the final step, there is little likelihood that the punch employed will break despite the fact that it has a relatively long unsupported effective length in relation to its minimum cross sectional dimension.

What proportion said part of the thickness of the metal must be to achieve a breaking loose of the slug will vary from one metal to another. In general it appears to be related to the ductility of the metal. With cold rolled carbon steel a penetration of from about 30% to about 40% of the thickness of the metal is sufficient to loosen the slug. Stainless steel requires a penetration more in the range of 50% to 55%. Other metals, e.g. copper, brass or pure nickel, may require a penetration of up to about 70%. In any event it is apparent that such part is substantially less than the thickness of the metal.

Another factor that contributes to the reduction of punch breakage in the application of the present invention is that throughout each punching step the speed of punch movement is kept at an absolute minimum for the particular punching machinery being utilized. With substantially all punching devices the rate of movement (i.e. velocity) of the moving part (e.g. ram) varies at each end of its stroke from what occurs during the middle part of the stroke. As the ram approaches the end of its stroke it gradually slows down until it finally stops and commences to move in the reverse direction at gradually increasing velocity. When the present invention is employed in conjunction with such a punching apparatus, the working, i.e. maximum force applying, portion of the stroke is only the terminal part at which the velocity almost is down to zero. In each successive step the punch is doing relatively little work at its higher velocity

stages and only commences to do significant work as it is immediately adjacent the terminal part of its stroke.

The invention may be carried out with a plurality of punches with the work being indexed with respect to the position of the punches between each punching step, or the punches being indexed with respect to the position of the work. Another alternative is to use a single punching means having lateral supports for the punch with the punch or the support being movable with respect to the other so that the effective unsupported length of the punch may be changed for successive punching steps.

When the work or the punches are indexed with respect to the other, i.e. one or the other being moved from station to station, it is important that at each successive station the opening produced by the punch at the preceding station be accurately aligned with the punch at the successive station. To alleviate somewhat the necessity for absolute accuracy in alignment, the initial punch is made slightly smaller than the final opening (in cross sectional size) and the punches at each succeeding station are made slightly smaller in cross sectional size than was the punch at the preceding station so that the succeeding punches will surely enter the opening formed by the punch at the preceding station. The punch at the final station, however, has the full cross sectional size required for the finished opening to completely clean out the finished opening to the required size. With this procedure the danger of a punch hitting the metal at a single side of the opening (and breaking as a result) due to a slight misalignment is greatly ameliorated.

The method of the invention will be more fully explained with reference to the drawings, in which:

FIGURE 1 diagrammatically illustrates an apparatus for carrying out the invention employing a series of four punches; and

FIGURE 2 is an alternative form of apparatus.

By way of example, an apparatus such as that illustrated in FIGURE 1 would be employed to produce a cylindrical opening having a nominal cross sectional diameter of one-sixteenth of an inch in a sheet 10 of cold rolled steel having a thickness of one-eighth of an inch. The sheet 10 is supported on a die or platen 11 having openings 12-15 therein. Openings 12-15 are three-thirty seconds of an inch in diameter. Platen 11 is fixedly mounted on the frame, not shown, of the machine. The machine also includes a ram 16 which is moved toward and away from the platen by a suitable power means 17. The position of each of openings 12-15 represents a work station. Sheet 11 is moved from station to station in the direction indicated by arrow 18 by a suitable power means 19. Punches 22-25 are secured to ram 16. At each station the sheet 10 is at rest while it is operated on by the punches 22-25 which are moved up and down, as indicated by arrow 26, by the power means 17.

The portion of each of the punches below dotted line 27 is the portion of the punch that penetrates the sheet 10 upon each downward stroke of ram 16. Thus, the effective unsupported portion of each punch must be at least equal in length to that illustrated below dotted line 27. For identification purposes: punch 22 has an effective unsupported portion 22', and punches 23-25 have effective unsupported portion 23', 24' and 25', respectively. Since the finished opening in sheet 10 is to be a cylindrical opening having a diameter of one-sixteenth of an inch, each of the effective portions 22'-25' are cylindrical in configuration. Portion 22' is 0.062" in diameter and about 0.0156" (one-sixty-fourth) long. Effective portion 23' is 0.060" in diameter and about 0.0312" (one-thirty-second) long. Effective portion 24' is 0.058" in diameter and about 0.0469" (three-sixty-fourths) long. Effective portion 25' is of a size to complete the finished opening. It can be 0.1875" long to insure effective removal of the metal slug from the sheet 10. With a diameter of 0.063" effective portion 25' will form a

hole in sheet 10 which for all practical purposes is one-sixteenth of an inch in diameter.

FIGURE 1 illustrates sheet 10 in the indexed position ready for the next reciprocation of ram 16. To achieve this indexing without interference from the downwardly projecting slugs, the apparatus would include knockout means to raise sheet 10 briefly while it was indexed. Also the apparatus would include suitable stripper means to hold the sheet 10 down while the punches were extracted therefrom. Such means are well known to those skilled in the art and are not illustrated in FIGURE 1.

On the preceding reciprocation of ram 16 (before sheet 10 was indexed) effective portion 22' of punch 22 formed a cylindrical opening or cavity 30. In doing so, punch 22 commenced moving a slug 31 of metal through the sheet and a bulge 32 of the metal appeared at the bottom of the sheet. At the second station effective portion 23' of punch 23 had entered opening 30 (produced by punch 22) and deepened the cavity by a first additional increment 33. Thus, slug 31 was moved further along with the bottom bulge increasing in size as illustrated at 34. Similarly, effective portion 24' of punch 24 at the third station had entered openings 30 and 33 and to produce a second increment thereto indicated by the number 35. Slug 31, at this stage, is substantially broken loose (in the sense heretofore indicated) and the bulge 36 at the bottom of sheet 10 has a substantial depth.

With the next reciprocation of ram 16 (with the sheet 10 indexed to the position illustrated) effective portion 21' will produce a new opening 30. Effective portion 23' will increase the depth of the present opening 30, illustrated therebelow, by a first increment 33. Effective portion 24' of punch 24 will increase the depth of the opening therebelow by a second increment 35. Effective portion 25' of punch 25 is slightly larger in diameter than any of openings 30, 33 and 35. It produces the finished opening in sheet 10 driving the ejected slug of metal into cavity 15 in the platen. Since the combined depths of openings 30, 33 and 35 is approximately one-third of the thickness of sheet 10, the force required to drive the slug of metal out of the sheet is relatively low as compared to the force that was required to produce the initial opening by the prepunching of punches 22-24. The fact that effective portion 25' is slightly larger in diameter does not add significantly to the force required, particularly as compared to the reduction (resulting from the prepunching) in the force that must be applied by punch 25. Since the force required to force effective portion 25' into and through the sheet 10 (after the prepunching has been done) is sufficiently small there is little likelihood of breaking effective portion 25' during this step.

Furthermore, in punching cavity 30, punch 22 was moving at its lowest velocity. When effective portion 23' of punch 23 was producing cavity 33 it was moving at a slower rate of speed than when it was moving through the previously existing cavity 30. Similarly, effective portion 24' of punch 24 is moving at a higher rate of speed in moving through cavities 30 and 33 (at which time it is doing no work) than when it is producing a second increment 35 (at which time it is doing work, but is moving at its slowest rate of speed). At the final step, punch 25 initially is only required to peel off the sides of the cavity 30, 33, 35. By the time that it reaches slug 31 and must additionally commence moving the slug it normally will have slowed down somewhat, and probably is receiving some lateral support from the sides of the sheet 10 about the opening thus already produced.

In an operation in which the tensile strength of the material 10 being punched is lower or in a situation in which the ratio of the minimum cross sectional dimension of the perforation to the thickness of the sheet 10 is more favorable, a lesser number of prepunching steps can be performed. For example, under more favorable conditions (e.g., type of metal, ratio of punch size to metal thickness) punches 22 and 23 could be eliminated with punch

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24 performing the complete prepunch opening. It will be noted that the effective portion 24' of punch 24 is substantially shorter than the effective portion 25' of punch 25. Upon reaching the work effective portion 24' also will be moving slower than was effective portion 25' at the time it first reached the work. Thus, substantially more force can be applied to effective portion 24' without any danger of breakage than is the case with effective portion 25'. After prepunching with punch 24 slug 31 would be substantially broken loose and the finished opening could be made by punch 25 with little or no risk of breakage of the effective portion 25'. In any event, however, to take advantage of the fact that the slug 31 is substantially broken loose, for all practical purposes, when the prepunch opening has reached a depth approximately equal to one-third the thickness of the sheet, the opening should be brought to this depth at the prepunching step immediately preceding the punching of the finished opening. Prepunching can be done even in a single step to a depth greater than one-third the thickness but except under particularly favorable conditions there is likely to be an increased risk of punch breakage.

The specific example described, of course, will be varied depending upon the requirements of the manufacturer. In addition to perforating cold rolled steel and stainless steel, it could be used for example, to perforate other alloys having comparable tensile strength. It has been employed to produce holes having a diameter of 0.010" in a stainless steel sheet having a thickness of 0.010". Such perforating is unheard of in prior art commercial practices. While most perforating is done in the form of round openings, the present invention is applicable to making perforations of other shapes. In such instances the smallest cross sectional dimension of the opening is usually considered to be the controlling factor in determining the punch dimension in relation to the thickness of the sheet of metal being perforated.

FIGURE 2 illustrates an alternative embodiment wherein a single punching means is employed both for the prepunching and for the final punching. In this embodiment there is no indexing of the work 10 (or of the punching means). Thus, there is no significant problem of obtaining accuracy of alignment of each successive punching operation with the opening made in the work by the preceding punching operation. With the elimination of this problem, the punch always will enter the previously made opening in the work, and the successive punching steps all can be performed with the same punch.

The ram 16 has mounted thereon a punch plate 45 and a gag bar 46. Gag bar 46 is mounted for a horizontal movement with respect to the ram as indicated by arrow 47. Of course, the punch plate 45 and gag bar 46 are moved vertically by ram 16 and power means 17. This is indicated by arrow 26.

Gag bar 46 has a plurality of stepped, pressure faces which correspond in number and position to the number and depth of the punching steps to be performed. In the illustrated embodiment there are three pressure faces 48, 49, and 50. In successive punching steps the respective pressure face bears against head 51 of punching member 52. Punch plate 45 has an opening 53 therein, which at the top is of truncated conical configuration as indicated at 54 to receive the truncated conical head 51 of the punch member.

Punch member 52 has a cylindrical portion 56 of reduced size at the bottom thereof which does the actual punching, as hereinafter described. Stripper plate 57 has an opening 58 therein to receive the punch member. At the bottom of opening 58 stripper plate 57 defines an annular support 59 for cylindrical portion 56 of the punch member.

The work 10 is supported on a die plate 61 having a die bushing 62 therein. Die bushing 62 has an opening 63 into which the slugs of metal from work 10 are pushed

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by the punch. Die plate 61, in turn, is supported on a fixed die plate holder 64.

With the first downward reciprocation of ram 16, gag bar 46 is positioned with pressure face 48 in alignment with head 51 of the punch member. As illustrated in FIGURE 2, only a relatively short portion of cylindrical part 56 projects below annular support 59 at this punching step. Thus, the effective unsupported length of the punch is only that minor extent of cylindrical portion 56 projecting below the annular support as illustrated in FIGURE 2.

On the subsequent upward movement of ram 16 head 51 of the punch member 52 seats in opening 54 in punch plate 45. Thereupon the punch plate raises punch member 52 removing cylindrical part 56 from the work 10. At this time, gag bar 46 is indexed to the left in FIGURE 2 to a position at which pressure face 49 is immediately above head 51 of the punch member. With the next downward reciprocation of ram 16, the extent of the downward movement of punch member 52 is increased by the amount of the step between pressure faces 48 and 49. Thus, the extending portion of cylindrical part 56, below annular support 59, is correspondingly increased. Since there are only three steps employed in the embodiment of FIGURE 2, the effective unsupported length of cylindrical part 56 (below support 59) at this stage should be at least about one-third the thickness of metal 10.

Upon the next upward movement of ram 16, punch member 52 is again lifted by punch plate 45. Gag bar 46 is indexed to the left to position pressure face 50 above head 51 of the punch member. Thus, on the following downward reciprocation of ram 16 punch member 52 is lowered to an extent such that cylindrical part 56 penetrates completely through the work 10 and ejects a slug of metal from the workout through opening 63 in the die bushing 62.

With most types of power means 17, the movement of ram 16 is such that it attains its highest velocity during the central portion of the movement between the top and bottom of the stroke. At the top and bottom of the stroke, the rate of movement is relatively slow. This is most apparent with a power means of the type of a crank or toggle. This factor is significant in considering the embodiment of FIGURE 2. In each punching step the punch member 52 is moved with the cylindrical part 56 penetrating into the work only during the downward terminal portion of the stroke. Since the punching at each step occurs when the rate of movement provided by the power means is the slowest, there is the least amount of the battering of the punch and the least likelihood of breakage of the effective portion of the punch member, namely the cylindrical part 56.

From the foregoing description and the illustrated embodiments, those skilled in the art may readily envision alternative embodiments of an apparatus for performing the invention. For example, with respect to FIGURE 2, the gag bar 46 could be eliminated and the punch member 52 rigidly affixed to ram 16. To obtain the increased depth of penetration, die plate 61, work 10, and stripper 57 would be indexed upwardly following each stroke to obtain the increased depth of penetration for each subsequent punching step. Another alternative would be to connect punch plate 45 to ram 16 only after the final punching step. Thus, after each prepunching step, the cylindrical portion 56 of the punch member would remain in the work. Only after the metal was completely perforated would the punch plate be raised to withdraw the punch from the work.

The foregoing description has emphasized the importance of prepunching cold rolled steel to a depth at least about equal to one-third the thickness of the work before the final punching step. With stainless steel it would be more in the range of 50% to 55%. These relative depths, of course, are the optimum to avoid punch breakage while at the same time performing a minimum number of punching operations. There is nothing to

prohibit prepunching in a series of steps to a depth of three-fourths the thickness of the work except that this obviously entails an additional number of punching steps without obtaining any significant value therefrom. As hereinbefore discussed, the prepunching of the first part of the depth is the significant problem from a force application and punch breakage standpoint. Conversely, one could prepunch to a depth of less than the optimum part of the thickness of the work before the final punch, but if the prepunching is substantially less than that part required to substantially loosen the slug, there is increased danger of punch breakage on the final punching step since more power must be applied in the final punching step with a comparatively fast moving punch and usually with a punch having a relatively long effective unsupported length.

The embodiment of FIGURE 2 contemplates that the effective portion of the cylindrical part 56 of the punch will receive lateral support from annular support 59 of the stripper plate. In actual commercial practice this may be difficult to maintain. Wear is likely to occur at this point because of the multitude of reciprocations of the punch in the stripper plate during a period of use in the punching of sheets. Wear will increase the tolerance of the fit, reduce the lateral support and increase the possibility of punch breakage, depending upon the extent thereof. Obviously, this problem is not present with the embodiment of FIGURE 1.

I claim:

1. In the method of punching sheet metal of a given thickness to produce a perforation of a given size having a dimension normal to the axis of the perforation so small in relation to the thickness of the metal that normally there would be a likelihood of breaking the punch, wherein the back of the metal is supported by a punching die about the point to be perforated with the back of the metal being unsupported at said point, the improvement comprising: prepunching from the front of the metal at that point to a depth of at least about one-third said thickness and less than about 70% of said thickness, said prepunching being performed with a punch having a cross-sectional configuration smaller than said given size and with an effective length substantially less than said thickness; and thereafter finish-punching the remaining metal at said point from the front of the metal, said finish-punching being performed with a punch having a cross-sectional configuration corresponding to said given size and with an effective length at least equal to said thickness.

2. In the method of claim 1, wherein the prepunching is performed by a succession of punching steps, each successive step being to a greater depth than the preceding punching step and being smaller in cross-sectional size of opening, as measured transverse to said depth, than the preceding punching step.

3. In the method of punching sheet metal of a given thickness to produce a perforation of a given size having a dimension normal to the axis of the perforation so small in relation to the thickness of the metal that normally there would be a likelihood of breaking the punch, wherein the back of the metal is supported by a punching die about the point to be perforated with the back of the metal being unsupported at said point, the improvement comprising: prepunching from the front of the metal at that point in a succession of punching steps with each punching step producing an additional depth of opening and of reduced cross-sectional size as compared to the previous opening, each of said openings having sides parallel to said axis, the opening produced by all of said prepunching steps having a depth of at least one-third of said thickness but less than said thickness; and thereafter finish punching from the front of the metal at the point of said prepunching and to said given size and entirely through the metal.

4. In an apparatus for punching metal of a given thickness to produce a perforation of a given cross-sectional size at a particular point and extending between the two sides of the metal, wherein the apparatus includes a platen member, and a ram member movable toward and away from the platen member, the improvement comprising: feed means to move the metal between the members in a given direction and to stop the metal successively at a series of work stations, the first of which are prepunching stations and the last of which is a final punching station; a plurality of punches secured to one of said members with one punch being positioned at each station, the punches at the prepunching stations being of an increasing length at each successive station and having effective unsupported length substantially less than the thickness of the metal, the punch at the last of the prepunching stations having an effective unsupported length of from about one-third to about 70% of said thickness, the punch at the first of the prepunching stations having a cross-sectional size less than said given size, the punches at each succeeding prepunching station being successively smaller in cross-sectional size, the punch at the final punching station having an effective unsupported length greater than said thickness and a cross-sectional size equal to said given size; and means on the other member to support the metal and having punching die openings at each station in alignment with the punches.

5. In an apparatus for punching a metal device of a given thickness to produce a perforation of a given cross-sectional size at a particular point and extending between the two sides of the metal, wherein the apparatus includes a platen member, a ram member movable toward and away from the platen member, a tool device on the members to punch the metal device, and means to index one device a step at a time in the intervals between the times that the ram member has moved into punching position in relation to the platen member to apply the tool device to the metal device at the same point on the latter upon successive strokes of the ram member, the improvement wherein: said tool device includes first means to prepunch said metal device at said point and second means to thereafter final punch said metal device at said point, said second means including a final punch and a punch die, the punch being secured to one member and the die to the other member, said punch having an effective unsupported length at least equal to said thickness and a cross-sectional size corresponding to said given size, said first means including punch means and punch die means, said punch means being secured to the one member and the die means to the other member, said punch means having an effective unsupported length substantially less than said thickness to prepunch the metal device at said point to a depth of between one-third and 70% of the thickness of the metal device to produce a depression therein, which depression is cleaned out for the full thickness of the metal device by the final punch.

6. In an apparatus for punching work of a given thickness to produce a perforation therein including a platen member, a ram member movable toward and away from the platen member, and power means connected to the ram member to move the ram member in successive strokes toward and away from the platen member with the velocity of the ram member decreasing as it approaches the one end of its stroke at which it is nearest the platen member, the improvement comprising: a punch device connected to a first member and including an adjustable punch; a die device connected to the second member and positioned in alignment with the punch device to cooperate with the punch device in perforating the work; and means mounted on one member and operatively associated with the device connected to the one member to index that device toward and away from the other device, the last means and punch device being effective to first present to the work a portion of said punch having an effective unsupported length substantially

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less than said thickness to cause said punch, upon one stroke of the ram member, to produce a depression in the work less than said thickness, and thereafter while said depression is aligned with said punch to present to the work a portion of said punch having an effective unsupported length at least equal to said thickness and to index one device toward the other device to increase the proximity of the two devices on the successive stroke to cause said punch upon a successive stroke of the ram member to perforate said work at the point of said depression.

7. In an apparatus as set forth in claim 6, wherein said punch device includes a punch having an effective portion of a size to produce said perforation in the work and an enlarged body at the proximal end of the portion, said body having an enlarged head at the end thereof opposite said effective portion, and a stripper plate having a guide opening adjacent the work of a size to slidably receive and guide said effective portion and a guide

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opening contiguous therewith of a size to receive and guide said body, said last means including a movable gag bar between the head and the ram member and having a plurality of steps whereby the free space between the ram and body may be changed by the changed position of the gag bar; and a stripper bar about the body and between the gag bar and the stripper plate.

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