United States Patent [19]

Green et al.

[11] 3,815,476

[45] June 11, 1974

[54] **GAS POWERED DRIVING UNIT FOR SURGICAL INSTRUMENT**

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[73] Assignee: **United States Surgical Corporation,** Baltimore, Md.

[22] Filed: **Mar. 17, 1971**

[21] Appl. No.: **125,077**

Related U.S. Application Data

[62] Division of Ser. No. 852,822, Aug. 25, 1969, Pat. No. 3,643,851.

[52] **U.S. Cl.** **91/410,** 91/469, 227/130

[51] **Int. Cl.** **B25c 1/04,** F15b 13/04

[58] **Field of Search** 91/318, 356, 398, 410, 91/469; 227/130; 173/15–17

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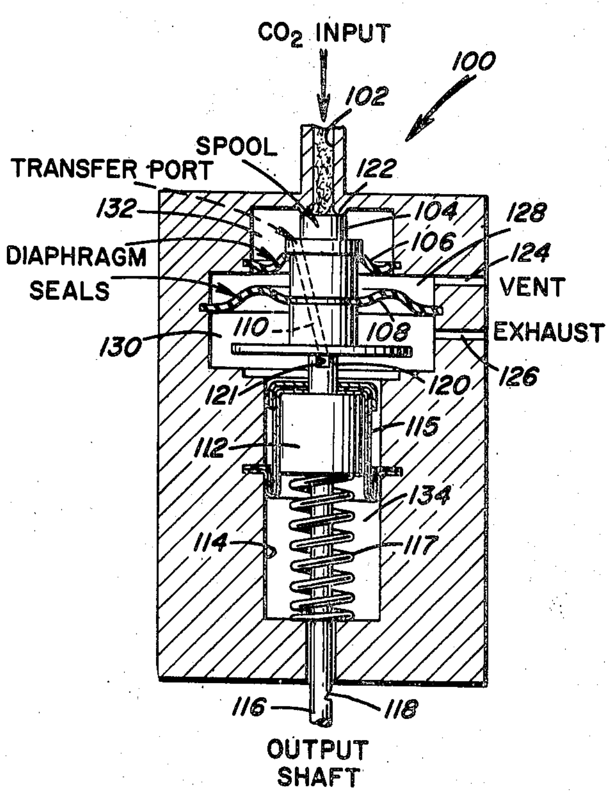
[57] **ABSTRACT**

A surgical instrument for applying sterilized staples from a disposable staple-carrying cartridge to the disunited skin of a patient in order to effect a joining of the skin. The instrument consists of an anvil adapted to lie flush with the skin, a disposable cartridge housing a plurality of staples which are to be folded around the anvil, and a pusher for bending the staples around the anvil. The pusher is U-shaped with chamfers on the arms thereof to effect the bending with a minimum of force. A gas-powered unit serves to eject and form the staples in a neat and uniform manner. A novel disposable gas cartridge is also disclosed.

6 Claims, 39 Drawing Figures



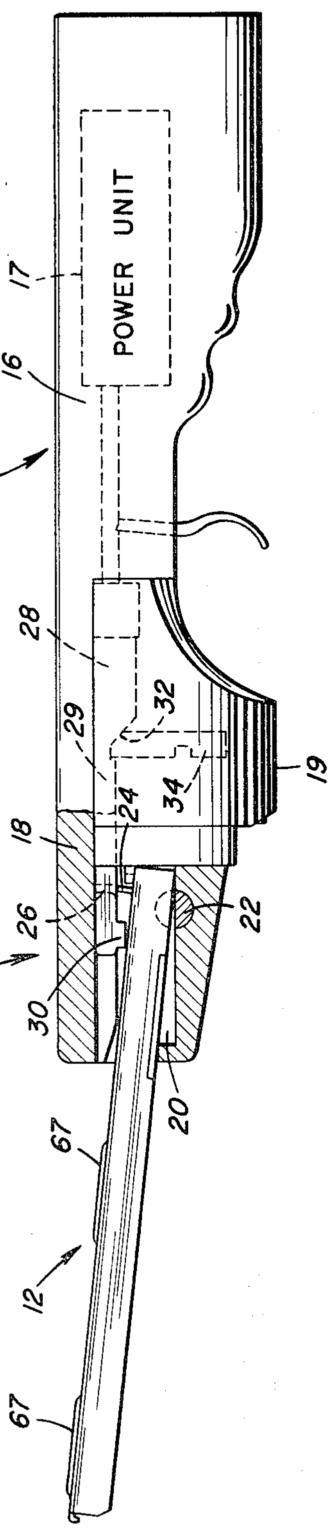


FIG. 1

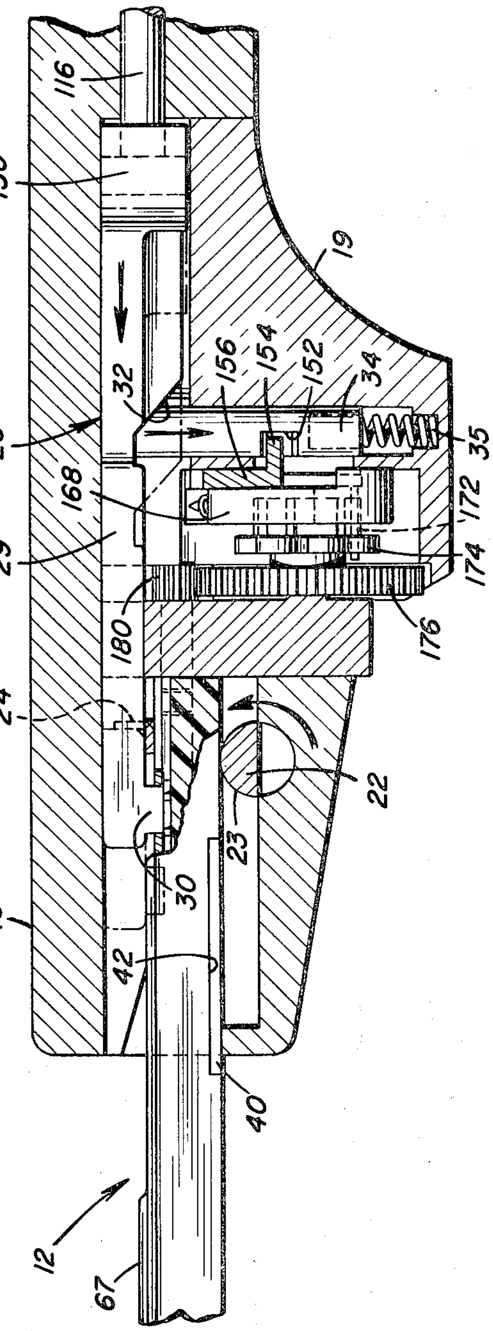


FIG. 2

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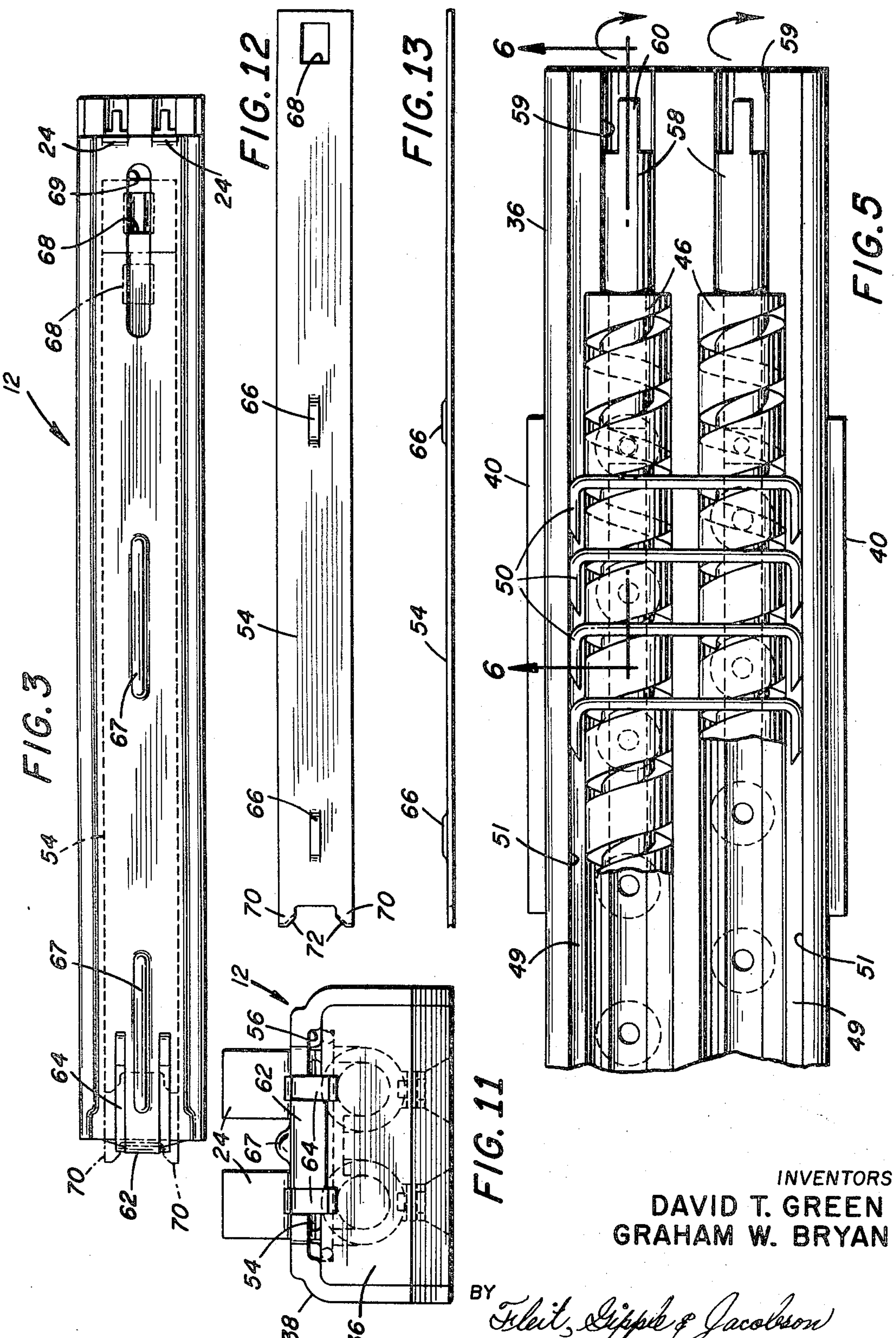

FIG. 3 FIG. 12 FIG. 13 FIG. 5 FIG. 11

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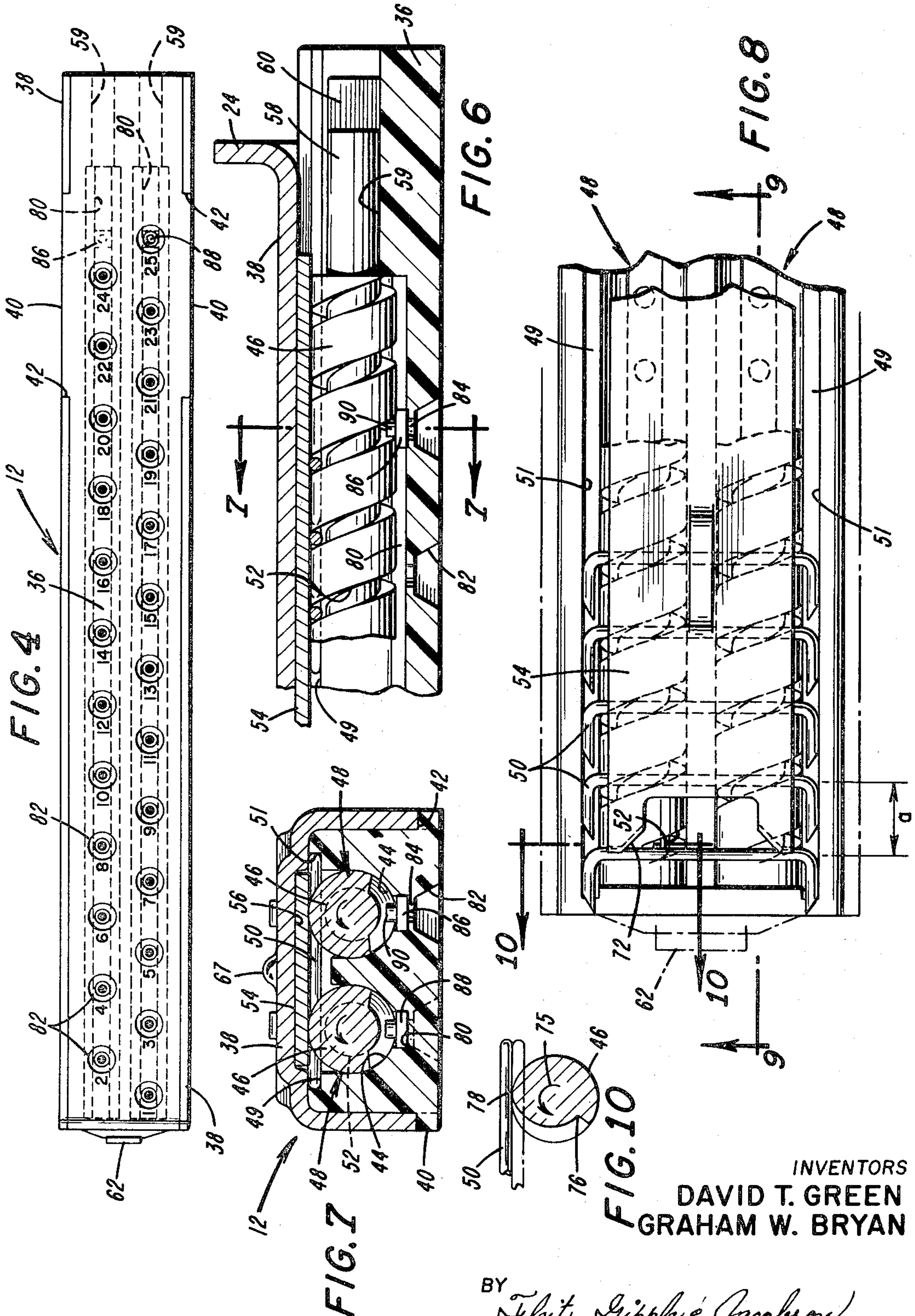

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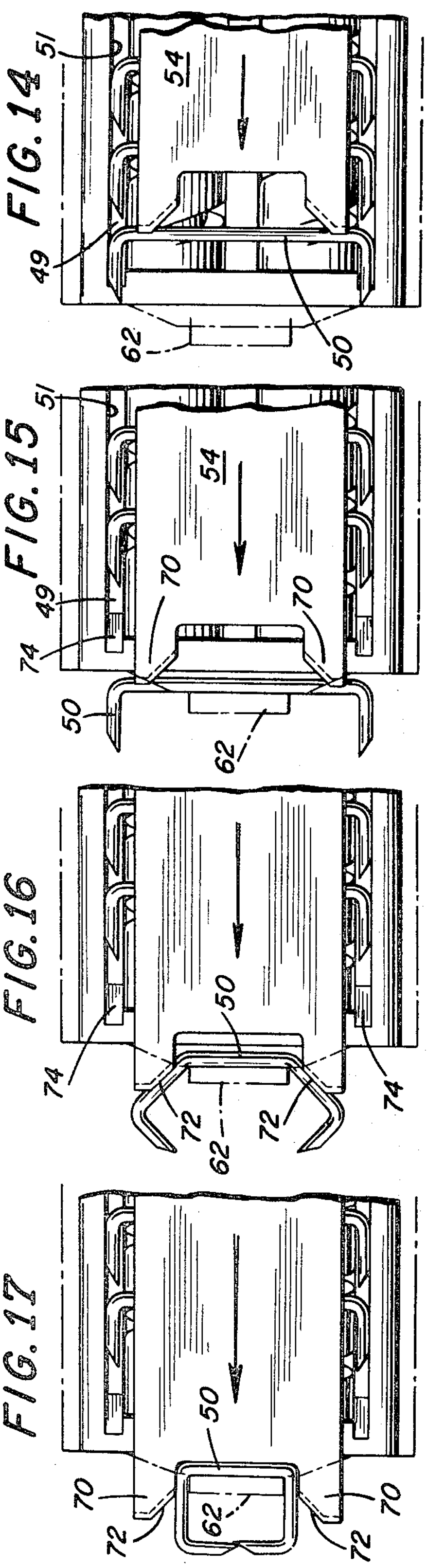

FIG. 14

FIG. 15

FIG. 16

FIG. 17

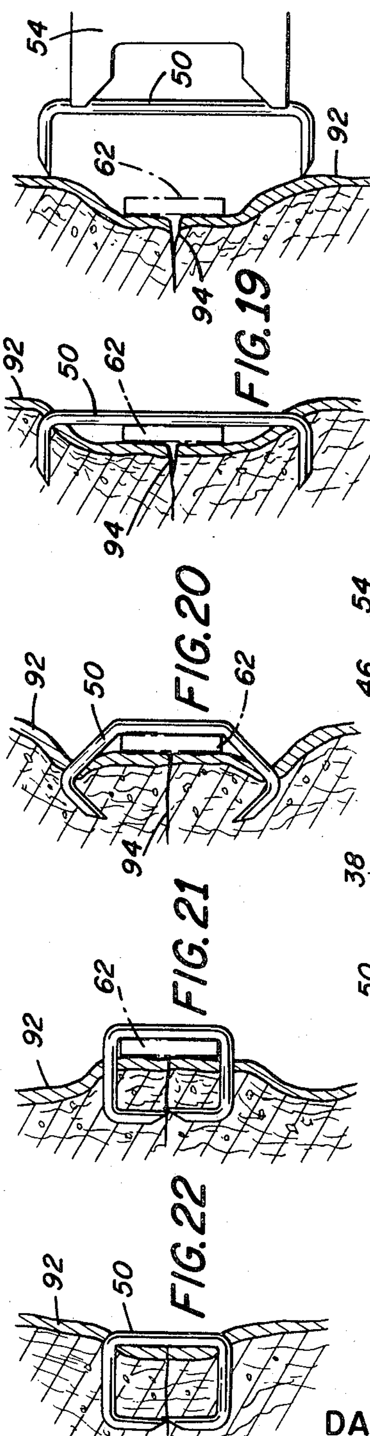

FIG. 18

FIG. 19

FIG. 20

FIG. 21

FIG. 22

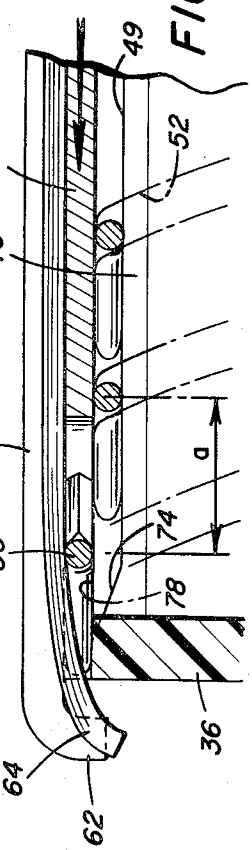

FIG. 9

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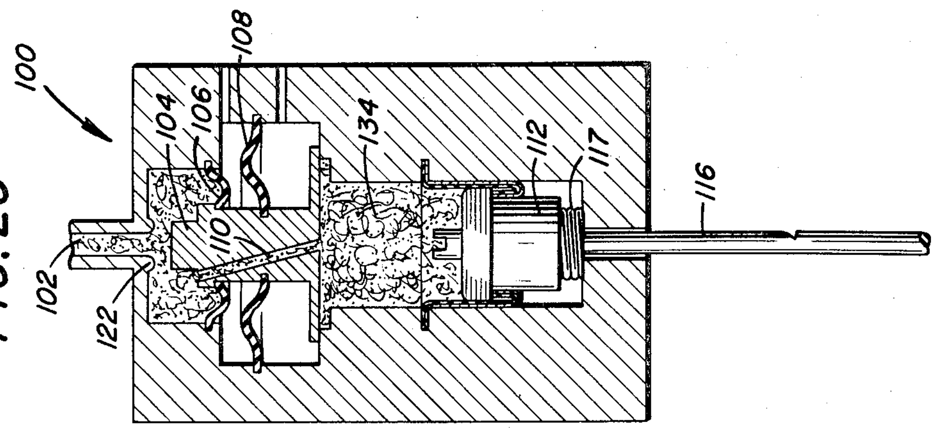

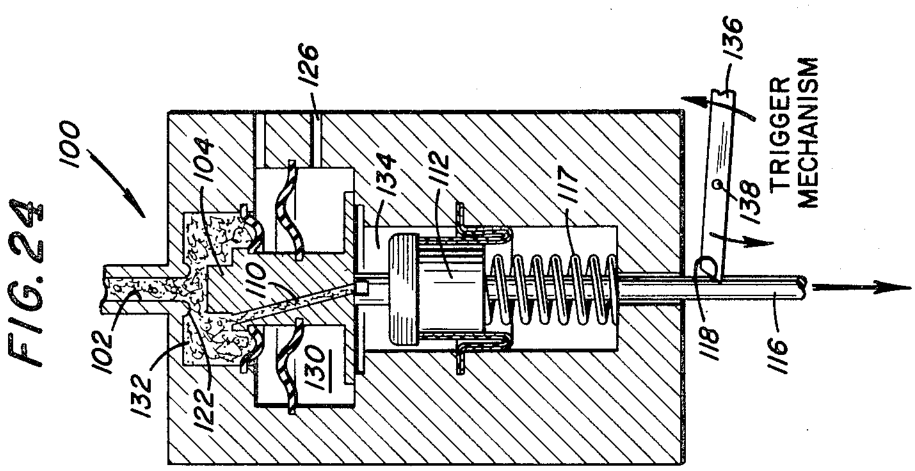

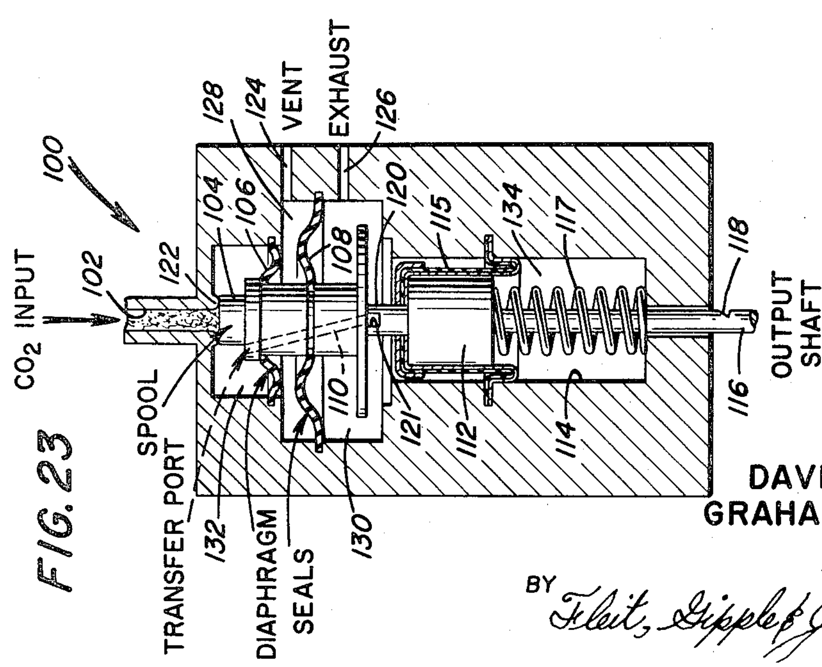

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FIG. 28

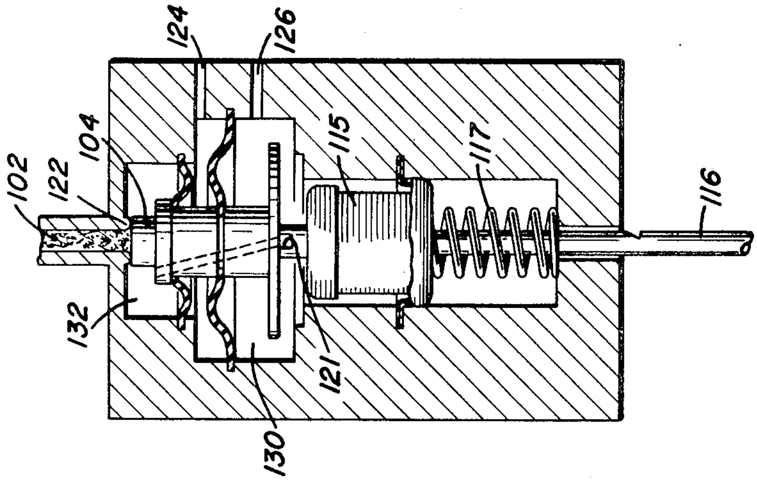


FIG. 27

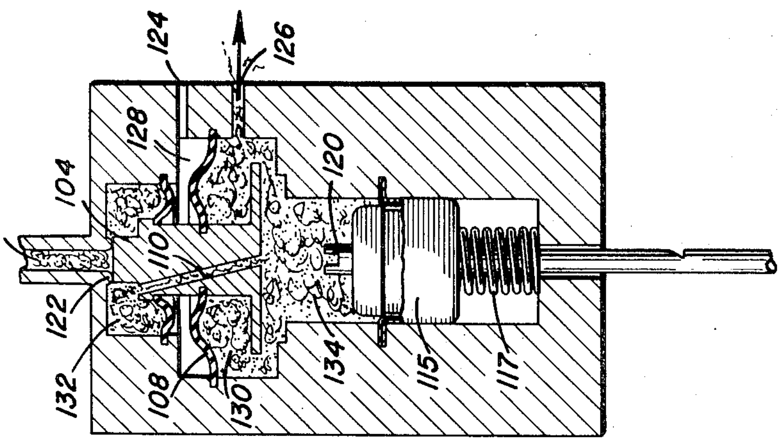
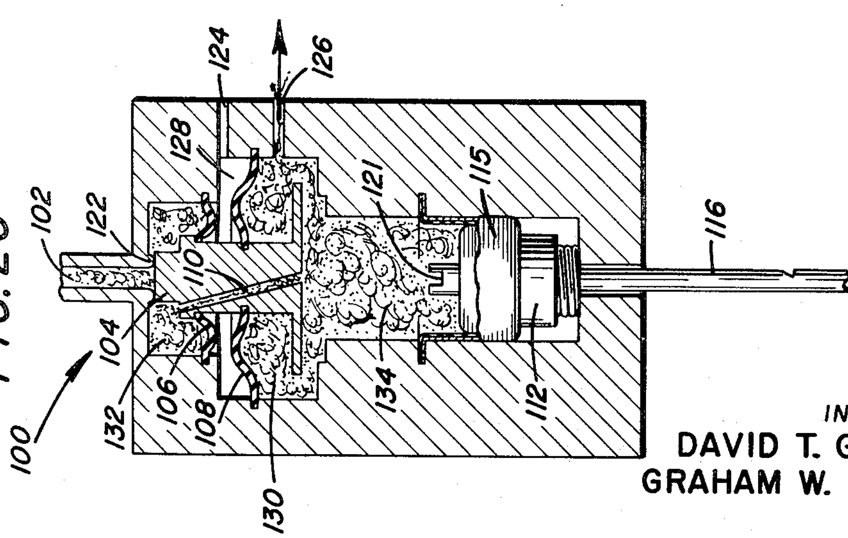


FIG. 26



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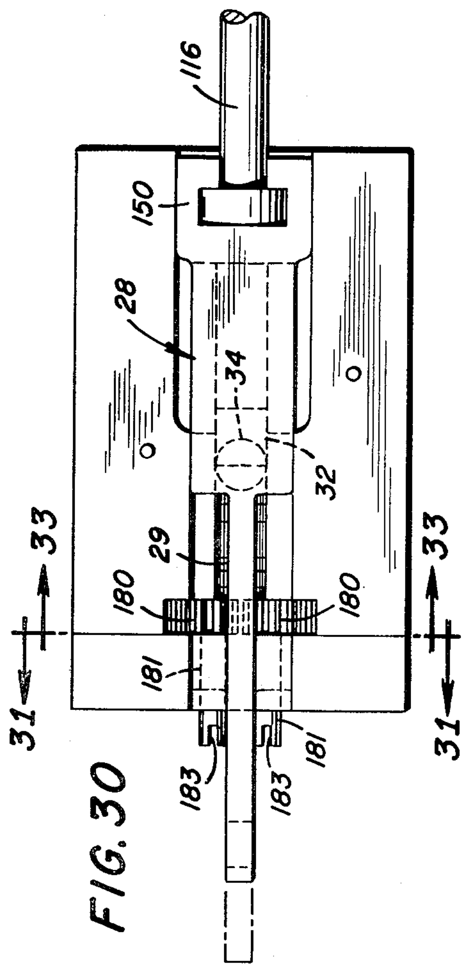

FIG. 30

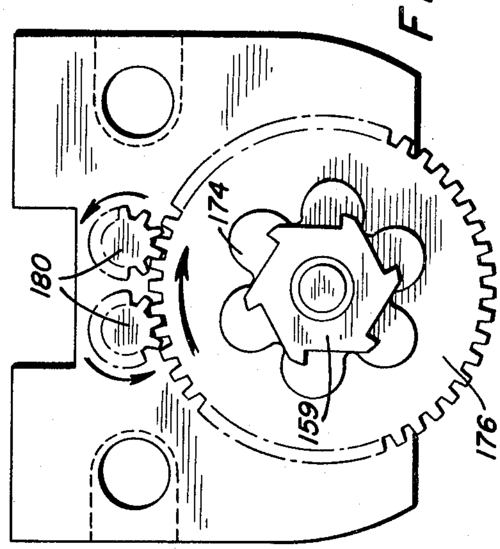

FIG. 31

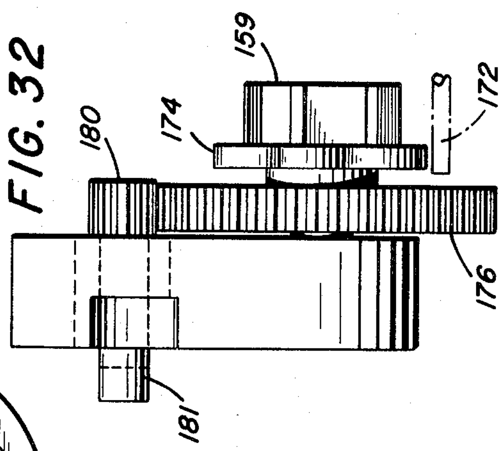

FIG. 32

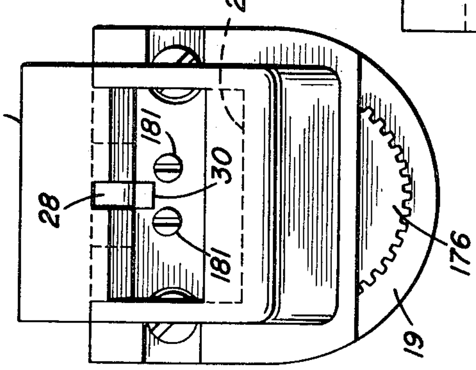

FIG. 29

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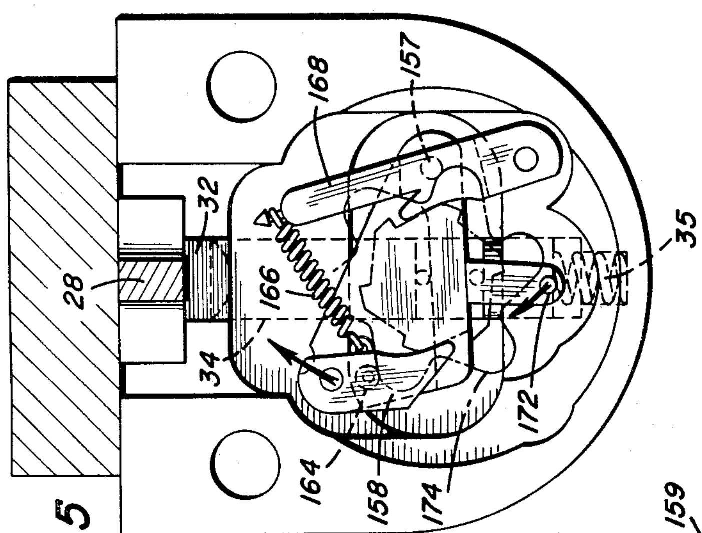

FIG. 35

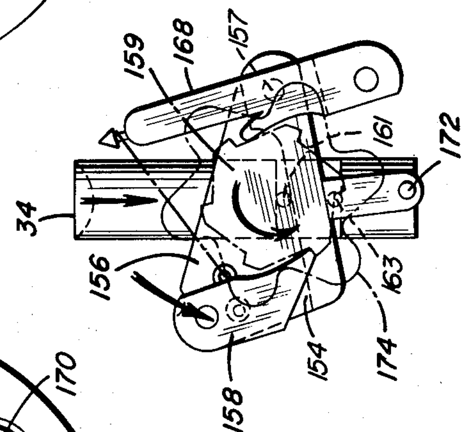

FIG. 34

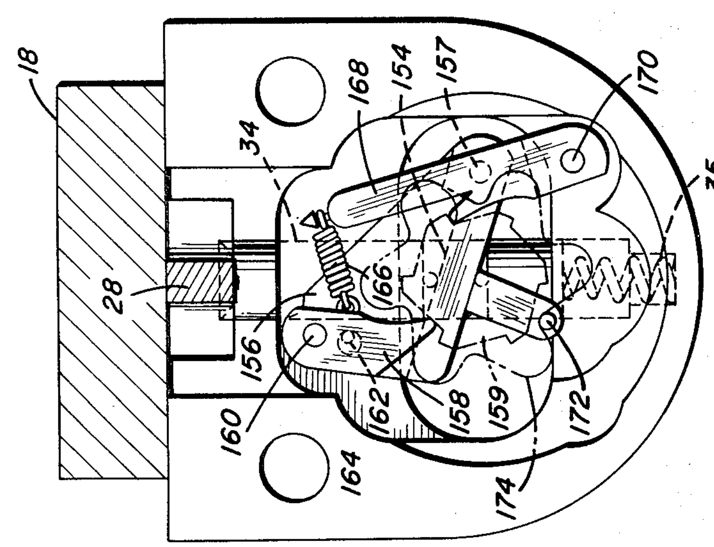

FIG. 33

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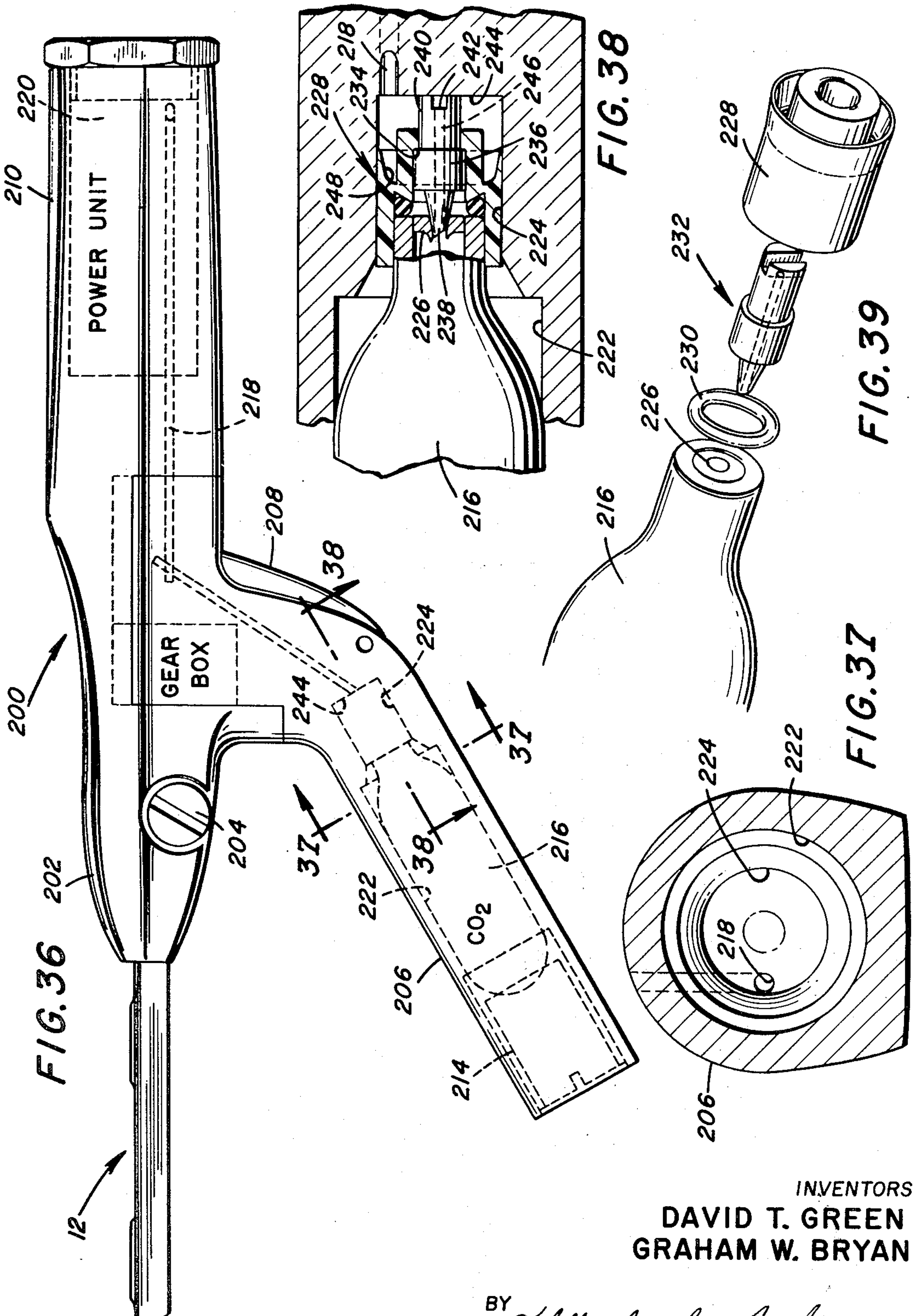

FIG. 36 FIG. 37 FIG. 38 FIG. 39

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GAS POWERED DRIVING UNIT FOR SURGICAL INSTRUMENT

REFERENCE TO ANOTHER APPLICATION

This application is a division of Ser. No. 852,822, filed August 25, 1969, now U.S. Pat. No. 3,643,851.

BACKGROUND OF THE INVENTION

The use of sterilized staples for medical applications has been steadily and rapidly increasing in popularity. However, the use has largely been restricted to applications wherein the tissue to be stapled can be positioned between the staple-ejecting unit and the anvil of the instrument. Where the tissue joint is to be made on the external skin of the patient, medical instrumentation is noticeably weak. Thus, there exists a void in modern surgical instruments making effective use of the staple in uniting external tissue.

There is another void in the field of modern surgical stapling instrumentation. Despite the wide use of sterilized staples for pefforming suture-like maneuvers, it has customarily been difficult for the surgeon, or assistant, to perform successive stapling operations in a way so that the staples are uniformly injected and shaped. The main reason for the resulting disuniformity of injection and shaping operations is that the surgeon is unable to exert a constant manipulative force on the instrument which he uses. Another reason is that after numerous stapling operations, the hand of the surgeon tends to tire, thus adding to the disuniformity of staple injection and shaping.

It is toward the elimination of the above-noted drawbacks of presently existing surgical stapling instruments, that the present invention is directed.

SUMMARY OF THE INVENTION

The present invention relates to a surgical instrument for stapling together disunited segments of the external skin of a patient.

Since this instrument functions externally to the body, the anvil serving to form the staple must be and is, at all times, external to the skin being stapled. More particularly, the anvil is adapted to rest on the external skin of the patient and to bend the staples so that they tightly grip and join the severed skin.

The staple is acted upon by a U-shaped pusher element having a chamfer on each leg thereof so that the staples are acted upon by forces remote from the points about which they are bent. In this manner, less force is required to bend the staples. The central region of each staple is made to contact the anvil. The pusher element then bends the staple around the anvil, the chamfer surfaces reducing the force required for such bending, and the U-shape of the pusher allowing the pusher to partially encircle the anvil during the bending operation for forming the staple. The anvil releases the staple by means of a spring and the stapling maneuver is complete.

In the instrument of the present invention, a plurality of staples are housed in a disposable cartridge. These staples are housed in such a manner that only a small area of the instrument need contact the patient. For this reason, the stapling instrument of the present invention may also be used for the stapling of internal fascia.

The instrument of the present invention is powered by a disposable gas cartridge. Thus, there is complete uniformity of staples from one stapling operation to the next. Also, there is no fatigue of the surgeon or his assistant since the gas-powered unit is activated by a slight movement of a lever or trigger. In operation, the gas-powered staple-ejecting unit is activated by the operator and performs its stapling operation, returning to its initial state for further activation in a minimum of time and with a maximum of efficiency. The power unit is simple in design, contains but few moving parts and is a repeating unit having an extremely long life cycle.

The cartridge contains 25 staples. Each staple lies in the threads of a pair of adjacent screws and each is propelled one step when the screws are simultaneously turned one revolution. The power unit is fired and a rod-like element initiates the operation of a gearbox and simultaneously drives the pusher forward. The gearbox ensures that a staple is put in a readiness position before the pusher reaches the contact area. The pusher unit then automatically returns to its rearward position and the instrument is put in readiness for another stapling maneuver.

The present invention thus provides a surgical stapling instrument which fills the gaps noted above with regard to the instrumentation known to the prior art. Staples may be used to unite the external skin of a patient and may be uniformly shaped without causing fatigue in the surgeon.

As noted above, the instrument of the present invention is powered by means of a sterilized disposable gas cartridge. It is customary when gas-powering units are employed, to provide the recipient device with a pin for puncturing the seal in the gas cartridge. It has been found, however, that the pin wears rapidly and thus detracts from the useful life of the gas-powered device.

The present invention contemplates that a gas cartridge be fitted with its own puncturing mechanism, thereby adding to the life of the basic instrument. In this manner, a sterilized gas cartridge with its puncturing mechanism and a sterilized and filled staple cartridge may be packaged together so that the reloading operation is greatly facilitated.

Accordingly, it is one object of the present invention to provide a surgical stapling instrument for stapling disunited portions of the external skin of a patient.

It is another object of the present invention to staple the skin of the patient in such a manner that a minimum of force if required to form the staple during the maneuver.

It is yet a further object of the invention to provide a stapling instrument having a disposable staple-carrying cartridge.

It is a further object of the invention to provide a medical instrument for stapling the skin of a patient, which instrument is powered by a gas under pressure.

It is still another object of the present invention to provide a unique and disposable pressurized gas-powering assembly.

It is yet a further object of the invention to provide a gas-powered driving mechanism which is simple in design, economical in cost and is yet efficient and long lived.

These and other objects of the invention, as well as many of the attendant advantages thereof, will become more readily apparent when reference is made to the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view, partially in section, showing the skin stapler of the present invention;

FIG. **2** is an enlarged side view, partially in section, of te mechanism shown in FIG. **1** after the cartridge is mounted and ready for use;

FIG. **3** is a top view of the cartridge of the present invention;

FIG. **4** is a bottom view of the cartridge shown in FIG. **3**;

FIG. **5** is an enlarged view of the rear portion of the cartridge shown in FIG. **3** with a portion of the cover removed;

FIG. **6** is a cross-section taken along lines **6—6** of FIG. **5**;

FIG. **7** is a cross-section taken along lines **7—7** of FIG. **6**;

FIG. **8** is an enlarged view of the front portion of the cartridge shown in FIG. **3** with the cover partially removed;

FIG. **9** is a cross-section taken along lines **9—9** of FIG. **8**;

FIG. **10** is a cross-section taken along lines **10—10** of FIG. **8**;

FIG. **11** is a front view of the cartridge shown in FIG. **3**;

FIG. **12** is a top view of the pusher element forming a part of the present invention;

FIG. **13** is a side view of the pusher element shown in FIG. **12**;

FIGS. **14** through **17** are sequential views showing the formation of a staple during a stapling operation;

FIGS. **18** through **22** show the sequential formation of a staple in the skin of a patient;

FIG. **23** is a cross-section through the gas-powered driving mechanism of the present invention;

FIGS. **24** through **28** are drawings showing the sequential steps involved in ejecting and forming a staple with the gas-powered mechanism shown in FIG. **23**;

FIG. **29** is a front view of the main body portion of the skin stapler shown in FIG. **1**;

FIG. **30** is a top plan view of the gearbox housing;

FIG. **31** is a cross-section through lines **31-31** of FIG. **30**;

FIG. **32** is a side elevation of the gear arrangement shown in FIG. **31**;

FIG. **33** is a cross-section of the gearbox through lines **33—33** of FIG. **30** in its retracted, or readiness, position;

FIG. **34** is a view similar to FIG. **33** but with the gearbox in its stapling position;

FIG. **35** is a view similar to FIGS. **33** and **34**, showing the moving parts of the gearbox when returning from the position shown in FIG. **34** to the position shown in FIG. **33**;

FIG. **36** is a side view of a second embodiment of the main body portion of a skin stapler constructed in accordance with the present invention;

FIG. **37** is a sectional view through lines **37—37** of FIG. **36** with the gas-cartridge assembly removed;

FIG. **38** is a sectional view through lines **38—38** of FIG. **36**; and

FIG. **39** is an exploded perspective view of the gas cartridge and piercing mechanism shown in FIGS. **36** through **38**.

DETAILED DESCRIPTION OF THE DRAWINGS

In FIG. **1**, the skin stapler of the present invention is shown generally at **10** and comprises a disposable staple cartridge indicated generally at **12** and a main body portion indicated generally at **14**. The main body portion **14** has a region **16** serving as the handle which the surgeon holds during use. The handle **16** further serves to house the gas-powered firing mechanism **17** including a source of CO_2 gas. The forwardmost region of the main body portion **14** defines a cartridge-mounting assembly **18** for positioning and holding the cartridge **12**. Intermediate the handle **16** and the cartridge mounting assembly **18** is a gearbox region **19**. Region **19** houses the gearbox which synchronizes the movements of the elements forming a part of the inventive skin stapler.

In FIG. **1**, the cartridge **12** is in the process of being seated in the cartridge-mounting assembly **18**. It can be seen that the assembly **18** has defined therein a cavity **20**, this cavity being of such dimensions as to allow the angular insertion of the cartridge **12**. A hand operated semicylindrical cam **22** is rotatably mounted on the assembly **18**.

When the cartridge **12** is being inserted or removed from the main body portion **14**, the cam **22** is in the position shown in FIG. **1**. To lock the cartridge **12** in the main body portion **14**, cam **22** is rotated 180° until it takes the position shown in FIG. **2** and securely contacts the bottom of cartridge **12** with its camming surface **23**. The cartridge **12** is held in horizontal alignment with the main body portion **14** by means of a pair of upwardly extending flanges **24** on the cover plate of the cartridge **12**. Flanges **24** engage a pair of recesses **26** defined in the cartridge mounting assembly **18**.

As is best shown in FIGS. **6** and **11**, the two flanges **24** extend upwardly from the rear end of the cartridge cover and are spaced apart. This spacing is provided to enable a driving member **28** (FIG. **2**) to reciprocate between the two flanges **24**.

As shown in FIG. **1**, the driving member **28** has an elongated central region **29**. A pusher-engaging extension **30** is positioned at the extreme front end and an inclined surface **32** is positioned at the mid section of the driving member **28**. The inclined surface **32** is adapted to engage a slidable plunger **34** which is spring biased upwardly by a spring **35**.

In FIG. **1**, the driving member **28** is shown in its rearwardmost position to allow for the insertion or the removal of the cartridge **12**. In this position, the plunger **34** is maintained in its uppermost position by the force of the biasing spring **35**. When the member **28** is driven forward during a stapling operation, the plunger **34** is acted upon by the surface **32** and is forced downward against the biasing force of spring **35**. The functions of these elements are described in more detail below.

The configuration of the cartridge **12**, and its operation, will now be explained with reference to FIGS. **3** through **13**. The cartridge **12** is defined by a body **36** adapted to be covered by a cover plate **38**. The body **36** has provided thereon a pair of alignment extensions **40** which serve to engage the cover plate **38** at respective recesses **42** provided therein. This is best shown in FIGS. **4** and **5**. The body **36** of the cartridge **12** is fitted with a pair of cylindrical depressions **44**, shown best in

FIG. 7. Depressions 44 extend substantially the entire length of the body 36 and serve to position a pair of rotatably mounted screws 46.

As best seen in FIGS. 7 and 8, the pair of depressions 44 are defined in the body 36 of the cartridge 12. These depressions 44 serve to define ledges 49 of lateral walls 51, which ledges and walls function to guide a plurality of staples 50.

From FIGS. 6 and 7, it can be seen that the ledges 49 and lateral walls 51 guide the staples 50, over a substantial length of the cartridge, at a level beneath the external circumference of each screw 46. This is made possible since the screws 46 are provided with threads 52 for guiding and propelling the staples 50 along the ledges 49 and between the walls 51.

A pusher plate 54 covers the staples 50 and slides within an indentation 56 provided in the cover plate 38, the pusher plate 54 being guided by the top of the screws 46 and the bottom of the cover plate 38. The pusher plate 54 serves to hold each staple 50 against the ledges 49 except during a driving operation. Then, the forwardmost staple is propelled forward and away from the cover of the pusher element 54.

Each screw 46 is provided, at its rearwardmost end, with an extension 58. Each extension 58 is unthreaded, is rotatably held in a cylindrical recess 59 in the body 36, and it fitted at its extremity with a flat extension 60. See FIGS. 5 and 6.

In FIGS. 12 and 13, the configuration of the pusher element 54 is illustrated. The pusher element 54 is in the form of a flat plate having a pair of upwardly extending guide projections 66 centered thereon. Projections 66 are adapted to slide in recesses 67 on the top of the cover plate 38. The rearwardmost region of the pusher element 54 is cut out at 68 and is adapted to be engaged by the pusher-engaging extension 30 on the driving member 28, described with reference to FIG. 1. The extension 30 reaches the hole 68 through a slot 69 provided in the cover plate 38. The forwardmost region of the pusher element 54 is U-shaped, defining a pair of tines 70. As best seen in FIGS. 8, 9, 12 and 13, the tines 70 are V-shaped in order to best guide the staples 50 during the staple-discharging operation. For reasons which are explained below, each tine 70 is provided with a chamfer 72.

At the forwardmost region of the cover plate 38, and as illustrated in FIGS. 1, 3, 9 and 11, projects an anvil 62. The anvil 62 is an extension of the top of the cover plate 38 and curls into the plane of the pusher element 54. The anvil 62 is fitted with staple-ejecting springs 64 for forcing the staples out of the region of the anvil 62 after the completion of each stapling operation. It should be evident that the pusher element 54 moves the springs 64 out of the staple-forming plane during the stapling operation and releases the springs when it begins to retract. Once the pusher element 54 is retracted from the anvil area, the springs 64 urge the staple 50, just formed, out of the plane of the pusher.

As best shown in FIG. 3, the tines 70 of the pusher element 54 are spaced apart a distance sufficient to comfortably accommodate the anvil 62. More particularly, with reference to FIG. 17, the distance between the tines 70 is equal to the width of the anvil 62, plus twice the diameter of a staple 50, plus a small clearance to avoid "sluggish" operation.

In loading the cartridge 12, the following procedure may be used. The screws 46 may be fitted into their respective cylindrical depressions 44. Then the staples 50 may be inserted between the lateral walls 59 of the body 36. The screws should be in the position shown in FIG. 5 with the flat extensions 60 aligned and vertical. The pusher element 54 is then fit over the staples 50 and the cover plate 38 is put in position. Once, this procedure has been followed, the cartridge 12 is ready to be loaded into the instrument.

The screws 46 are threaded so that when they, by means of the extensions 60, are rotated through 360°, each staple moves one staple unit. A "staple unit" may be defined as that distance required to move the second staple from its readiness position into a position ready to be fired. Thus, in FIGS. 8 and 9, one staple unit is shown at *a*.

With reference now to FIGS. 8, 9 and 10, the positioning of the forwardmost staple 50 will be described. This staple is, initially, one staple unit from a position ready for firing. The pusher element 54 is then in its rearwardmost position, which position holds all staples in the threads 52 of the screws 46.

As is seen in FIG. 9, each ledge 49 is terminated as its forwardmost region in an inclined surface 74. Surface 74 serves to guide the point of the forwardmost staple 50 upwardly and into the plane of the pusher element 54 during the forward thrust of the pusher. Simultaneous with the action of the surface 74, the forwardmost portion of each screw 46 serves to raise the cross-piece of the first staple 50 into the plane of the pusher element 54. This is best shown in FIG. 10 which illustrates the forwardmost portion of the screw 46. The direction of rotation of screw 46 is indicated by arrow 75. It is seen that the thread depth decreases from a maximum at 76 to a minimum at 78. The thread depth at 76 is equal to the thread depth uniform throughout the thread save for the most forward region. The depth of the thread at 78 is zero. Thus, when the cross-piece of a staple rides along the screw at 78, it is in the plane of the pusher element 54.

The staple-ejecting and guiding operation will now be explained. When the pusher element 54 is activated, it is thrust forward by the member 28. Before, however, the pusher element 54 reaches the contact area, the inclined surface 32 on member 28 causes plunger 34 to be depressed, thus advancing a staple into stapling position. Once the staple is properly positioned, pusher element 54 reaches the contact area and forces the first staple (See FIGS. 8 and 9.) out of the cartridge 12 and against the anvil 62. When the pusher element 54 reaches its forwardmost position, its direction of travel is reversed (it being controlled by the driving member 28 shown in FIGS. 1 and 2). At a time during the rearward journey of the pusher element 54, the inclined surface 32 on the driving member 28 releases the plunger 34, allowing the plunger and the gearing mechanism to be put in readiness for the next stapling operation. The gear mechanism causes the two screws 46 to turn slightly better than one revolution during the forward movement of the pusher element 54. This will be explained below.

The interaction of the pusher element 54, the staples 50, the ledge 49 with its inclined surface 74 and the screws 46 with their diminishing thread arrangements will now be explained. A gearbox, described below, turns each screw 46 through slightly more than one revolution during the forward stroke of the pusher element 54, thereby advancing each staple but the first, slightly more than one staple unit. The forwardmost staple moves only one staple unit and into a readiness position because of the lack of threads at the forward ends of the screws **46.** When the screws **46** turn, thereby advancing each staple, the forwardmost staple **50** is simultaneously acted upon by the ledge **74** and the diminishing thread of the screws **46.** In this manner, the first staple is raised from its position below the pusher element **54** into the plane of the pusher, while remaining parallel, at all times, to the plane of the pusher. This is done while the pusher moves forward but before it reaches the contact area. Once the first staple is ready to be expelled from the instrument, the pusher element **54** makes contact with the staple.

The disposable cartridge of the present invention may house any number of staples, but is shown to house, in this example, twenty-five. It is therefore possible that more than one cartridge is required during a single operation. It becomes important, then to keep the surgeon advised as to the number of staples remaining in his disposable cartridge. The present invention provides for the indication of the number of remaining staples.

Reference should now be directed to FIGS. **4** through **7.** Beneath each cylindrical depression **44** in the body **36** is a small rectangular depression **80.** Depressions **80** extend substantially the entire length of the body **36** and communicate with depressions **44.** Through the bottom of body **36** extend twenty-five tapered bores **82.** As is best seen in FIG. **7,** the recesses **44** communicate with the bores **82** by means of a plurality of cylindrical bores **84** of a smaller diameter than the smallest diameter of the tapered bores **82.**

A pair of pads **86** and **88** of a rectangular shape are housed within the slide in the recesses **80.** Each pad **86** and **88** is provided with a cylindrical extension **90.** Each extension **90** serves to ride within the thread **52** of a screw **46.**

As shown in FIG. **4,** the tapered bores **82** are staggered throughout the length of the cartridge **12.** As is also seen in FIG. **4,** the pads **86** and **88** ride in their respective recesses **80** in alignment. Because of the alignment between pads **86** and **88** and the staggered arrangement of bores **82,** only a single pad at a time is visible through a bore.

In operation, the pads **86** and **88** are positioned in alignment with the rearwardmost bore **82,** as shown in FIG. **4.** This bore is numbered "25" and indicates that 25 staples remain in the cartridge. Initially, pad **88** is visible through this bore. After one staple has been ejected from the cartridge, each screw **46** has been rotated 360°. Since the projections **90** on the pads **86** and **88,** respectively, engage the threads **52** of the screws **46,** the pads move one staple unit. The bores **82** are separated by one staple unit. Consequently, pad **86** is visible through bore **82** which is labeled "24". This staggering relationship of visible pads continues until pad **88** is visible through the bore **82** referenced 1, this indicating that one staple remains. When the last staple is ejected, the pads **86** and **88** are both masked by the body **36.** In this manner, the surgeon is constantly appraised of the number of staples remaining in this instrument.

With reference now to FIGS. **14** through **17,** the interaction between the pusher element **54,** a staple **50** and the anvil **62** is explained. In each of these four figures, the pusher element **54** is shown to be moving toward the left of the page, in the direction of the arrow.

In FIG. **14,** the relative positions of the pusher element **54** and a staple **50** are shown at impact. In FIG. **14,** the pusher element is shown in the contact area. It is evident, then, that the screws have already been turned to advance the staples **50.**

The pusher element **54** moves forward from the position shown in FIG. **14** until the staple **50** contacts the anvil **62,** the staple **50** being guided by the V-shaped surface of the pusher tine **70.** The pusher **54** is driven to the left and, because of the chamfers **72** in the tines **70,** staple **50** is easily bent around the anvil **62.** After the pusher element **54** advances slightly, the staple takes the shape shown in FIG. **16,** still being guided by the V-shape of the pusher tine. The chamfer surface allows a bending force to be exerted on the staple **50** at points remote from the anvil **62.** In this manner, the required initial bending force is reduced.

Once the staple is in the position shown in FIG. **16,** the bending force is moved from the outermost region of the chamfer to the innermost region. However, because of the build-up of inertial forces, bending is still easily accomplished. The pusher element advances until it reaches the position shown in FIG. **17.** In this position, the staple **50** is substantially rectangular and has its points in engagement.

With reference now to FIGS. **18** through **22,** the formation of the staple with respect to the skin will be explained. The external skin of the patient is shown at **92** and is split at an incision **94.** The function of the skin stapler of the present invention is to securely fasten the two segments of skin **92** and to maintain the fastened position neatly and securely to facilitate the healing process.

As seen in FIG. **18,** the front end of the skin stapler is pressed against the skin of the patient covering the incision **94.** If properly positioned, the anvil **62** is centered with respect to the incision **94.** The member **28** is activated and the pusher element **54** begins its forward journey. Simultaneously, the staples **50** are guided forward. When the pusher element **54** reaches the contact area, the forward staple is ready to be ejected. The pusher contacts the first staple, as shown in FIG. **18.** Pusher element **54** then expels the staple **50** from the cartridge and drives same until it contacts the anvil **62,** as shown in FIG. **19.** In this Figure, it is seen that the staple pierces the skin of the patient.

In FIG. **20,** the staple is shown when beginning to crimp the skin **92.** In this position, the staple is formed as described above with respect to FIG. **16.**

The staple is then completely curled around the anvil **62** so that it takes the shape illustrated in FIG. **17.** The corresponding position of the staple with respect to the skin is shown in FIG. **21.**

During the forward thrust of the pusher element **54,** the tines **70** move the springs **64** out of the staple plane. After the stapling operation is completed and the pusher begins to return to its rest position, springs **64,** associated with the anvil **62,** serve to eject the staple **50** from the anvil. The skin **92** is then free, under the force of sub-surface tissue, to expand toward the crossbar of the staple. This is shown in FIG. **22.**

Since only the forwardmost portion of the skin stapler **10,** which portion is relatively small, contacts the patient during a stapling operation, the stapler of the present invention is quite versatile. It may be used to staple external skin or an internal organ. This has never before been possible in the prior art.

The pusher element may be driven by any of a large number of configurations. It may be driven manually or it may be driven by springs. The present invention, however, contemplates that the pusher element be driven by a gas under pressure. More particularly, the present invention contemplates that the pusher element be driven by a charge of carbon dioxide housed within small pressurized and disposable tanks.

With reference, now, to FIGS. 23 through 28, the gas-powering unit of the present invention is described.

With reference first to FIG. 23, the configuration of the drive mechanism is as follows. The drive mechanism is shown generally at **100** and comprises a gas inlet port **102**, a spool **104**, a pair of diaphragm seals **106** and **108**, respectively, a transfer port **110** extending from one side to the other of the spool **104**, a piston **112** sealed against the wall **114** of a piston chamber **134** by means of a rolling diaphragm **115** and a spring **117** serving to resiliently bias the piston **112** upwardly. Secured to the piston **112** is an output shaft **116** provided with a notch **118**. The uppermost part of the output shaft **116** is designated **120** and serves, under the action of spring **117**, to exert an upward force on the spool **104**. A seal **122** is defined at the opening of the gas inlet port **102** and prevents the escape of gas from the inlet port **102** when contacted by the spool **104**. A vent **124** and an exhaust **126** are provided and communicate with a vent chamber **128** and an exhaust chamber **130**, respectively. An inlet chamber **132** communicates with the inlet port **102**.

With reference, now, to FIGS. 24 through 28, the operation of the power unit **100** will be explained. As noted above, when the spool **104** is acted upon by the spring **117**, it impinges upon the seal **122**, thus preventing the entrance of the pressurized gas into the inlet chamber **132**. The pressure acting on the top of spool **104** is less than the force exerted by the spring **117** since the pressure in the inlet port acts on a small area when spool **104** abuts seal **122**.

In FIG. 24, a trigger mechanism **136** is shown pivoting around a pivot **138**. The forwardmost end of the trigger **136** engages the notch **118** in the output shaft **116**. Thus, when the trigger **136** is activated, the force exerted by the spring **117** is overcome and the spool **104** is driven from the seal **122**, downwardly, off the inlet port **102**, by the gas under pressure. When the spool **104** reaches the bottom of the exhaust chamber **130**, the exhaust port **126** is sealed with respect to the pressurized gas in the inlet port **102**. The pressurized gas then flows through the inlet port **102**, into the inlet chamber **132**, then through the transfer port **110** and into the piston chamber **134**. The pressure exerted by the gas drives the piston **112** downwardly and into the position shown in FIG. 25.

Initially, the pressure in the piston chamber **134** is lower than the pressure in the inlet chamber **132** due to the restriction in the transfer port **110**. The pressure in the piston chamber **134**, however, rapidly builds up until it overcomes the pressure in the inlet chamber **132**. The pressure in the piston chamber overcomes the pressure in the inlet chamber because the piston chamber acts on a larger area (the bottom of spool **104**) than does the inlet chamber pressure (which acts on the top of diaphragm **106**).

As a consequence the area differential noted above, the pressure in the piston chamber **134** drives the spool **104** upwardly, thus sealing the inlet port when the spool again contacts seal **122**. This is shown in FIG. 26. The pressure in the piston chamber **134** at this point is directly proportional to the ratio of the areas between the upper and lower diaphragm seals **106** and **108**. The pressures inside the system then tend to equalize.

The gas in the piston chamber **134** is now free to escape through the restricted exhaust port **126** and into the atmosphere. At the same time, the spring **117** forces the piston **112** upwardly, thus maintaining a back pressure on the lower diaphragm **108** and thus holding the spool **104** against the seal **122**. This continues until the upper region **120** of the output shaft **116** contacts the spool **104**. Once this contact occurs, the action of the spring **117** maintains the spool **104** against the seal **122**. An intermediate step is shown in FIG. 27, and the final step is shown in FIG. 28. When the system reaches the position shown in FIG. 28, it is ready for another firing operation. It should be noted that in FIG. 28, all regions of the mechanism but for the inlet port **102** are held at atmospheric pressure. The notch **121** on the member **120** allows chamber **132** to communicate with the exhaust port **126**, notwithstanding the contact between element **120** and the port **110**.

The vent **124**, communicating with the vent chamber **128**, is provided to ensure that sluggish operation of the spool and pistons is prevented. In this manner, no pressure buildup occurs between diaphragms **106** and **108**.

With particular reference, now, to FIG. 2 and FIGS. 29 through 35, the construction and operation of the gearbox will be explained. As best seen in FIG. 2, the rear portion of the driving member **28** is fitted with a yolk **150** adapted to be engaged by the forward end of the output shaft **116**. When the power unit **17** is fired, the output shaft **116**, the driving member **28** and the pusher element **54** are driven forward and effect the formation of a rectangular staple against the anvil **62**.

When the member **28** is thrust forward, the inclined surface **32**, integral with member **28**, moves forward and engages the plunger **34**, which plunger **34** moves downwardly against the compression in the biasing spring **35**.

As is best shown in FIG. 2, the front surface of the plunger **34** is provided with a notch **152**, which notch engages a flange **154** fitted on the bottom of the rear surface of a triangular carrier plate **156**. Thus, when the member **28** is thrust forward and the inclined surface **32** engages the plunger **34**, the notch **152** in the plunger **34** causes the triangular carrier plate **156** to move downwardly due to the interaction between the notch **152** and the flange **154**. In FIG. 34, it can be seen that the flange **154** extends a substantial distance across the triangular carrier plate **156**, which carrier plate **156** is adapted to pivot at **157**. This arrangement is further shown in FIG. 35 where there are also shown a pair of pins **161** and **163**, mounted in the plunger **34**, which pins serve to prevent wear on the flange **154** of the triangular carrier plate **156**.

In FIGS. 2 and 33, the relative positions of the plunger **34** and the triangular carrier plate **156** are shown when the driving member **28** is out of engagement with the plunger **34**. FIG. 34 shows the relative positions of these elements when the plunger **34** engages the inclined surface 32 on the driving member 28 during the stapling operation. When comparing FIGS. 33 and 34, then, it is readily seen that when the plunger 34 moves downwardly, the carrier plate 156 pivots in a counterclockwise direction around its pivot point 157.

With continuing reference to FIG. 33, a pawl 158 is shown mounted on the triangular carrier plate 156 by means of a pivot pin 160. The forwardmost surface of the pawl 158 is adapted to engage the surface of a six-toothed ratchet 159. It is seen, though, that in its rest position, the pawl 158 is out of engagement with the teeth of the ratchet 159. The movement of the pawl 158 is restricted by a pin 162, mounted on the rear surface of the pawl and extending through a hole 164 in the carrier plate 156. A second pawl 168 is pivotally mounted on a pin 170 secured to the housing of the gearbox and thus independent of both the carrier plate 156 and the pawl 158. Pawls 158 and 168 are, however, biased towards the ratchet 159 by means of a spring 166. Spring 166 may be replaced by a pair of tension springs (not shown) mounted on the respective pivot pins of the pawl 158 and 168. Pawl 168 serves as a stop member for limiting the rotation of the ratchet 159.

On the lower portion of the carrier plate 156 is an extension carrying a pin 172. Pin 172 extends forwardly a distance sufficient to engage a depression in a clover-shaped cam 174 which serves to positively position the elements of the gearbox when the instrument is in its readiness mode.

With reference to FIG. 32, a main drive gear 176 is shown to be mounted on the same axis that carries the ratchet 159 and the cam 174. These elements move together and in unison. FIG. 31 shows that the main drive gear 176 engages two pinion gears 180, the ratio between the main drive gear 176 and the pinion gears 180 being 6 to 1. In this manner, when the ratchet 159 is turned through the rotation necessary to move from one tooth to the next, each pinion gear 180 turns one complete revolution.

Each pinion gear 180 is mounted on a shaft 181 which terminates in a slot 183. Each slot 183 is adapted to engage a respective extension 60 integral with each screw 46. In this manner, when the pinion gear turns through one revolution, the staples are driven forward one "staple unit."

With particular reference, now, to FIGS. 33 through 35, the operation of the gearbox will be described. Prior to firing the skin stapler (FIG. 33), the driving member 28 is in its rearwardmost position. The plunger 34, with its notch 152, is in its upper position, biased by the spring 35. Thus, the carrier plate 156 is in its full clockwise position, pawl 168 being in engagement with a tooth on the rachet 159. The driving region of pawl 158 is removed from the nearest tooth on the ratchet 159 to allow for slight "play" in the plate 156 before the ratchet 159 is rotated. This allows the pin 172 to disengage from the depression in the cam 174.

When the driving member 28 moves forward, during a stapling operation, plunger 34 moves down against the force of the spring 35. During the downward movement of the plunger 34, the carrier plate 156 rotates in a counter-clockwise direction about its pivot point 157, pawl 158 rotating the ratchet 159.

In FIG. 34, the elements of the gearbox are shown after the pawl 158 has rotated the ratchet 159 through its maximum angle. This maximum angle is greater than that needed to advance each staple one staple unit. Thus, the gearbox elements are overdriven.

In FIG. 35, the gearbox elements are shown in their overdriven condition, but after the plunger 32 is partially raised due to the member 28 having moved rearwardly for part of its return stroke.

The gearbox operation will now be described. In FIG. 33, the gears are at rest, the member 28 retracted and waiting for an activating charge. The pin 172 is in engagement with a depression in the cam 174 and thus the ratchet 159, the main gear 176 and the pinion gears 180 are locked in place. In this position, the slots 183 are aligned as shown in FIGS. 29 and 30 to allow for the easy insertion or removal of a staple-carrying cartridge.

When the powering unit is fired, the driving member is thrust forward and its inclined surface 32 moves plunger 34 downward. Plunger 34 carries with it plate 156 which rotates in a counter-clockwise direction.

During the first stage of movement, no gears turn. The play between pawl 158 and the nearest tooth in the ratchet 159 allows the pin 172 to move out of the depression in cam 174 before gear rotation. The necessity for this is obvious. Then pawl 158 engages a tooth on the ratchet 174 and rotates the ratchet, the main gear 176 and the pinion gears 180 to the positions shown in FIG. 34.

In the position shown in FIG. 34, the gears are over-indexed. That is, they are driven more than is necessary to move the staples one staple unit. This is done to ensure that the slots 183 associated with pinion gears 180 are in proper alignment for insertion or removal of a cartridge.

After the stapling operation, member 28 moves rearwardly, thus allowing the plunger 34 to ride upwardly on the incline 32. This moves the plate 156 and hence the pin 172 into the position shown in FIG. 35 with the pin 172 moving toward the surface of the cam 174. From this position, the spring 35 urges the pin 172 against the surface of the cam 174 with the pin coming into contact with the cam at one of its depressions. Because of the stopping position of this cam, the action of the pin 172 rotates cam 174 in a clockwise direction. This rotation continues until the gear mechanism is in the position shown in FIG. 33, in readiness for another stapling maneuver.

With reference, now, to FIG. 36, a second embodiment of the main body portion of the inventive skin stapler will be described. The main body portion is shown generally at 200 and comprises a region 202 for mounting the cartridge 12 described above with reference to FIGS. 3 through 13. A cam 204, similar to the cam 22 shown in FIG. 2, is provided. The main body portion 200 has a handle region 206 and a trigger 208. A region 210 serves to house a power unit identical with that described in FIGS. 23 through 28.

The handle 206 is threaded at the extremity thereof and is fitted with a plug 214. A pressurized cartridge 216 is filled with a gas such as carbon dioxide and held in the handle 206, and its charge is fed to the powering unit 210 by means of a passage 218, which passage terminates in a chamber 220, similar to the gas inlet port 202 shown in FIG. 23.

The trigger 208 is similar to the triggering mechanism 136 shown in FIG. 24. Therefore, when the trigger 208 is depressed, the output shaft of the power unit is moved slightly so as to initiate the power stroke necessary to drive and form a staple.

When the surgeon uses the instrument **200**, all four fingers of one hand wrap around the handle **206** with the thumb of that hand resting against trigger **208**. The anvil of the staple-carrying cartridge **12** is pressed against the region of the body to be stapled and the trigger **208** is depressed. The power stroke is initiated, the staple is formed and the unit is then removed from the stapled area and moved to the next area where it is desired to position a staple. The operation is repeated until the incision is completely sutured.

FIG. 37 is a cross-section viewed in the direction of arrows 37—37 of FIG. 36. From this Figure, it is evident that the passage **218** communicates with the forwardmost bore in the handle **206** at a position removed from the center thereof. The off-center position is to ensure that the gas passage is not blocked by any portion of the gas cartridge or the cartridge-piercing mechanism.

In FIGS. **36** and **37**, it can be seen that the handle **206** is fitted with a bore **222** adapted to house the gas cartridge **216** and a bore **224** serving to mount the cartridge-piercing mechanism described below. Bores **222** and **224** are communicated by means of a sloped wall.

As indicated above, it has been found that when gas-powering units have been used in the past, the pin which serves to pierce the gas cartridge tends to wear rapidly. As also noted above, it is contemplated that a loaded and sterilized staple-carrying cartridge be packaged with a filled and sterilized gas-containing cartridge. To overcome the drawbacks noted above, a piercing mechanism which is simple in design and inexpensive in cost is fitted on a gas cartridge and is adapted to break the seal of the gas cartridge when same is positioned within the handle **206** of the instrument **200** and screwed into place by means of the plug **214**.

With reference, now, to FIGS. 38 and 39, the novel cartridge-piercing mechanism will be described. A bottle containing a pressurized gas such as carbon dioxide is shown at **216**. The mouth of the bottle **216** is fitted with a conventional seal **226**. A cap **228** is positioned over the mouth of the bottle **216** and an O-ring **230** serves to seal the joint between the bottle **216** and the cap **228**. When packaged and ready for use, a pin shown generally at **232** is positioned between an inwardly directed flange **234** on the cap **228** and the seal **226** of the bottle **216**. The pin **232** comprises a main body region, a pointed region **238** and an end region **240**. The end region **240** is fitted with a slot **242** extending entirely thereacross. A passage **246** passes from the extremity of the pin **238** to the extremity of the slot **242**.

As seen in FIGS. **36** and **38**, when the plug **214** is screwed into the handle **206**, the bottle **216** is urged to move toward the base **244** of the bore **224**. When this takes place, region **240** abuts the base **244** and thus the pointed region **238** of the pin **232** pierces the seal **226** of the bottle **216**. Gas from the bottle **216** is thus forced through the passage **246**, out of the slot **242** and into the chamber defined by the bore **224**.

The cap **228** has a thin extension **248** which is flexible and which comfortably rests against the wall of the core **224**. When the pressurized gas passes into the chamber defined by the bore **224**, it rushes into the region between the main body of the cap **228** and the extension **248**, thus forcing the extension **248** against the wall of the bore **224**. In this manner, the passage of gas is prevented from backing up into the handle **206**.

Above, there have been described specific embodiments of the present invention. It should be noted, however, that the above description was given for illustrative purposes only and that many alterations and modifications may be practiced by those skilled in the art without departing from the spirit or the scope of the invention. It is the intent therefore that the present invention not be limited to the above but be limited only as defined in the appended claims.

What is claimed is:

1. A gas-powered driving unit for converting gas pressure into a single forward thrust and for then returning to its static readiness position, the unit comprising: a body defining a plurality of chambers including an inlet chamber and a piston chamber; an inlet port in said body for the introduction of pressurized gas into said body; a piston mounted to reciprocate between a forward and returned position in said piston chamber; spool valve means intermediate said inlet port and said piston for sealing said inlet port, said spool valve means mounted to reciprocate in said body into and away from sealing engagement with said inlet port and away from and into sealing engagement with said piston chamber; biasing means for urging said piston towards said inlet port, said biasing means further biasing said spool valve means via said piston into sealing engagement with said inlet port when said piston reciprocates to its return position; sealing means connected to said spool means and defining said inlet chamber between said sealing means and said inlet port; the area of said spool valve means exposed to said piston chamber and the area of said spool valve means and said sealing means in the inlet chamber when said spool valve means is in sealing engagement with said piston chamber being such that equal pressure in both said chambers urges the spool means towards said inlet port: a transfer port through said spool valve means communicating between said inlet chamber and said piston chamber; a seal connected to said piston for preventing the passage of pressurized gas past said piston and out of said piston chamber; exhaust means for relieving pressure from said piston chamber for permitting the return stroke of said piston; and triggering means connected to said body for overcoming the bias imparted to said spool valve means by said biasing means so that the gas pressure in said inlet port can be introduced into said inlet chamber and thence through the transfer port to the piston chamber to cause said piston to reciprocate to its forward position, and further so that when pressure substantially equalizes in said piston chamber and said inlet chamber via said transfer port, said spool means moves into sealing engagement with said inlet port whereupon the gas pressure in said piston chamber is relieved and said biasing means moves said piston back to its return position.

2. The unit as defined in claim **1** wherein said transfer port is of a small orifice size so that a finite period of time elapses between the time when said spool valve means moves out of sealing engagement with said inlet port and the time when enough pressurized gas flows through said transfer port to equalize the pressure in said inlet chamber and said piston chamber, said finite time period being sufficiently long to enable the piston to substantially move from its return position to its forward position under the influence of the gas pressure in the piston chamber.

3. The unit of claim **1** wherein said exhaust means is an exhaust port communicating on one side with said transfer port and said piston chamber during the return stroke of said piston and on its other side with the atmosphere.

4. The unit as defined in claim **3** wherein said exhaust port is of a small orifice size so that the pressure of the gas in said piston chamber remains high enough to move said spool valve into sealing engagement with said inlet port and keep said spool valve in sealing engagement with said inlet port until said piston means

returns to its return position so that said biasing means can then urge said spool valve means into sealing engagement with said inlet port via said piston.

5. The unit as defined in claim **3** wherein said sealing means includes first and second seals which define a chamber therebetween, said body having a vent port communicating on one side with said chamber intermediate said first and second seals and on its other side with the atmosphere.

6. The unit as defined in claim **1** wherein said piston means comprises a piston and an output shaft integral therewith.

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