March 13, 1962 P. R. HASKELL ETAL 3,024,749

SHOCK ABSORBING AND ENERGY DISSIPATING MEANS

Original Filed May 10, 1955 3 Sheets-Sheet 1

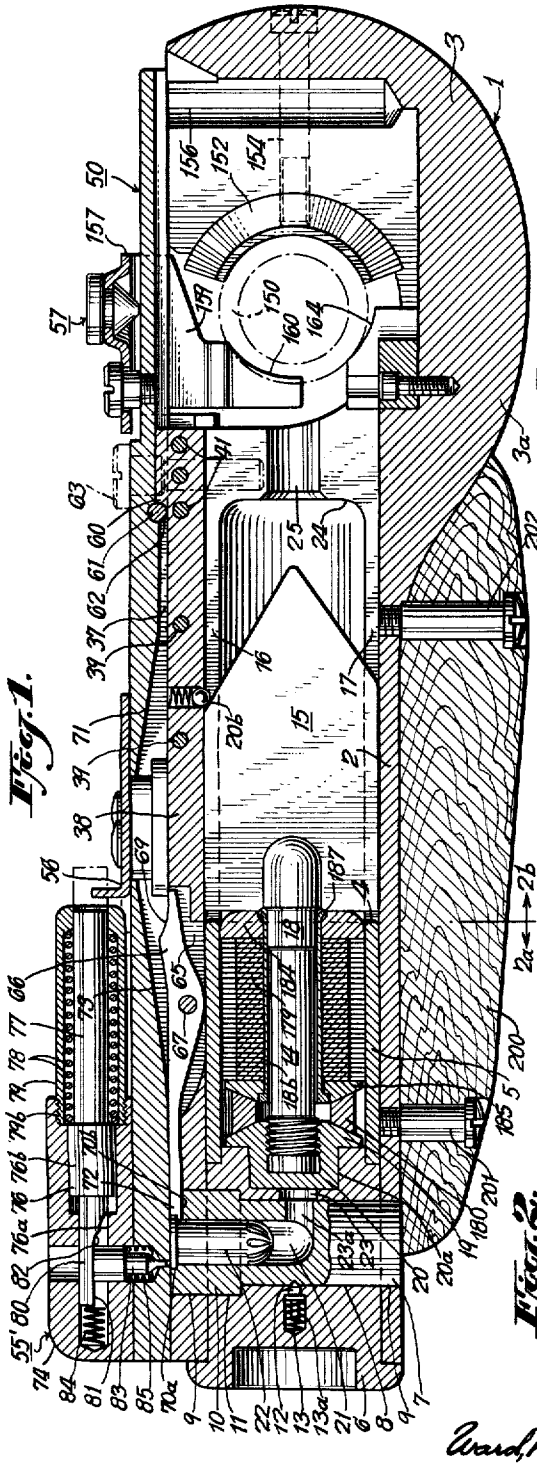


Fig. 1.

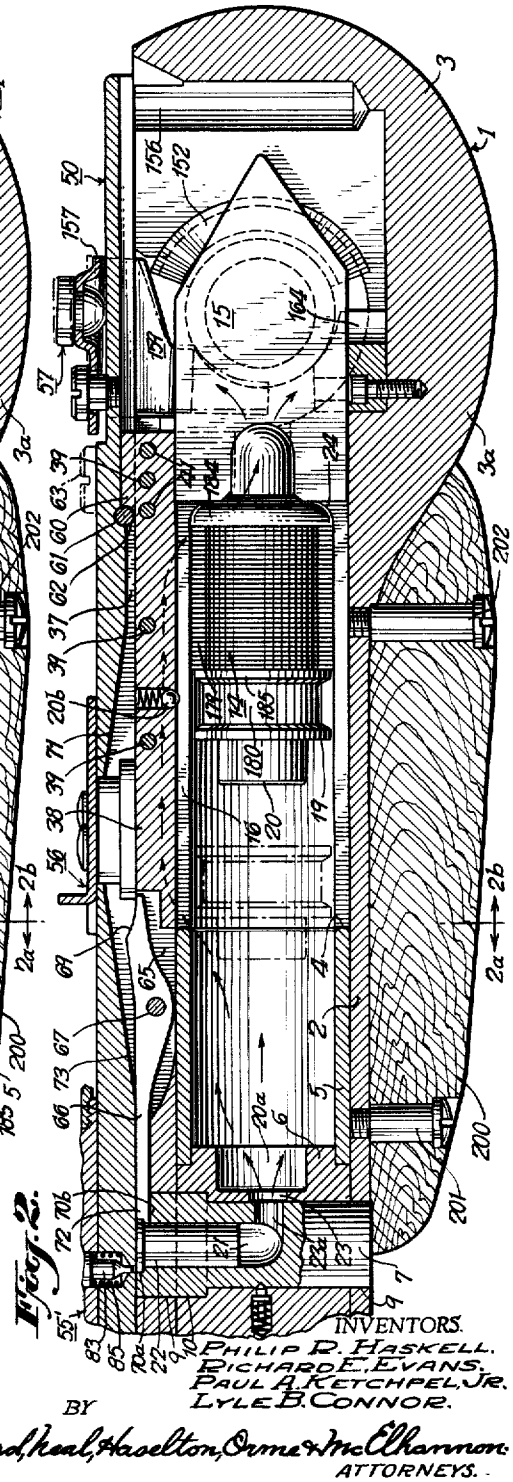


Fig. 2.

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SHOCK ABSORBING AND ENERGY DISSIPATING MEANS

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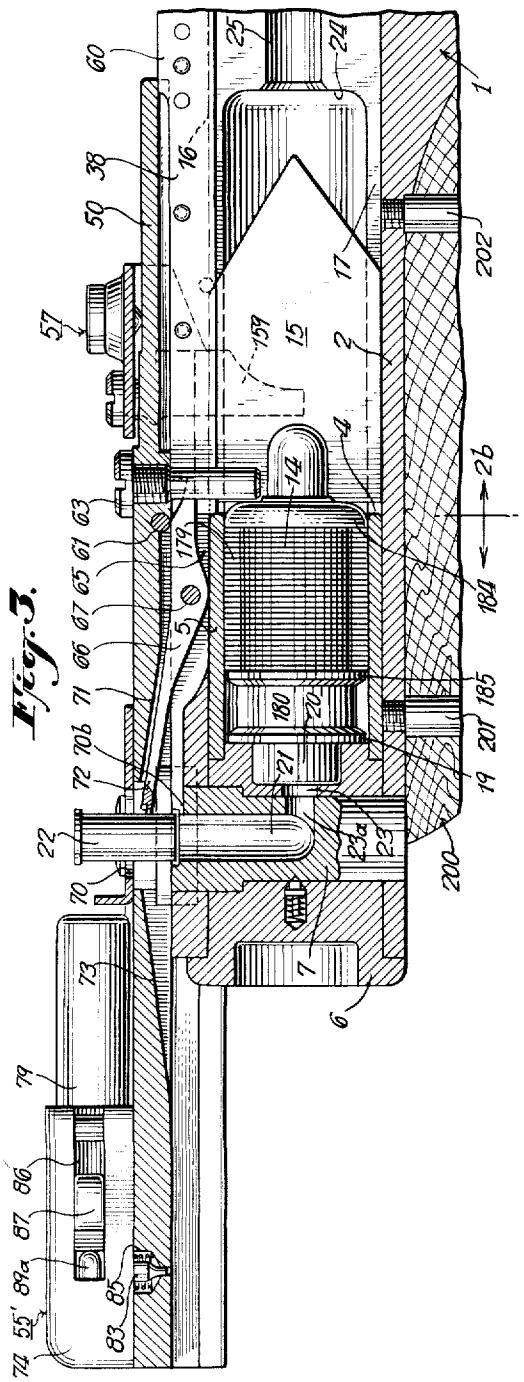


Fig. 3.

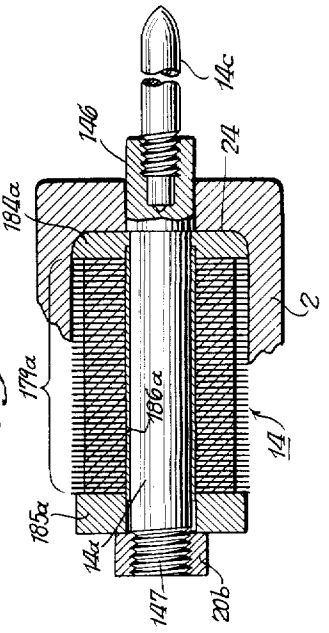


Fig. 8.

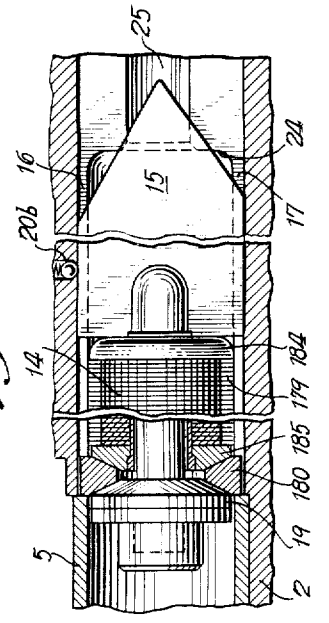


Fig. 7.

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Original Filed May 10, 1955 3 Sheets-Sheet 3

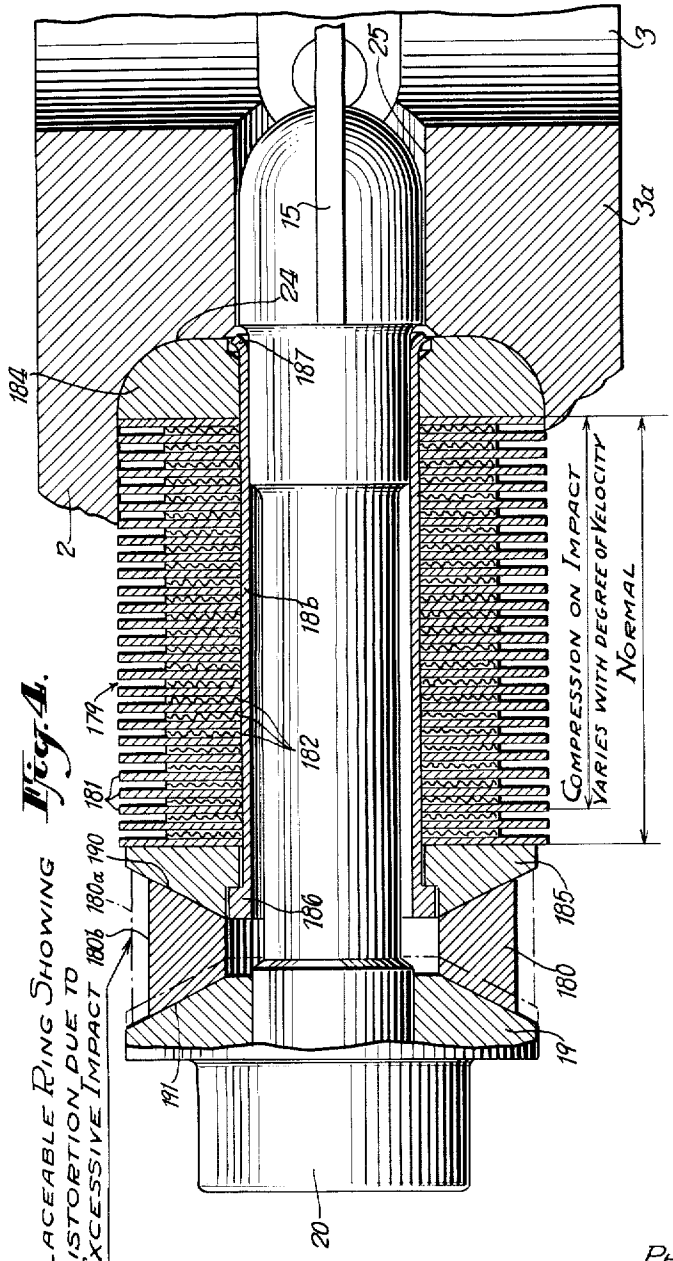


Fig. 4.

REPLACEABLE RING SHOWING DISTORTION DUE TO EXCESSIVE IMPACT

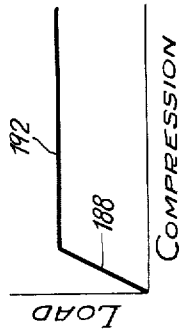


Fig. 6.

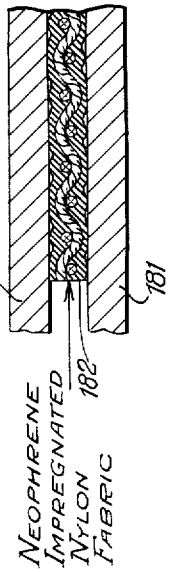


Fig. 5.

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3,024,749

SHOCK ABSORBING AND ENERGY DISSIPATING MEANS

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Original application May 10, 1955, Ser. No. 507,281. Divided and this application May 12, 1961, Ser. No. 109,644

12 Claims. (Cl. 60—26.1)

This invention relates to means for dissipating kinetic energy and more particularly to shock absorbing buffers which dissipate kinetic energy in excess of that which is required to perform useful work from energy systems which include impact elements. An explosively actuated tool is such an energy system.

This application is a division of our co-pending application Serial No. 507,281, filed May 10, 1955.

Although the invention may have other uses, it will be described as embodied in a cartridge powered piston type tool which may be adapted for performing a wide variety of work functions, such as the cutting of conduit, bar stock and heavy cable, etc., the punching of holes, riveting, the swaging of terminals or sleeves on electrical cables for terminating or uniting the same, the uniting of electrical conduit sections by means of an interposed coupling member, as well as the securing of threaded members on electrical conduit terminations, etc.

An explosively actuated tool of the like comprises in its essentials and in accordance with the preferred modifications thereof which are more fully described in the referred to co-pending application, an elongated frame member of steel comprising a tubular or barrel section terminating at one end in a hook-like retainer arm of substantially C-shaped configuration for mounting a work piece to be operated upon. Within the barrel section is slidably displaceable a piston which mounts on its forward end a work tool, such as a cutter blade, hole puncher, cable swager, riveting plunger, etc. The tubular section of the frame is of reduced aperture at its muzzle end to provide a shouldered impact face for arresting forward motion of the piston thereat. The muzzle end is, in addition, appropriately apertured for passage of the work tool therethrough to work engaging position with a work piece held in the retainer arm.

The breech end of the barrel section is closed by means of a barrel plug insertable therein. The breech end of the frame as well as the barrel plug are transversely apertured and counterbored for insertion of a relatively massive cartridge chamber plug having an enlarged head which seats in the counterbore. This chamber plug contains a bore extending axially through the head for insertion of a cartridge, whereby the tool is cartridge chambered substantially at right angles to the barrel axis, a feature which permits of substantially shortening the effective length of the tool as compared with conventional constructions wherein the cartridge chamber is aligned with the barrel. The cartridge chamber has access to the barrel through a sidewall outlet and an aligned bore extending through the end of the barrel plug.

In the firing position the piston is disposed at the breech end of the frame barrel and against the barrel plug in a relatively short barrel sleeve which rests against a shoulder of the frame barrel and is held in position by the barrel plug.

Mounted adjacent the cartridge chamber opening is an elongated ejector, one end of which engages a slot in the upper face of the cartridge chamber plug for assuring

proper alignment of the outlet passage thereof with the aligned barrel plug outlet passage aforesaid. This ejector is pivotally mounted on the frame and pivots between cartridge seating and ejecting positions.

The tubular section of the frame is longitudinally slotted along its upper outer sidewalls for slidable reception of a cover having downwardly extending and turned in sidewalls for lockingly engaging these grooves against the explosive action of the tool when fired. This cover, when appropriately assembled on the frame as noted below, is longitudinally displaceable between loading and firing stations. It mounts on its breech end a firing unit including a firing pin which, in the firing position of the cover, is disposed in alignment with the rim of a cartridge inserted in the cartridge chamber for firing the same. The firing unit also includes a firing hammer or bolt which is displaceable longitudinally of the cover. Mounted on the cover adjacent this hammer is a safety locking device, which takes the form of a cross slide member, and which prevents firing of the firing unit except when the cover is adjusted to the firing station and the cross slide adjusted thereat to a firing position.

Threaded through the cover is a bolt which extends through an elongated slot in the upper face of the frame, which bolt is positioned in the path of traverse of the piston, and serves to position the piston at the breech end of the frame barrel when the cover is actuated from its firing station to its loading station. At the firing station position of the cover, however, this bolt is longitudinally positioned beyond the impact face at the muzzle end of the frame and thus does not interfere with the forward traverse of the piston to the work piece actuating position. For removing the cover from the frame this bolt is unscrewed and withdrawn, whereby the cover may be slid endwise off the frame as the first step in the takedown operation.

Mounted on the under side of the cover is a cross pin which, on actuation of the cover from the firing to the loading station, engages a concave camming face on the cartridge ejector and thus tilts it to the cartridge ejecting position. The cover and cross slide are also provided with an appropriate aperture which, with the cover positioned at the loading station, exposes the cartridge chamber bore for cartridge insertion and ejection purposes. The under side of the cover is also provided with an inclined ramp which, on displacement of the cover from the loading to the firing station, seats the cartridge in the chamber cavity and also seats the ejector end of the ejector in the cartridge chamber plug slot above mentioned, thus assuring that the unit is in proper condition for firing when the cover is adjusted to the firing station.

The C-shaped retainer arm of the frame mounts appropriate bushings or dies for reception of a work piece, which is clamped in position with the cover adjusted to the firing station by means of a cooperating clamping device resiliently mounted on the muzzle end of the cover. Also the cover is of such length that when adjusted to the firing station, it covers the open C of the retainer arm and thus shields the operator against chips, etc., ejected from the workpiece on engagement of the work tool therewith.

The underside of the frame mounts an appropriate handle for gripping the tool in one hand while the other hand is employed to manipulate the cross slide safety device and also actuate the trigger of the firing unit.

In addition to the novel features of construction and operation of the tool above discussed, the tool in connection with which the present invention will be described embodies various other unique features which will be omitted from the present application. For a description of these features, reference is made to application of which the present application is a division, as well as the follow-

ing patents and applications which are also divisions of the referred to application: Serial No. 674,533, filed July 26, 1957; U.S. Patents Nos. 2,890,685, 2,949,898, 2,954,759; Serial No. 674,537, filed July 26, 1957; and Serial No. 55,098, filed Sept. 9, 1960.

However, one of the most important of these is the novel shock absorbing assembly of the present invention which is mounted on the piston for preventing injury to the equipment on impact of the piston with the impact face of the frame, particularly if the tool is fired inadvertently with no workpiece mounted in the retainer arm. This shock absorbing mechanism comprises an elastically deformable member which is adapted to absorb the excess kinetic energy for stopping the piston at the impact face after the work tool has performed its function. The other is a plastically deformable member for absorbing such excess kinetic energy as cannot be taken up by the elastically deformable unit, and which comes into play particularly if the tool is fired with no workpiece mounted in the retainer arm. These two units are mounted in axial alignment on the piston so that the elastically deformable shock absorber absorbs the initial impact to its maximum extent whereupon the residue is absorbed by the plastically deformable component. The elastically deformable unit is of laminated construction and in its preferred embodiment, comprises an axially aligned assemblage of metal rings, preferably of steel, interleaved with which are other rings formed of fibrous material impregnated with an elastic polymer, preferably woven nylon fabric impregnated with neoprene.

Having thus described the invention in general terms, reference will now be had for a more detailed description of the construction and additional novel features of the invention, to the accompanying drawings wherein:

FIGURE 1 is a longitudinal sectional elevation through the entire assembly of a tool incorporating the shock absorbing buffer of the present invention, and showing the tool in condition for firing;

FIGURE 2 is a fragmentary view similar to FIGURE 1, but subsequent to firing and showing the piston and cutter assembly as it appears at the end of a working stroke;

FIGURE 3 is a partial showing, similar to FIGURE 1, but illustrating the tool in the cartridge ejecting or loading condition and the means for returning the piston to its normal position;

FIGURE 4 is an enlarged longitudinal sectional view of the tool piston assembly illustrating in detail a preferred embodiment of the shock absorbing means and safety feature constructions of the present invention;

FIGURE 5 is an enlarged fragmentary sectional detail showing two of the steel shim laminae and interposed neoprene-impregnated nylon fabric laminae of the shock absorbing assembly of FIGURE 4;

FIGURE 6 is a graph idealizing the load-compression characteristics of the shock absorbing constructions illustrated in FIGURES 4 and 5;

FIGURE 7 is a fragmentary, axial sectional elevation of a modified form of the piston and frame assembly illustrating the action of the safety feature of the shock absorbing assembly in disabling the tool when fired in the absence of a workpiece;

FIGURE 8 is a fragmentary axial sectional elevation of a further modification of the invention as shown in an explosively actuated tool adapted for the driving of studs and related fastening devices.

Referring to FIGURES 1–3, of the drawings, the cartridge-powered conduit-cutting tool which is shown comprises a frame, identified generally by numeral **1**, consisting of a tubular frame portion **2** extending from the breech end **2***a* at the left to the muzzle end **2***b* at the right, and a C-frame extension comprising a work support **3** in general longitudinal alignment with the frame portion **2** and connected therewith by a curved shank **3***a*. The breech end of the frame portion is of slightly enlarged bore as compared to the muzzle end of the frame portion **2** and thus provides a shoulder at **4** against which a relatively short sleeve barrel **5** is held by means of a barrel plug **6** inserted in the breech end of the frame. In a modified form of the construction shown in FIGURE 7, the forward end of the barrel sleeve **5** supplies a forwardly facing shoulder for a purpose to be described below with reference to said FIGURE 7. The barrel plug is locked in the position shown by a cylindrical cartridge chamber plug **7**, which extends transversely of the barrel axis through suitable holes **8**, **9** drilled in the barrel plug and the breech end of the frame portion **2**, respectively. The cartridge chamber plug **7** is provided with an enlarged head **10** which seats in a counterbore **11** of the barrel plug, thus to maintain the assembly locked in position as shown in FIGURE 1.

The mouth of the chamber plug is radially slotted to receive an ejector (to be described), and to locate chamber plug **7** in proper longitudinal and radial position in the bores **8**, **9**. The cylindrical wall of the plug is notched for reception of a detent pin **12**, backed by a small compression spring **13**, mounted in an axial bore **13***a* of the barrel plug **6**.

In the firing position shown in FIGURE 1, a piston **14** is slidably disposed in the sleeve barrel **5**, and to which is secured a cutter blade **15** positioned in advance of the piston in the frame portion of smaller inside diameter. The cutter blade is slidable in grooves **16**, **17** extending along the upper and lower portions of the frame barrel, these grooves being formed as explained below.

The cutter assembly **15** shown as a cutter blade is secured to or formed integral with a shank **18**, which extends through a central sleeve member **18***b* of the piston **14** and is secured to the piston by means of a piston cap **19** threaded onto the breech end of the shank **18**. This piston and cutter assembly will be described more in detail, infra.

As shown in FIGURE 1, the breech end of the piston cap **19** terminates in a protuberant extension **20** of considerably smaller diameter than the piston **14**, which extension in the action or firing position, rests in a conforming bore **20***a* drilled in the inner end of the barrel plug **6**.

Also in the action or firing position of FIGURE 1, the piston and cutter blade assembly **14**, **15** is resiliently held in place by means of a resiliently mounted detent **20***b* which engages the upper edge of the cutter blade as shown.

The cartridge chamber plug **7** has formed in the upper portion thereof a bore **21** for insertion of a blank cartridge, as at **22**, the cavity below the cartridge forming an explosion chamber which has access through aligned openings in the sidewall of the chamber plug and the forward end of the barrel plug, as at **23***a*, **23** to the bore **20***a* of the barrel plug.

Thus, when the cartridge is fired, the piston and cutter assembly **14**, **15**, is impelled progressively forward as indicated by FIGURES 1 and 2 until the pointed end of the cutter blade has advanced to the position shown in FIGURE 2 to sever a conduit **150** mounted in work support **3**. The piston and cutter assembly is thereupon brought to rest by engagement of the forward end of the piston **14** with a shouldered piston abutment means such as impact face **24** of conforming configuration formed at the muzzle end **2***b* of the tubular frame section **2**, at which the bore is tapered to an outlet passage **25** of relatively small bore through which the explosion gases escape. The muzzle end of the frame is also vertically slotted to permit advance therethrough of the cutter blade to the conduit cutting position of FIGURE 2.

The tubular frame section **2** is longitudinally slotted through its upper surface as at **37**, this slot being offset somewhat from the axis of the frame. Mounted in this slot and partially closing the same is an insert member **38** which is positioned in engagement with one side of

the slot 37. This insert member is secured to the frame by means of screws as at 39 which extend through holes in the sidewall of frame 2 and into threaded engagement with the insert member 38, thereby clamping the insert member to the frame. For additional strength the screws 39 are supplemented by dowel pins 41, which also extend through the sidewall of the frame section 2 and into suitable apertures provided in the insert member 38, these dowels frictionally engaging the frame and insert member in a tight fit.

The insert member 38 is of substantially rectangular cross section except for a depending flange whereby the insert and the oppositely disposed surface portion of the frame 2 provide a longitudinally extending grooved recess 16 in which the upper edge of the cutter blade 15 is slidably guided. Diametrically opposite to the grooved recess 16 thus provided, there is also machined in the frame 2 a corresponding groove 17, for slidably guiding the lower edge of the cutter blade 15.

The frame 1 is provided with a cover or carriage 50 having in end view a relatively flat C-shaped configuration, with turned in lower lateral edges. The frame section 2 is correspondingly grooved along the upper edges of its opposite outer sidewalls whereby the cover may be slid endwise onto the frame in vertically locking engagement therewith.

Mounted on the breech end of the cover is the firing unit 55'. Mounted adjacent thereto is the cross slide protective device 56 which is transversely adjustable to locking, ejecting and firing positions, and which prevents firing except when adjusted to the position last mentioned. Resiliently mounted on the muzzle end of the cover is a clamping device 57 which clamps the conduit to be cut in the C terminus or work support 3 of the frame when the cover is longitudinally positioned with respect to the frame as shown in FIGURE 1. These features of the tool are set forth in detail in aforementioned applications Serial Nos. 507,281 and 674,533.

For limiting the forward displacement of the cover 50 with respect to the frame 1, the insert 38 is provided with a raised portion or shoulder 60 at the muzzle end of the frame section 2. When the cover is advanced to the position of FIGURE 1, this shoulder is engaged by a pin 61 extending transversely along the under side of the cover 50, and mounted in a bore 62 drilled through the sidewalls of the cover.

For returning the piston 14 from the impact face 24 of the frame barrel 2, against which the piston rests after firing as above explained, a piston return bolt 63 is tapped vertically through the cover with the lower end of this bolt projecting into the slot 37 of the frame for a sufficient depth to engage the piston as the cover 50 is displaced to the left from the firing position of FIGURE 1 to the cartridge ejecting position of FIGURE 3. It will be noted that the slot 37 extends at the muzzle end of the frame barrel 2, beyond the piston abutment means or impact face 24, and is thus protected from impact by the piston even if the shoulder 24 is set back by repeated impact.

A shallow axially extending slot 65, is provided in the upper face of the frame section 2 near the breech end, in which is mounted an elongated cartridge ejector 66, which pivots on a pin 67 retained in a transverse bore of the frame. The ejector 66 is actuated by displacement of the cover 50 as follows: As the cover is retracted from the firing position of FIGURE 1 to the cartridge ejecting position of FIGURE 3, the pin 61 mounted on the under side of the cover, engages a concave cam face 69 of the ejector and rotates it clockwise to the canted position shown in FIGURE 3, to eject the cartridge shell 22, through an opening 70 formed in the cover of the cross slide 56. The under face of the frame cover 50 is provided with a sloping ramp, as at 71, to permit of this actuation of the ejector. With the cover in the position of FIGURE 3, a new cartridge may be inserted through the cross slide opening 70, until the rim thereof engages the cartridge ejector end 72 of the ejector, whereupon the frame cover 50 is returned to the position of FIGURE 1. As the cover is thus moved into position a second sloping ramp provided on the opposite under side of the cover, as at 73, engages the rim of the cartridge and seats it in the cartridge chamber cavity 28 with the shell rim flush with the upper edge of the cavity as shown in FIGURE 1, while at the same time returning the ejector 66 to the cartridge seating position of FIGURE 1 as the frame cover pin 61 rides off the cam face 69. In order to provide for seating of both the cartridge shell 22 and the ejector 66 flush with the upper surface of the chamber plug 7, this surface is peripherally recessed, as at 70*a* and radially slotted, as at 70*b* appropriately to seat the shell rim and ejector, respectively.

The firing unit 55' comprises a housing 74, secured to the frame cover 50, by means of screws (not shown). The housing is drilled for axially displaceable reception of a firing bolt or hammer 76 having an intermediate portion 76*b* of enlarged diameter which is slidably displaceable in the frame bore 76*a* and from one end of which extends a hammer terminus 77 of smaller diameter, sleeved through a hammer spring 78, housed in an open-ended sleeve-like retainer 79, the inner end of which is threaded to the housing as at 79*b*.

From the opposite end of the enlarged hammer portion 76*b*, there extends a second hammer terminus 80 having a flat under face 81 which terminates adjacent the enlarged hammer portion 76*b* in a stepped cam face 82 for actuating a firing pin 83. Interposed in the housing bore between the end of the shank 80 and the bore terminus, is a relatively light spring 84 which is compressed in the firing movement of the hammer and thereafter returns the hammer to normal uncocked position with the shouldered end of enlarged hammer portion 76*b* contacting the spring 78.

As shown in FIGURE 1, the flat under face 81 of the terminus 80, normally bears against the enlarged head of the firing pin 83, which latter is positioned in a bore extending through the housing 74 and into the frame cover 50. The lower end of the firing pin is of reduced diameter as shown and sleeves through a firing pin spring 85, which is retained in position between the enlarged head of the firing pin and the reduced diameter base of the frame cover aperture, through which the tapered lower end of the firing pin extends into engagement with the rim of the cartridge 22, when the tool is loaded in the manner illustrated in FIGURE 1.

The housing 74 also mounts in a laterally extending slot 86 thereof, FIGURE 3, a trigger 87, which projects horizontally from the housing, the trigger being pivotally mounted on a pin extending through the housing 74 and spanning the slot 86. The trigger is normally maintained in the firing position by a compression spring disposed in a bore of the housing which bears at its opposite ends against the housing and a cup-like retainer sleeve 89*a*, slidable within the housing bore, and the closed end of which bears against the trigger, as shown.

Slidably mounted in a bore of the trigger is a sear which normally engages a notch formed in the side of the hammer terminus 80 adjacent the shoulder 93 of the enlarged diameter hammer or intermediate portion 76*b*. The sear is normally retained in position by means of a compression spring disposed in the trigger.

As the trigger is gripped and rotated clockwise about its pivot point against the restoring action of its compression spring retainer sleeve 89*a*, the sear engages the hammer shoulder 93 and forces the hammer to the right against the compressive restoring action of the spring 78, until the hammer shoulder 93 overrides the sear and thus depresses the sear against the restoring action of the sear spring, thereby permitting the bolt to be snapped smartly to the left by the restoring action of the hammer spring 78. As the hammer is thus snapped to the left, the flat

under face **81** of the terminus **80** rides along the head of the firing pin until it is engaged by the camming surface **82**, which abruptly depresses the firing pin to fire the cartridge. Overcarry of the hammer **76** compresses the hammer return spring **84** which immediately restores the hammer to the position of FIGURE 4 whereupon the momentarily compressed firing pin spring **85** returns the firing pin **83** to the position of FIGURE 4, in engagement with the flat under face of the hammer terminus **80**.

The conduit **150** to be cut, is positioned in the hook-like retainer arm **3** of the tool frame, and against a pair of arcuate bushings **152**, these bushings being secured to the rear of the retainer arm by means of a pair of bolts **154**, which extend through the rear of the retainer arm and thread into the bushings. In the drawings of this application, only one of the bushings and its corresponding bolt are shown. These bushings are spaced apart slightly in excess of the width of the cutter blade **15** and the retainer arm or work support **3** of the frame is centrally slotted for passage of the cutter blade in severing the conduit to the position illustrated in FIGURE 2, the slot terminating at the rear end of the retainer arm **3** in a vertical bore **156** from which the chips resulting from the severing of the conduit may be dumped by inverting the tool.

As above stated, there is resiliently mounted on the frame cover **50** at the muzzle end thereof, a clamping assembly **57**, which includes a metal clamping member **157** of substantially U-shaped configuration viewed in end elevation and which spans the frame cover **50** and is formed at its opposite ends with turned down or depending arms **159** only one of which is shown. These arms have the configuration, viewed in side elevation, as shown in FIGURE 1, and are provided with arcuately curved lower front edges, as at **160**, adapted to engage the surface of the conduit **150** and thereby force the same against the bushings **152**. As the frame cover is moved to the firing position of FIGURE 1, the arcuate edges **160** of the clamping element arms **159** engage the conduit **150** and force the same against the bushings **152**, and in so doing resiliently clamp the conduit **150** in position in the manner shown. After the conduit is severed by the cutter blade in the manner illustrated in FIGURE 2, retraction of the frame cover **50**, of course, retracts the clamping element **157** along with it, thus to permit of inserting a new conduit section in the frame arm **3** to be cut.

In firing the tool, and to insure that the work is cut completely through, it is necessary to impart to the piston and blade assembly an excess of say 25% of the energy actually required to sever the work or to perform other operations heretofore outlined, and, to stop the movement of the piston and tool assembly after its work is completed, a buffer is associated with this assembly. In a preferred form of the invention, this buffer comprises two elements, the first being a stack of radially elastically deformable members and the second a "ring spring" type of assembly comprising one or more members which are radially elastically deformed and under excessive stress undergo a plastic deformation. Such excessive stress may be applied when the tool is inadvertently fired without a workpiece in place. Under these conditions the buffer assembly must absorb and dissipate from the tool system the entire kinetic energy of the piston and blade assembly, there being no other resistance to the forward movement of this assembly. The construction of the tool may be such that plastic deformation of the ring spring disables the tool, in a manner to be described, both indicating that the tool has been fired without a workpiece in place and necessitating replacement of the plastically deformable ring. As particularly shown in FIGURES 4 and 5, the elastically deformable shock absorbing compenent is identified generally by numeral **179** and the elastically and plastically deformable member by numeral **180**. The function of the elastically deformable shock absorbing component **179** is to absorb and dissipate from the tool system the excess kinetic energy of the piston, over and above that required to sever the conduit when the tool is fired and the piston impelled thereafter against the impact surface **24** of the frame. The function of the plastically deformable member **180** is to absorb and dissipate from the tool system the excess kinetic energy of the piston which is not taken up both in severing the conduit, and in elastic deformation of the shock absorbing member **179**, or which is not taken up by the shock absorbing member **179** alone such as would be necessary, for example, if the tool is inadvertently fired with no conduit in the retainer arm.

In order for the elastically deformable shock absorbing component **179** satisfactorily to perform its function above stated, it must be designed to meet two rigid requirements. First, the compression modulus of elasticity of this member must be such as to decelerate the piston without exceeding the tensile strength of the blade. In this connection it will be observed that upon impact of the piston against the frame impact face **24**, tending abruptly to stop the piston, the inertia of the blade places the same under tension so that if the piston is stopped too abruptly, the cutter blade will fail in tension. Therefore the shock absorbing component **179** must have a modulus of elasticity which is sufficiently low that the tensile strength of the cutter blade is not exceeded. The second requirement which the shock absorbing component **179** must meet is that it must be capable of supporting a compression load equal to the tensile strength of the blade. This is explainable as follows: As the front face of the piston impacts the frame impact face **24**, the shock absorbing component becomes analogous to a compression spring, the rear end of which is connected to, and compressed by, the piston cap **19** threaded onto the terminus of the blade shank **18**. The momentum of the blade is thus resisted by the force exerted by the spring as it is compressed. If this spring has too high a compression modulus, the blade will fail in tension. Metal springs even in coiled forms of low modulus, have nevertheless too high a compression modulus, and, being made of metal, a shock wave is built up that outraces the load velocity and "sets" the spring. On the other hand, solid plastics have too high a compression modulus, and, in addition, cannot withstand the compressive forces which their high modulus quickly produces. For example, leather approximates a satisfactory modulus, but fails in compression loading during repeated cycles, because its outer tough fibres break loose from their supporting matrix. Rubber and rubber-like material, including the synthetic rubbers such as neoprene, display a compression modulus somewhat under that of leather, so that considerably more stroke is required to store the same energy. While rubber and equivalent materials can withstand heavy loading with elastic recovery, they require support within a container both to raise their natural modulus and to prevent shredding failure under load. As thus compressed in a container, for example, in a steel sleeve, rubber behaves like an incompressible fluid, exerting tremendous hydraulic pressure on the surrounding container. The strength of the retainer thus required cannot be provided in a tool of reasonable size.

In accordance with one aspect of the present invention, this problem is successfully solved in a compact structure by making the elastically deformable component **179** of a laminated construction and consisting of a series of axially aligned metal rings **181**, such as steel shims, which are interleaved with other rings **182** formed of woven fabric, preferably woven nylon fibres, which are impregnated with an elastic polymer, preferably neoprene. This laminated arrangement is preferably assembled, in axial alignment as shown, on a steel assembly tube **18***b* between an impact plate **184** mounted on the forward end of the assembly tube and an annular spacer member or backing plate **185** assembled on the rear end

of the assembly tube. To facilitate this assembly, the assembly tube is formed with a flanged terminus **186** at its rear or left end in the drawing and the backing plate **185** is formed with a conforming axial counterbore, which seats against this shoulder. The assembly tube at its opposite end is crimped up against the impact plate **184** as at **187**, thus to lock the entire assembly together.

In this assembly, in the elastic polymer-impregnated fabric rings **182**, such as the neoprene impregnated woven nylon fibers, the fibers act as stay bolts to hold the elastic polymer or neoprene from expanding, and thus absorb the lateral strain on these rings resulting from impact of the piston against the frame impact face **24**. Neoprene has been found to be a convenient elastic binder for nylon fibers, and thus facilitates the establishment of a synthetic modulus of elasticity which neither the nylon alone nor the neoprene alone can possess. The surface of the steel shims separating the layers of impregnated fabric are preferably roughened, as by sand-blasting. These shims frictionally support the fabric layers, giving added strength and retarding radial expansion; their friction against the fabric also dissipates a substantial amount of energy. When, as illustrated, the plastically deformable member **180** is used in conjunction with the elastically deformable component **179**, the latter is of such length and construction as to sustain without plastic flow a compression substantially equal to that which will initiate plastic deformation of the member **180**.

Referring to FIGURE 6, by appropriately dimensioning or apportioning the number of elastic polymer impregnated fabric rings **182** in relation to the metal rings **181**, the modulus of elasticity **188** of the elastically deformable component **179** may be sloped as desired within limits, thus to adjust the deceleration of the piston in accordance with the requirements above stated.

Because of the requirement that the piston weight be minimized, the amount of elastic shock absorption that can be built into the shock absorbing component **179**, is limited, and the excess must be taken up by the plastically deformable member **180**, both as regards excess kinetic energy resulting from the conduit severing operation, and more particularly as regards the excess kinetic energy resulting from inadvertent firing of the tool with no conduit mounted in the retaining arm. This latter is strictly a protective feature to prevent injury to the cutting blade, piston and the tool itself resulting from such inadvertent firing. To this end the plastically deformable member **180** comprises a ring made of a malleable metal like aluminum or aluminum alloy of such dimensions that it will fail in compression before the other tool components will fail in tension. That is to say, the compression strenghth of the plastically deformable member **180** must be substantially less than the tensile strength of the tool frame, cutting element and piston. It will be noted in this connection that when the piston impacts the frame impact face **24**, the tubular portion of the frame is placed under tension. Likewise, as above explained, the cutting element is placed under tension due to its inertia. As shown in FIGURE 4, the plastically deformable member **180** of malleable metal is of trapezium configuration, as viewed in axial section, and is mounted between the backing plate **185** and the piston cap **19**, both of which are made of a metal having a high elastic limit, such as steel. The abutting surfaces **190**, **191** between the plastically deformable member **180** and the adjacent steel backing plate and piston cap members **185**, **19**, are preferably sloped in accordance with the minimum slope or friction angle of the contiguous metals, i.e., aluminum vs. steel in the preferred modification as above mentioned, thus to enhance the energy absorption by the malleable metal plastically deformable member **180** as the latter is plastically deformed, and squeezed from the full line sectional area **180***b* to that of the dotted line **180***a*.

Thus the camming angles of the sloped surfaces **190**, **191**, approximate the friction angles between the contacting metal surfaces, so that the yield strength of the plastically deformable member **180**, is mechanically increased by the friction. The plastically deformable member **180** shown, approximates a rectangular stress-strain diagram for maximum efficiency of energy dissipation as a function of piston stroke. The maximum force developed thereon accordingly never exceeds a value exceeding the tensile strength of the cutter blade and shank.

Referring again to FIGURE 6, the plastic deformation of the member **180** may be designed to occur at any given load level such as **192**. As a result, therefore, of the composite assembly comprising the elastically deformable shock absorbing component **179** and the plastically deformable energy absorption member **180**, the composite load compression graph thereof will be approximately as indicated at **188**, **192** of FIGURE 6. That is to say, as the piston impacts the frame shoulder, the impact of the piston against the shoulder will at first be gradually absorbed by elastic deformation of the shock absorbing member **179** (and, of course, any elastic deformation of the "ring spring," or plastically deformable member **180** as does occur) along the line **188** of FIGURE 6, until a load corresponding to the level **192** is reached at which the elastic limit of member **180** will be exceeded whereupon additional load will be assumed by plastic deformation of the plastically deformable member **180** which holds the load substantially constant thereafter at the level **192** as shown in FIGURE 6.

It should be noted that in the ordinary usage of the tool the plastically deformable member **180** is not deformed beyond its elastic limit and that it is only the event that the tool is operated without a workpiece in place that the stress applied to this ring is sufficient to plastically and permanently deform it. Under some conditions, it is desirable that such permanent deformation of the plastically deformable member **180** be indicated and disable the tool until such is replaced. This can be accomplished by providing that permanent deformation of the plastically deformable member **180** increases its diameter beyond the bore diameter of the barrel sleeve **5** in the manner illustrated in FIGURE 7. In this condition, when an attempt is made to retract the piston to firing position, the margin of plastically deformable member **180** engages the end **5***a* of the barrel sleeve **5**, preventing complete retraction of the piston.

While the buffer above described comprises both an elastically deformable component **179** and a plastically deformable member **180**, where space requirements permit, it is possible to so extend and enlarge the elastically deformable member **179**, as to provide the energy absorption and dissipating capacity needed for firing in the absence of a workpiece without the use of the plastically deformable member **180**. Either arrangement is adapted to use in a stud driving tool, as distinguished from a cutting or swaging tool, the former as illustrated in FIGURE 8, in which the tool shank **14***a* terminates in an enlarged end **146**, recessed and threaded to receive the threaded shank of a stud **14***c*, which is designed to be fired into a difficultly penetrable material, such as aged concrete or steel. When such a tool is fired in the absence of work which will stop the stud after the desired penetration, the stud, instead of being projected into space, is retained by its threaded connection to shank **14***a*, the kinetic energy of stud, tool and piston being all absorbed in and dissipated by the buffer device.

Reverting to FIGURES 4 and 5, while the elastically deformable component **179** is a buffer and preferably comprises layers of impregnated fabric alternating with metal shims, under some conditions it is possible to omit the shims and place successive layers of impregnated fabric in face-to-face relation. It is essential, however, that the buffer comprise a plurality of rings or disks of fibrous material held in an elastic impregnating medium, such that the transversely disposed elastic fibers and the

elastic impregnant interact to oppose radial deformation while enabling the required longitudinal deformation.

Reverting to FIGURE 4, the piston impact plate **184** is likewise preferably made of a malleable metal like aluminum or an aluminum alloy, having a compression strength substantially below that of the metal of the frame **1**, which latter is made of steel. The purpose of this is to assure that the impact plate will fail through compression before the steel frame is broken under tension, this being an additional safety precaution in the piston construction. Moreover, the stress incident to stopping the piston assembly, either in normal usage or in firing without a workpiece, is received by the main frame barrel **2**, and not by the work support **3**, thus avoiding any bending stress in the curving connecting shank *3a*.

The tool is provided with a handle **200** of wood, hard rubber or equivalent, which is assembled on the under side of the tubular frame section **2**, by means of bolts, as at **201**, **202**, threaded into the frame.

In assembling the tool from its components, the piston and cutter assembly **14**, **15** are first inserted in the frame barrel **2**, with the upper and lower edges of the cutter blade aligned with the grooves **16**, **17**, in which the blade slides. The sleeve barrel 5 is thereupon inserted against the shoulder **4**. Since the bore of the sleeve barrel **5** is less than that of the width of the cutter blade **15**, it is apparent that the piston and cutter assembly **14**, **15** must first be inserted, for this reason. The barrel plug **6** is then inserted in the breech end of the frame and the cartridge chamber plug **7** inserted in the aligned holes **8**, **9**, and rotated until the pin **12** of the barrel plug seats in the notch of the chamber plug. As thus positioned, the slot **70***b* cut in the upper face of the chamber plug **7**, is positioned to seat the ejector end **72** of the cartridge ejector **66**.

The enlarged head of the barrel plug **6** assures that the proper end will be inserted in the frame barrel **2**. The chamber plug cannot be inserted until the barrel plug has been rotatively positioned with its bore **8**, in alignment with the frame bore **9**. The chamber plug cannot be incorrectly inserted by reason of its enlarged head **10** which can seat properly in the barrel plug counterbore **11** only when the plug is inserted as shown in FIGURE 1.

With the aforesaid components thus assembled, the cover **50** may then be slid into position on the frame, to effect which the piston return bolt **63** must first be removed. As the cover is advanced to the firing position shown in FIGURE 1 the frame cover pin **61** engages the shoulder **60** of the insert member **38** thus to limit the forward displacement of the cover. Also the cross slide **56** will snap into place in a cover cutout due to the centering action of resiliently mounted plungers (not shown). The piston return bolt **63** is thereupon inserted and threaded into the cover **50**. The tool is now ready for operation.

The method of operation is as follows: In loading the tool, the firing unit **55'** is grasped with one hand and one of the fingers thereof used to shift the cross slide protective device **56** to the release position. The firing unit **55'** and cover can then be drawn back to the cartridge ejecting position, thus exposing the open **C** at the front of the tool frame into which a section of conduit may be placed against the bushings **152** and the member **164**. Also exposed in this position is the aperture **70** in the cross slide cover, into which a blank cartridge **22** is dropped into the cartridge chamber bore **21**. The bolt is then pushed forward, and, in one motion, completely encases the conduit and cartridge, the conduit being resiliently gripped by the clamping device **57**. The cross slide protective device **56** is then shifted to the firing position, locking the cover to the frame, whereupon the trigger **87** may be pulled to fire. Thereafter the cross slide protective device **56** is shifted to the release position, whereupon the cover can again be withdrawn to the cartridge ejecting position by grasping the breech bolt, the spent shell thus being ejected through the cross slide cover aperture or opening **70**. The severed pieces of conduit can now be removed from the now open **C** of the frame retainer arm. The tool is then inverted whereupon the sheared conduit chips fall out of the tool. An absolute minimum of manual motion is thus entailed from start to finish.

Referring to FIGURE 8, it has been noted that the tool shank *14a* terminates in an enlarged end **146**. The impact plate *184a*, elastically deformable shock absorbing component *179a*, and the backing plate *185a* may be assembled on an assembly tube *186a* which is mounted on the shank *14a* between the enlarged end **146** and a piston cap extension member *20b*, the latter being threaded on to the threaded opposite end **147** of the shank *14a*. Where the impact plate *184a* is made of malleable metal, as previously noted, it will serve as a plastically deformable component of the shock absorbing buffer of the tool, and the backing plate *185a* together with the cap extension member *20b*, each made of steel, will serve as the piston cap. In this arrangement, as in the principal embodiment, the assembly tube *186a* facilitates replacement of the shock absorbing buffer elements.

Once the principles are understood, it will be apparent to those having skill in the art that the novel shock absorbing and energy dissipating means provided by the invention may have uses other than as hereinbefore described. Accordingly, it is intended that the true scope of the invention be not limited to the foregoing description thereof, but shall be limited only by the appended claims.

What is claimed is:

1. A shock absorbing and energy dissipating buffer comprising a stacked assembly of laminae of fibrous material, each of said laminae being separately impregnated with a polymer having rubber-like resilient characteristics, the fibers of said fibrous material being disposed for resisting deformation of said laminae in lateral direction with respect to the direction of the stacking thereof.

2. A shock absorbing and energy dissipating buffer according to claim 1 wherein said fibrous material is fabric woven.

3. A shock absorbing and energy dissipating buffer according to claim 1 wherein said fibrous material is nylon and said polymer is neoprene.

4. A shock absorbing and energy dissipating buffer comprising a stacked assembly of laminae of substantially incompressible material and laminae of fibrous material, each of said fibrous laminae being separately impregnated with a polymer having rubber-like resilient characteristics, the fibers of said fibrous material being disposed for resisting deformation of said impregnated fibrous laminae in lateral direction with respect to the direction of the stacking thereof.

5. A shock absorbing and energy dissipating buffer according to claim 4 wherein the surfaces of said laminae of substantially incompressible material which are in face-to-face relation with surfaces of said laminae of impregnated fibrous material are adapted to provide increased engagement friction between said respective surfaces.

6. A shock absorbing and energy dissipating buffer comprising a stacked assembly of thin metal discs and thin discs of fabric woven nylon material, each of said nylon discs being separately impregnated with neoprene.

7. A shock absorbing and energy dissipating buffer comprising an assembly member, a multiplicity of annular laminae mounted for displaceable movement on said assembly member, each of said laminae comprising interlocked fibrous material impregnated with a polymer having rubber-like resilient characteristics, and means for re-

taining said multiplicity of annular laminae on said assembly member.

8. A shock absorbing and energy dissipating buffer comprising an assembly member, an impact plate displaceably mounted at one end of said assembly member, a backing plate mounted at the opposite end of said assembly member, a multiplicity of annular laminae displaceably mounted on said assembly member and interposed between said impact and backing plates, each of said laminae comprising interlocked fibrous material impregnated with a polymer having rubber-like resilient characteristics, and means for retaining said impact and backing plates on said assembly member, said impact plate being of malleable metal having a compression strength slightly less than that of said multiplicity of laminae.

9. A shock absorbing and energy dissipating piston comprising an assembly tube member, a metal impact plate displaceably mounted on said tube at one end thereof, a metal backing plate mounted on said tube at the opposite end thereof, a multiplicity of annular laminae displaceably mounted on said tube and interposed between said impact and backing plates, said laminae comprising thin metal elements and laminae of interlocked fibrous material, each of said fibrous laminae being separately impregnated with a polymer having rubber-like resilient characteristics, a metal shank extending through said tube, a metal piston cap secured to one end of said shank adjacent said backing plate, and a relatively thick ring of malleable metal interposed between said backing plate and cap, said ring of malleable metal having a compression strength relative to that of said multiplicity of laminae such that said ring is plastically deformable upon the energy absorption capacity of said multiplicity of laminae having been substantially reached.

10. A shock absorbing and energy dissipating piston according to claim 9 wherein said ring has sides each sloping at an angle to the central axis of said shank, and said backing plate and cap each have a face in conforming abutment relationship respectively with one of said sides of the ring, said angles of abutment conforming substantially to the respective friction angles between the metals of said ring and said backing plate, and the metals of said ring and said cap.

11. A shock absorbing and energy dissipating buffer comprising a stacked assembly of elastically deformable members, and a plastically deformable member abutting said assembly of elastically deformable members, said plastically deformable member having a compression strength relative to that of said assembly of elastically deformable members such that said plastically deformable member is plastically deformable upon the energy absorption capacity of said assembly of elastically deformable members having been substantially reached.

12. Shock absorbing and energy dissipating means adapted for use in an explosively actuated tool wherein a piston is explosively impelled in a working stroke into impact engagement with piston abutment means of the tool and wherein the piston carries an elongated work tool element projecting therefrom in the direction of piston travel, said means comprising a stacked assembly of metal laminae and laminae of fabric woven nylon material, each of said nylon laminae being separately impregnated with neoprene, said assembly being adapted for displaceable mounting on such work tool element, the number of said impregnated nylon laminae and the number of said metal laminae in proportion to the number of said impregnated nylon laminae being such as to decelerate the piston upon its said impact without exceeding the tensile strength of such work tool element.

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