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(54) **DETACHABLE MOTOR POWERED
SURGICAL INSTRUMENT**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

66,052 A 6/1867 Smith
662,587 A 11/1900 Blake

(Continued)

FOREIGN PATENT DOCUMENTS

AU 2008207624 A1 3/2009
AU 2010214687 A1 9/2010

(Continued)

OTHER PUBLICATIONS

U.S. Appl. No. 14/459,485, filed Aug. 14, 2014.

(Continued)

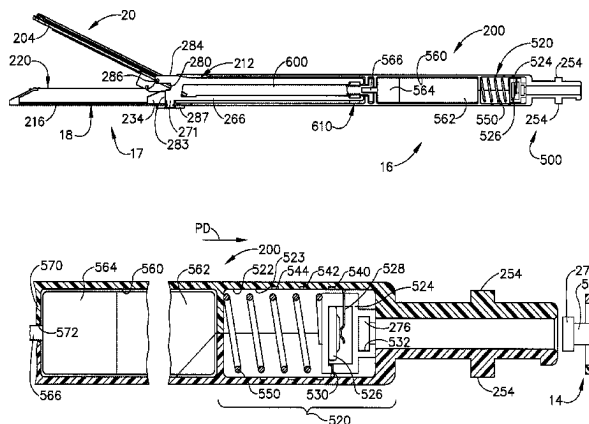
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(57)

ABSTRACT

A detachable motor-powered surgical instrument is dis-
closed. The instrument may include a housing that includes at
least one engagement member for removably attaching the
housing to an actuator arrangement. A motor is supported
within the housing for supplying actuation motions to various
portions of a surgical end effector coupled to the housing. The
housing may include a contact arrangement that is configured
to permit power to be supplied to the motor only when the
housing is operably attached to the actuator arrangement.

18 Claims, 95 Drawing Sheets



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(56) References Cited

U.S. PATENT DOCUMENTS

670,748 A 3/1901 Weddeler
951,393 A 3/1910 Hahn
1,306,107 A 6/1919 Elliott
1,314,601 A 9/1919 McCaskey
1,677,337 A 7/1928 Grove
2,037,727 A 4/1936 La Chapelle
2,132,295 A 10/1938 Hawkins
2,161,632 A 6/1939 Nattenheimer
2,211,117 A 8/1940 Hess
2,214,870 A 9/1940 West
2,441,096 A 5/1948 Happe
2,526,902 A 10/1950 Rublee
2,674,149 A 4/1954 Benson
2,804,848 A 9/1957 O'Farrell et al.
2,808,482 A 10/1957 Zanichkowsky et al.
2,853,074 A 9/1958 Olson
2,959,974 A 11/1960 Emrick
3,032,769 A 5/1962 Palmer
3,075,062 A 1/1963 Iaccarino
3,078,465 A 2/1963 Bobrov
3,079,606 A 3/1963 Bobrov et al.
3,166,072 A 1/1965 Sullivan, Jr.
3,196,869 A 7/1965 Scholl
3,266,494 A 8/1966 Brownrigg et al.
3,269,630 A 8/1966 Fleischer
3,275,211 A 9/1966 Hirsch et al.
3,317,103 A 5/1967 Cullen et al.
3,317,105 A 5/1967 Astafjev et al.
3,357,296 A 12/1967 Lefever
3,490,675 A 1/1970 Green et al.
3,494,533 A 2/1970 Green et al.
3,499,591 A 3/1970 Green
3,551,987 A 1/1971 Wilkinson
3,572,159 A 3/1971 Tschanz
3,598,943 A 8/1971 Barrett
3,643,851 A 2/1972 Green et al.
3,662,939 A 5/1972 Bryan
3,717,294 A 2/1973 Green
3,734,207 A 5/1973 Fishbein
3,740,994 A 6/1973 DeCarlo, Jr.

3,744,495 A 7/1973 Johnson
3,746,002 A 7/1973 Haller
3,751,902 A 8/1973 Kingsbury et al.
3,819,100 A 6/1974 Noiles et al.
3,821,919 A 7/1974 Knohl
3,841,474 A 10/1974 Maier
3,851,196 A 11/1974 Hinds
3,885,491 A 5/1975 Curtis
3,892,228 A 7/1975 Mitsui
3,894,174 A 7/1975 Cartun
3,940,844 A 3/1976 Colby et al.
3,955,581 A 5/1976 Spasiano et al.
RE28,932 E 8/1976 Noiles et al.
3,981,051 A 9/1976 Brumlik
4,054,108 A 10/1977 Gill
4,060,089 A 11/1977 Noiles
4,106,446 A 8/1978 Yamada et al.
4,111,206 A 9/1978 Vishnevsky et al.
4,129,059 A 12/1978 Van Eck
4,169,990 A 10/1979 Lerdman
4,198,734 A 4/1980 Brumlik
4,198,982 A 4/1980 Fortner et al.
4,207,898 A 6/1980 Becht
4,213,562 A 7/1980 Garrett et al.
4,226,242 A 10/1980 Jarvik
4,244,372 A 1/1981 Kapitanov et al.
4,250,436 A 2/1981 Weissman
4,261,244 A 4/1981 Becht et al.
4,272,002 A 6/1981 Moshofsky
4,272,662 A 6/1981 Simpson
4,275,813 A 6/1981 Noiles
4,289,133 A 9/1981 Rothfuss
4,305,539 A 12/1981 Korolkov et al.
4,312,685 A 1/1982 Riedl
4,317,451 A 3/1982 Cerwin et al.
4,321,002 A 3/1982 Froehlich
4,328,839 A 5/1982 Lyons et al.
4,331,277 A 5/1982 Green
4,340,331 A 7/1982 Savino
4,347,450 A 8/1982 Colligan
4,349,028 A 9/1982 Green
4,353,371 A 10/1982 Cosman
4,379,457 A 4/1983 Gravener et al.
4,380,312 A 4/1983 Landrus
4,382,326 A 5/1983 Rabuse
4,383,634 A 5/1983 Green
4,393,728 A 7/1983 Larson et al.
4,396,139 A 8/1983 Hall et al.
4,397,311 A 8/1983 Kanshin et al.
4,402,445 A 9/1983 Green
4,408,692 A 10/1983 Siegel et al.
4,409,057 A 10/1983 Molenda et al.
4,415,112 A 11/1983 Green
4,416,276 A 11/1983 Newton et al.
4,428,376 A 1/1984 Mericle
4,429,695 A 2/1984 Green
4,434,796 A 3/1984 Karapetian et al.
4,438,659 A 3/1984 Desplats
4,442,964 A 4/1984 Becht
4,451,743 A 5/1984 Suzuki et al.
4,454,887 A 6/1984 Krüger
4,467,805 A 8/1984 Fukuda
4,473,077 A 9/1984 Noiles et al.
4,475,679 A 10/1984 Fleury, Jr.
4,485,816 A 12/1984 Krumme
4,486,928 A 12/1984 Tucker et al.
4,488,523 A 12/1984 Shichman
4,489,875 A 12/1984 Crawford et al.
4,500,024 A 2/1985 DiGiovanni et al.
4,505,272 A 3/1985 Utyamyshev et al.
4,505,273 A 3/1985 Braun et al.
4,505,414 A 3/1985 Filipi
4,506,671 A 3/1985 Green
4,520,817 A 6/1985 Green
4,522,327 A 6/1985 Korthoff et al.
4,526,174 A 7/1985 Froehlich
4,527,724 A 7/1985 Chow et al.
4,530,453 A 7/1985 Green
4,531,522 A 7/1985 Bedi et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

4,532,927 A	8/1985	Mikszs, Jr.	4,873,977 A	10/1989	Avant et al.
4,548,202 A	10/1985	Duncan	4,880,015 A	11/1989	Nierman
4,565,109 A	1/1986	Tsay	4,890,613 A	1/1990	Golden et al.
4,565,189 A	1/1986	Mabuchi	4,892,244 A	1/1990	Fox et al.
4,566,620 A	1/1986	Green et al.	4,893,622 A	1/1990	Green et al.
4,571,213 A	2/1986	Ishimoto	4,896,678 A	1/1990	Ogawa
4,573,468 A	3/1986	Conta et al.	4,903,697 A	2/1990	Resnick et al.
4,573,469 A	3/1986	Golden et al.	4,915,100 A	4/1990	Green
4,573,622 A	3/1986	Green et al.	4,930,503 A	6/1990	Pruitt
4,576,167 A	3/1986	Noiles et al.	4,930,674 A	6/1990	Barak
4,580,712 A	4/1986	Green	4,931,047 A	6/1990	Broadwin et al.
4,585,153 A	4/1986	Failla et al.	4,932,960 A	6/1990	Green et al.
4,589,416 A	5/1986	Green	4,938,408 A	7/1990	Bedi et al.
4,591,085 A	5/1986	Di Giovanni	4,941,623 A	7/1990	Pruitt
4,600,037 A	7/1986	Hatten	4,944,443 A	7/1990	Oddsens et al.
4,604,786 A	8/1986	Howie, Jr.	4,955,959 A	9/1990	Tompkins et al.
4,605,001 A	8/1986	Rothfuss et al.	4,965,709 A	10/1990	Ngo
4,605,004 A	8/1986	Di Giovanni et al.	4,973,274 A	11/1990	Hirukawa
4,606,343 A	8/1986	Conta et al.	4,978,049 A	12/1990	Green
4,607,638 A	8/1986	Crainich	4,978,333 A	12/1990	Broadwin et al.
4,608,981 A	9/1986	Rothfuss et al.	4,986,808 A	1/1991	Broadwin et al.
4,610,250 A	9/1986	Green	4,988,334 A	1/1991	Hornlein et al.
4,610,383 A	9/1986	Rothfuss et al.	5,002,543 A	3/1991	Bradshaw et al.
4,619,262 A	10/1986	Taylor	5,002,553 A	3/1991	Shiber
4,619,391 A	10/1986	Sharkany et al.	5,009,661 A	4/1991	Michelson
4,629,107 A	12/1986	Fedotov et al.	5,014,899 A	5/1991	Presty et al.
4,632,290 A	12/1986	Green et al.	5,015,227 A	5/1991	Broadwin et al.
4,633,874 A	1/1987	Chow et al.	5,024,671 A	6/1991	Tu et al.
4,634,419 A	1/1987	Kreizman et al.	5,027,834 A	7/1991	Pruitt
4,641,076 A	2/1987	Linden	5,031,814 A	7/1991	Tompkins et al.
4,646,722 A	3/1987	Silverstein et al.	5,038,109 A	8/1991	Goble et al.
4,655,222 A	4/1987	Florez et al.	5,040,715 A	8/1991	Green et al.
4,662,555 A	5/1987	Thornton	5,042,707 A	8/1991	Taheri
4,663,874 A	5/1987	Sano et al.	5,061,269 A	10/1991	Muller
4,664,305 A	5/1987	Blake, III et al.	5,062,563 A	11/1991	Green et al.
4,665,916 A	5/1987	Green	5,065,929 A	11/1991	Schulze et al.
4,667,674 A	5/1987	Korthoff et al.	5,071,052 A	12/1991	Rodak et al.
4,669,647 A	6/1987	Storace	5,071,430 A	12/1991	de Salis et al.
4,671,445 A	6/1987	Barker et al.	5,074,454 A	12/1991	Peters
4,676,245 A	6/1987	Fukuda	5,080,556 A	1/1992	Carreno
4,684,051 A	8/1987	Akopov et al.	5,083,695 A	1/1992	Foslien et al.
4,693,248 A	9/1987	Failla	5,084,057 A	1/1992	Green et al.
4,708,141 A	11/1987	Inoue et al.	5,088,979 A	2/1992	Filipi et al.
4,709,120 A	11/1987	Pearson	5,088,997 A	2/1992	Delahuerga et al.
4,715,520 A	12/1987	Roehr, Jr. et al.	5,094,247 A	3/1992	Hernandez et al.
4,719,917 A	1/1988	Barrows et al.	5,100,420 A	3/1992	Green et al.
4,727,308 A	2/1988	Huljak et al.	5,104,025 A	4/1992	Main et al.
4,728,020 A	3/1988	Green et al.	5,104,397 A	4/1992	Vasconcelos et al.
4,728,876 A	3/1988	Mongeon et al.	5,106,008 A	4/1992	Tompkins et al.
4,729,260 A	3/1988	Dudden	5,111,987 A	5/1992	Moeinzadeh et al.
4,730,726 A	3/1988	Holzwarth	5,116,349 A	5/1992	Aranyi
4,741,336 A	5/1988	Failla et al.	5,122,156 A	6/1992	Granger et al.
4,743,214 A	5/1988	Tai-Cheng	5,129,570 A	7/1992	Schulze et al.
4,747,820 A	5/1988	Hornlein et al.	5,137,198 A	8/1992	Nobis et al.
4,750,902 A	6/1988	Wuchinich et al.	5,139,513 A	8/1992	Segato
4,752,024 A	6/1988	Green et al.	5,141,144 A	8/1992	Foslien et al.
4,754,909 A	7/1988	Barker et al.	5,142,932 A	9/1992	Moya et al.
4,767,044 A	8/1988	Green	5,155,941 A	10/1992	Takahashi et al.
4,773,420 A	9/1988	Green	5,156,315 A	10/1992	Green et al.
4,777,780 A	10/1988	Holzwarth	5,156,609 A	10/1992	Nakao et al.
4,787,387 A	11/1988	Burbank, III et al.	5,156,614 A	10/1992	Green et al.
4,790,225 A	12/1988	Moody et al.	5,158,567 A	10/1992	Green
4,805,617 A	2/1989	Bedi et al.	D330,699 S	11/1992	Gill
4,805,823 A	2/1989	Rothfuss	5,163,598 A	11/1992	Peters et al.
4,809,695 A	3/1989	Gwathmey et al.	5,171,247 A	12/1992	Hughett et al.
4,817,847 A	4/1989	Redtenbacher et al.	5,171,249 A	12/1992	Stefanchik et al.
4,819,853 A	4/1989	Green	5,171,253 A	12/1992	Klieman et al.
4,821,939 A	4/1989	Green	5,188,111 A	2/1993	Yates et al.
4,827,911 A	5/1989	Broadwin et al.	5,190,517 A	3/1993	Zieve et al.
4,834,720 A	5/1989	Blinkhorn	5,192,288 A	3/1993	Thompson et al.
4,844,068 A	7/1989	Arata et al.	5,195,968 A	3/1993	Lundquist et al.
4,848,637 A	7/1989	Pruitt	5,197,648 A	3/1993	Gingold
4,865,030 A	9/1989	Polyak	5,200,280 A	4/1993	Karasa
4,869,414 A	9/1989	Green et al.	5,205,459 A	4/1993	Brinkerhoff et al.
4,869,415 A	9/1989	Fox	5,207,697 A	5/1993	Carusillo et al.
			5,209,747 A	5/1993	Knoepfler
			5,211,649 A	5/1993	Kohler et al.
			5,211,655 A	5/1993	Hasson
			5,217,457 A	6/1993	Delahuerga et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

5,217,478 A	6/1993	Rexroth	5,364,001 A	11/1994	Bryan
5,219,111 A	6/1993	Bilotti et al.	5,364,003 A	11/1994	Williamson, IV
5,221,036 A	6/1993	Takase	5,366,134 A	11/1994	Green et al.
5,221,281 A	6/1993	Kliceck	5,366,479 A	11/1994	McGarry et al.
5,222,963 A	6/1993	Brinkerhoff et al.	5,368,015 A	11/1994	Wilk
5,222,975 A	6/1993	Crainich	5,368,592 A	11/1994	Stern et al.
5,222,976 A	6/1993	Yoon	5,370,645 A	12/1994	Kliceck et al.
5,223,675 A	6/1993	Taft	5,372,596 A	12/1994	Kliceck et al.
5,234,447 A	8/1993	Kaster et al.	5,372,602 A	12/1994	Burke
5,236,440 A	8/1993	Hlavacek	5,374,277 A	12/1994	Hassler
5,239,981 A	8/1993	Anaplotis	5,376,095 A	12/1994	Ortiz
5,240,163 A	8/1993	Stein et al.	5,379,933 A	1/1995	Green et al.
5,242,457 A	9/1993	Akopov et al.	5,381,782 A	1/1995	DeLaRama et al.
5,244,462 A	9/1993	Delahuerga et al.	5,382,247 A	1/1995	Cimino et al.
5,246,156 A	9/1993	Rothfuss et al.	5,383,880 A	1/1995	Hooven
5,246,443 A	9/1993	Mai	5,383,881 A	1/1995	Green et al.
5,253,793 A	10/1993	Green et al.	5,383,888 A	1/1995	Zvenyatsky et al.
5,258,009 A	11/1993	Connors	5,383,895 A	1/1995	Holmes et al.
5,258,012 A	11/1993	Luscombe et al.	5,389,098 A	2/1995	Tsuruta et al.
5,259,366 A	11/1993	Reydel et al.	5,389,104 A	2/1995	Hahnen et al.
5,260,637 A	11/1993	Pizzi	5,391,180 A	2/1995	Tovey et al.
5,263,629 A	11/1993	Trumbull et al.	5,392,979 A	2/1995	Green et al.
5,263,973 A	11/1993	Cook	5,395,030 A	3/1995	Kuramoto et al.
5,268,622 A	12/1993	Philipp	5,395,033 A	3/1995	Byrne et al.
5,271,543 A	12/1993	Grant et al.	5,395,034 A	3/1995	Allen et al.
5,271,544 A	12/1993	Fox et al.	5,395,312 A	3/1995	Desai
RE34,519 E	1/1994	Fox et al.	5,395,384 A	3/1995	Duthoit
5,275,323 A	1/1994	Schulze et al.	5,397,046 A	3/1995	Savage et al.
5,275,608 A	1/1994	Forman et al.	5,397,324 A	3/1995	Carroll et al.
5,279,416 A	1/1994	Malec et al.	5,403,312 A	4/1995	Yates et al.
5,281,216 A	1/1994	Kliceck	5,405,072 A	4/1995	Zlock et al.
5,282,806 A	2/1994	Haber et al.	5,405,073 A	4/1995	Porter
5,282,829 A	2/1994	Hermes	5,405,344 A	4/1995	Williamson et al.
5,284,128 A	2/1994	Hart	5,405,360 A	4/1995	Tovey
5,285,945 A	2/1994	Brinkerhoff et al.	5,407,293 A	4/1995	Crainich
5,289,963 A	3/1994	McGarry et al.	5,409,498 A	4/1995	Braddock et al.
5,297,714 A	3/1994	Kramer	5,411,508 A	5/1995	Bessler et al.
5,304,204 A	4/1994	Bregen	5,413,267 A	5/1995	Solyntjes et al.
5,307,976 A	5/1994	Olson et al.	5,413,268 A	5/1995	Green et al.
5,309,927 A	5/1994	Welch	5,413,272 A	5/1995	Green et al.
5,312,023 A	5/1994	Green et al.	5,413,573 A	5/1995	Koivukangas
5,312,024 A	5/1994	Grant et al.	5,415,334 A	5/1995	Williamson, IV et al.
5,312,329 A	5/1994	Beaty et al.	5,415,335 A	5/1995	Knodell, Jr.
5,314,424 A	5/1994	Nicholas	5,417,203 A	5/1995	Tovey et al.
5,314,445 A	5/1994	Heidmueller et al.	5,417,361 A	5/1995	Williamson, IV
5,318,221 A	6/1994	Green et al.	5,421,829 A	6/1995	Olichney et al.
5,330,487 A	7/1994	Thornton et al.	5,422,567 A	6/1995	Matsunaga
5,330,502 A	7/1994	Hassler et al.	5,423,471 A	6/1995	Mastri et al.
5,332,142 A	7/1994	Robinson et al.	5,423,809 A	6/1995	Kliceck
5,333,422 A	8/1994	Warren et al.	5,425,745 A	6/1995	Green et al.
5,333,772 A	8/1994	Rothfuss et al.	5,431,322 A	7/1995	Green et al.
5,334,183 A	8/1994	Wuchinich	5,431,654 A	7/1995	Nic
5,336,232 A	8/1994	Green et al.	5,431,668 A	7/1995	Burbank, III et al.
5,339,799 A	8/1994	Kami et al.	5,433,721 A	7/1995	Hooven et al.
5,341,724 A	8/1994	Vatel	5,437,681 A	8/1995	Meade et al.
5,341,810 A	8/1994	Dardel	5,438,302 A	8/1995	Goble
5,342,381 A	8/1994	Tidemand	5,439,155 A	8/1995	Viola
5,342,395 A	8/1994	Jarrett et al.	5,439,156 A	8/1995	Grant et al.
5,342,396 A	8/1994	Cook	5,439,479 A	8/1995	Shichman et al.
5,344,060 A	9/1994	Gravener et al.	5,441,191 A	8/1995	Linden
5,346,504 A	9/1994	Ortiz et al.	5,441,193 A	8/1995	Gravener
5,348,259 A	9/1994	Blanco et al.	5,441,483 A	8/1995	Avitall
5,350,388 A	9/1994	Epstein	5,441,494 A	8/1995	Ortiz
5,350,391 A	9/1994	Iacovelli	5,445,155 A	8/1995	Sieben
5,350,400 A	9/1994	Esposito et al.	5,445,304 A	8/1995	Plyley et al.
5,352,229 A	10/1994	Goble et al.	5,445,644 A	8/1995	Pietrafitta et al.
5,352,235 A	10/1994	Koros et al.	5,447,417 A	9/1995	Kuhl et al.
5,352,238 A	10/1994	Green et al.	5,447,513 A	9/1995	Davison et al.
5,354,303 A	10/1994	Spaeth et al.	5,449,355 A	9/1995	Rhum et al.
5,356,006 A	10/1994	Alpern et al.	5,449,365 A	9/1995	Green et al.
5,358,506 A	10/1994	Green et al.	5,449,370 A	9/1995	Vaitekunas
5,358,510 A	10/1994	Luscombe et al.	5,452,836 A	9/1995	Huitema et al.
5,359,231 A	10/1994	Flowers et al.	5,452,837 A	9/1995	Williamson, IV et al.
D352,780 S	11/1994	Glaeser et al.	5,454,378 A	10/1995	Palmer et al.
5,360,428 A	11/1994	Hutchinson, Jr.	5,454,827 A	10/1995	Aust et al.
			5,456,401 A	10/1995	Green et al.
			5,458,579 A	10/1995	Chodorow et al.
			5,462,215 A	10/1995	Viola et al.
			5,464,013 A	11/1995	Lemelson

(56)

References Cited

U.S. PATENT DOCUMENTS

5,464,144	A	11/1995	Guy et al.	5,556,416	A	9/1996	Clark et al.
5,464,300	A	11/1995	Crainich	5,558,665	A	9/1996	Kieturakis
5,465,894	A	11/1995	Clark et al.	5,558,671	A	9/1996	Yates
5,465,895	A	11/1995	Knodel et al.	5,560,530	A	10/1996	Bolanos et al.
5,465,896	A	11/1995	Allen et al.	5,560,532	A	10/1996	DeFonzo et al.
5,466,020	A	11/1995	Page et al.	5,562,239	A	10/1996	Boiarski et al.
5,467,911	A	11/1995	Tsuruta et al.	5,562,241	A	10/1996	Knodel et al.
5,468,253	A	11/1995	Bezwada et al.	5,562,682	A	10/1996	Oberlin et al.
5,470,006	A	11/1995	Rodak	5,562,690	A	10/1996	Green et al.
5,470,007	A	11/1995	Plyley et al.	5,562,701	A	10/1996	Huitema et al.
5,470,009	A	11/1995	Rodak	5,562,702	A	10/1996	Huitema et al.
5,470,010	A	11/1995	Rothfuss et al.	5,564,615	A	10/1996	Bishop et al.
5,472,132	A	12/1995	Savage et al.	5,569,161	A	10/1996	Ebling et al.
5,472,442	A	12/1995	Klicek	5,569,270	A	10/1996	Weng
5,473,204	A	12/1995	Temple	5,569,284	A	10/1996	Young et al.
5,474,057	A	12/1995	Makower et al.	5,571,090	A	11/1996	Sherts
5,474,566	A	12/1995	Alesi et al.	5,571,100	A	11/1996	Goble et al.
5,476,206	A	12/1995	Green et al.	5,571,116	A	11/1996	Bolanos et al.
5,476,479	A	12/1995	Green et al.	5,571,285	A	11/1996	Chow et al.
5,478,003	A	12/1995	Green et al.	5,573,543	A	11/1996	Akopov et al.
5,478,354	A	12/1995	Tovey et al.	5,574,431	A	11/1996	McKeown et al.
5,480,089	A	1/1996	Blewett	5,575,054	A	11/1996	Klinzing et al.
5,480,409	A	1/1996	Riza	5,575,789	A	11/1996	Bell et al.
5,482,197	A	1/1996	Green et al.	5,575,799	A	11/1996	Bolanos et al.
5,484,095	A	1/1996	Green et al.	5,575,803	A	11/1996	Cooper et al.
5,484,398	A	1/1996	Stoddard	5,575,805	A	11/1996	Li
5,484,451	A	1/1996	Akopov et al.	5,577,654	A	11/1996	Bishop
5,485,947	A	1/1996	Olson et al.	5,579,978	A	12/1996	Green et al.
5,485,952	A	1/1996	Fontayne	5,580,067	A	12/1996	Hamblin et al.
5,487,499	A	1/1996	Sorrentino et al.	5,582,611	A	12/1996	Tsuruta et al.
5,487,500	A	1/1996	Knodel et al.	5,582,617	A	12/1996	Klieman et al.
5,489,058	A	2/1996	Plyley et al.	5,584,425	A	12/1996	Savage et al.
5,489,256	A	2/1996	Adair	5,586,711	A	12/1996	Plyley et al.
5,496,312	A	3/1996	Klicek	5,588,579	A	12/1996	Schnut et al.
5,496,317	A	3/1996	Goble et al.	5,588,580	A	12/1996	Paul et al.
5,497,933	A	3/1996	DeFonzo et al.	5,588,581	A	12/1996	Conlon et al.
5,503,320	A	4/1996	Webster et al.	5,591,170	A	1/1997	Spievack et al.
5,503,635	A	4/1996	Sauer et al.	5,591,187	A	1/1997	Dekel
5,503,638	A	4/1996	Cooper et al.	5,597,107	A	1/1997	Knodel et al.
5,505,363	A	4/1996	Green et al.	5,599,151	A	2/1997	Daum et al.
5,507,426	A	4/1996	Young et al.	5,599,344	A	2/1997	Paterson
5,509,596	A	4/1996	Green et al.	5,599,350	A	2/1997	Schulze et al.
5,509,916	A	4/1996	Taylor	5,601,224	A	2/1997	Bishop et al.
5,511,564	A	4/1996	Wilk	5,603,443	A	2/1997	Clark et al.
5,514,129	A	5/1996	Smith	5,605,272	A	2/1997	Witt et al.
5,514,157	A	5/1996	Nicholas et al.	5,605,273	A	2/1997	Hamblin et al.
5,518,163	A	5/1996	Hooven	5,607,094	A	3/1997	Clark et al.
5,518,164	A	5/1996	Hooven	5,607,095	A	3/1997	Smith et al.
5,520,678	A	5/1996	Heckele et al.	5,607,433	A	3/1997	Polla et al.
5,520,700	A	5/1996	Beyar et al.	5,607,450	A	3/1997	Zvenyatsky et al.
5,522,817	A	6/1996	Sander et al.	5,609,285	A	3/1997	Grant et al.
5,527,320	A	6/1996	Carruthers et al.	5,609,601	A	3/1997	Kolesa et al.
5,529,235	A	6/1996	Boiarski et al.	5,611,709	A	3/1997	McAnulty
D372,086	S	7/1996	Grasso et al.	5,613,966	A	3/1997	Makower et al.
5,531,744	A	7/1996	Nardella et al.	5,615,820	A	4/1997	Viola
5,533,521	A	7/1996	Granger	5,618,294	A	4/1997	Aust et al.
5,533,581	A	7/1996	Barth et al.	5,618,303	A	4/1997	Marlow et al.
5,533,661	A	7/1996	Main et al.	5,618,307	A	4/1997	Donlon et al.
5,535,934	A	7/1996	Boiarski et al.	5,619,992	A	4/1997	Guthrie et al.
5,535,935	A	7/1996	Vidal et al.	5,620,289	A	4/1997	Curry
5,535,937	A	7/1996	Boiarski et al.	5,620,452	A	4/1997	Yoon
5,540,375	A	7/1996	Bolanos et al.	5,624,452	A	4/1997	Yates
5,541,376	A	7/1996	Ladtchow et al.	5,626,587	A	5/1997	Bishop et al.
5,542,594	A	8/1996	McKean et al.	5,626,595	A	5/1997	Sklar et al.
5,542,949	A	8/1996	Yoon	5,628,446	A	5/1997	Geiste et al.
5,543,119	A	8/1996	Sutter et al.	5,628,743	A	5/1997	Cimino
5,547,117	A	8/1996	Hamblin et al.	5,628,745	A	5/1997	Bek
5,549,621	A	8/1996	Bessler et al.	5,630,539	A	5/1997	Plyley et al.
5,549,628	A	8/1996	Cooper et al.	5,630,540	A	5/1997	Blewett
5,549,637	A	8/1996	Crainich	5,630,541	A	5/1997	Williamson, IV et al.
5,551,622	A	9/1996	Yoon	5,630,782	A	5/1997	Adair
5,553,675	A	9/1996	Pitzen et al.	5,632,432	A	5/1997	Schulze et al.
5,553,765	A	9/1996	Knodel et al.	5,632,433	A	5/1997	Grant et al.
5,554,148	A	9/1996	Aebischer et al.	5,634,584	A	6/1997	Okorochoa et al.
5,554,169	A	9/1996	Green et al.	5,636,779	A	6/1997	Palmer
				5,636,780	A	6/1997	Green et al.
				5,639,008	A	6/1997	Gallagher et al.
				5,643,291	A	7/1997	Pier et al.
				5,645,209	A	7/1997	Green et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

5,647,526 A	7/1997	Green et al.	5,728,110 A	3/1998	Vidal et al.
5,647,869 A	7/1997	Goble et al.	5,728,121 A	3/1998	Bimbo et al.
5,649,937 A	7/1997	Bito et al.	5,730,758 A	3/1998	Allgeyer
5,651,491 A	7/1997	Heaton et al.	5,732,821 A	3/1998	Stone et al.
5,653,373 A	8/1997	Green et al.	5,732,871 A	3/1998	Clark et al.
5,653,374 A	8/1997	Young et al.	5,732,872 A	3/1998	Bolduc et al.
5,653,677 A	8/1997	Okada et al.	5,733,308 A	3/1998	Daugherty et al.
5,653,721 A	8/1997	Knodel et al.	5,735,445 A	4/1998	Vidal et al.
5,655,698 A	8/1997	Yoon	5,735,848 A	4/1998	Yates et al.
5,657,921 A	8/1997	Young et al.	5,735,874 A	4/1998	Measamer et al.
5,658,281 A	8/1997	Heard	5,738,474 A	4/1998	Blewett
5,658,300 A	8/1997	Bito et al.	5,738,648 A	4/1998	Lands et al.
5,658,307 A	8/1997	Exconde	5,743,456 A	4/1998	Jones et al.
5,662,258 A	9/1997	Knodel et al.	5,747,953 A	5/1998	Philipp
5,662,260 A	9/1997	Yoon	5,749,889 A	5/1998	Bacich et al.
5,662,662 A	9/1997	Bishop et al.	5,749,893 A	5/1998	Vidal et al.
5,665,085 A	9/1997	Nardella	5,752,644 A	5/1998	Bolanos et al.
5,667,517 A	9/1997	Hooven	5,752,965 A	5/1998	Francis et al.
5,667,526 A	9/1997	Levin	5,755,717 A	5/1998	Yates et al.
5,667,527 A	9/1997	Cook	5,758,814 A	6/1998	Gallagher et al.
5,669,544 A	9/1997	Schulze et al.	5,762,255 A	6/1998	Chrisman et al.
5,669,904 A	9/1997	Platt, Jr. et al.	5,762,256 A	6/1998	Mastri et al.
5,669,907 A	9/1997	Platt, Jr. et al.	5,766,188 A	6/1998	Igaki
5,669,918 A	9/1997	Balazs et al.	5,766,205 A	6/1998	Zvenyatsky et al.
5,673,840 A	10/1997	Schulze et al.	5,769,892 A	6/1998	Kingwell
5,673,841 A	10/1997	Schulze et al.	5,772,379 A	6/1998	Evensen
5,673,842 A	10/1997	Bittner et al.	5,772,578 A	6/1998	Heimberger et al.
5,674,286 A	10/1997	D'Alessio et al.	5,772,659 A	6/1998	Becker et al.
5,678,748 A	10/1997	Plyley et al.	5,776,130 A	7/1998	Buyse et al.
5,680,981 A	10/1997	Mililli et al.	5,779,130 A *	7/1998	Alesi et al. 227/176.1
5,680,982 A	10/1997	Schulze et al.	5,779,131 A	7/1998	Knodel et al.
5,680,983 A	10/1997	Plyley et al.	5,779,132 A	7/1998	Knodel et al.
5,683,349 A	11/1997	Makower et al.	5,782,396 A	7/1998	Mastri et al.
5,685,474 A	11/1997	Seeber	5,782,397 A	7/1998	Koukline
5,686,090 A	11/1997	Schilder et al.	5,782,749 A	7/1998	Riza
5,688,270 A	11/1997	Yates et al.	5,782,859 A	7/1998	Nicholas et al.
5,690,269 A	11/1997	Bolanos et al.	5,784,934 A	7/1998	Izumisawa
5,692,668 A	12/1997	Schulze et al.	5,785,232 A	7/1998	Vidal et al.
5,693,020 A	12/1997	Rauh	5,785,647 A	7/1998	Tompkins et al.
5,693,042 A	12/1997	Boiarski et al.	5,787,897 A	8/1998	Kieturakis
5,693,051 A	12/1997	Schulze et al.	5,792,135 A	8/1998	Madhani et al.
5,695,494 A	12/1997	Becker	5,792,165 A	8/1998	Klieman et al.
5,695,502 A	12/1997	Pier et al.	5,794,834 A	8/1998	Hamblin et al.
5,695,504 A	12/1997	Gifford, III et al.	5,796,188 A	8/1998	Bays
5,695,524 A	12/1997	Kelley et al.	5,797,536 A	8/1998	Smith et al.
5,697,543 A	12/1997	Burdorff	5,797,537 A	8/1998	Oberlin et al.
5,697,943 A	12/1997	Sauer et al.	5,797,538 A	8/1998	Heaton et al.
5,700,270 A	12/1997	Peyser et al.	5,797,906 A	8/1998	Rhum et al.
5,702,387 A	12/1997	Arts et al.	5,797,959 A	8/1998	Castro et al.
5,702,408 A	12/1997	Wales et al.	5,799,857 A	9/1998	Robertson et al.
5,702,409 A	12/1997	Rayburn et al.	5,800,379 A	9/1998	Edwards
5,704,087 A	1/1998	Strub	5,806,676 A	9/1998	Wasgien
5,704,534 A	1/1998	Huitema et al.	5,807,376 A	9/1998	Viola et al.
5,706,997 A	1/1998	Green et al.	5,807,378 A	9/1998	Jensen et al.
5,706,998 A	1/1998	Plyley et al.	5,807,393 A	9/1998	Williamson, IV et al.
5,707,392 A	1/1998	Kortenbach	5,809,441 A	9/1998	McKee
5,709,334 A	1/1998	Sorrentino et al.	5,810,721 A	9/1998	Mueller et al.
5,709,680 A	1/1998	Yates et al.	5,810,811 A	9/1998	Yates et al.
5,709,706 A	1/1998	Kienzle et al.	5,810,846 A	9/1998	Virnich et al.
5,711,472 A	1/1998	Bryan	5,810,855 A	9/1998	Rayburn et al.
5,713,128 A	2/1998	Schrenk et al.	5,813,813 A	9/1998	Daum et al.
5,713,505 A	2/1998	Huitema	5,814,055 A	9/1998	Knodel et al.
5,713,895 A	2/1998	Lontine et al.	5,814,057 A	9/1998	Oi et al.
5,713,896 A	2/1998	Nardella	5,816,471 A	10/1998	Plyley et al.
5,713,920 A	2/1998	Bezwada et al.	5,817,084 A	10/1998	Jensen
5,715,987 A	2/1998	Kelley et al.	5,817,091 A	10/1998	Nardella et al.
5,715,988 A	2/1998	Palmer	5,817,093 A	10/1998	Williamson, IV et al.
5,716,366 A	2/1998	Yates	5,817,109 A	10/1998	McGarry et al.
5,718,359 A	2/1998	Palmer et al.	5,817,119 A	10/1998	Klieman et al.
5,718,360 A	2/1998	Green et al.	5,820,009 A	10/1998	Melling et al.
5,718,548 A	2/1998	Cotellessa	5,823,066 A	10/1998	Huitema et al.
5,720,744 A	2/1998	Eggleston et al.	5,826,776 A	10/1998	Schulze et al.
D393,067 S	3/1998	Geary et al.	5,827,271 A	10/1998	Buyse et al.
5,725,536 A	3/1998	Oberlin et al.	5,827,298 A	10/1998	Hart et al.
5,725,554 A	3/1998	Simon et al.	5,829,662 A	11/1998	Allen et al.
			5,833,690 A	11/1998	Yates et al.
			5,833,695 A	11/1998	Yoon
			5,833,696 A	11/1998	Whitfield et al.
			5,836,503 A	11/1998	Ehrenfels et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

5,836,960	A	11/1998	Kolesa et al.	6,039,733	A	3/2000	Buyssse et al.
5,839,639	A	11/1998	Sauer et al.	6,039,734	A	3/2000	Goble
5,843,021	A	12/1998	Edwards et al.	6,042,601	A	3/2000	Smith
5,843,096	A	12/1998	Igaki et al.	6,045,560	A	4/2000	McKean et al.
5,843,122	A	12/1998	Riza	6,047,861	A	4/2000	Vidal et al.
5,843,132	A	12/1998	Ilvento	6,050,472	A	4/2000	Shibata
5,846,254	A	12/1998	Schulze et al.	6,050,990	A	4/2000	Tankovich et al.
5,849,011	A	12/1998	Jones et al.	6,050,996	A	4/2000	Schmaltz et al.
5,855,311	A	1/1999	Hamblin et al.	6,053,390	A	4/2000	Green et al.
5,855,583	A	1/1999	Wang et al.	6,053,922	A	4/2000	Krause et al.
5,860,581	A	1/1999	Robertson et al.	RE36,720	E	5/2000	Green et al.
5,860,975	A	1/1999	Goble et al.	6,056,735	A	5/2000	Okada et al.
5,865,361	A	2/1999	Milliman et al.	6,056,746	A	5/2000	Goble et al.
5,868,760	A	2/1999	McGuckin, Jr.	6,062,360	A	5/2000	Shields
5,871,135	A	2/1999	Williamson, IV et al.	6,063,097	A	5/2000	Oi et al.
5,873,885	A	2/1999	Weidenbenner	6,063,098	A	5/2000	Houser et al.
5,876,401	A	3/1999	Schulze et al.	6,065,919	A	5/2000	Peck
5,878,193	A	3/1999	Wang et al.	6,066,132	A	5/2000	Chen et al.
5,878,937	A	3/1999	Green et al.	6,068,627	A	5/2000	Orszulak et al.
5,878,938	A	3/1999	Bittner et al.	6,071,233	A	6/2000	Ishikawa et al.
5,891,160	A	4/1999	Williamson, IV et al.	6,074,386	A	6/2000	Goble et al.
5,893,506	A	4/1999	Powell	6,074,401	A	6/2000	Gardiner et al.
5,893,835	A	4/1999	Witt et al.	6,077,286	A	6/2000	Cuschieri et al.
5,894,979	A	4/1999	Powell	6,079,606	A	6/2000	Milliman et al.
5,897,552	A	4/1999	Edwards et al.	6,082,577	A	7/2000	Coates et al.
5,897,562	A	4/1999	Bolanos et al.	6,083,191	A	7/2000	Rose
5,899,914	A	5/1999	Zirps et al.	6,083,234	A	7/2000	Nicholas et al.
5,901,895	A	5/1999	Heaton et al.	6,083,242	A	7/2000	Cook
5,902,312	A	5/1999	Frater et al.	6,086,600	A	7/2000	Kortenbach
5,904,693	A	5/1999	Dicesare et al.	6,090,106	A	7/2000	Goble et al.
5,906,625	A	5/1999	Bito et al.	6,093,186	A	7/2000	Goble
5,908,402	A	6/1999	Blythe	6,099,537	A	8/2000	Sugai et al.
5,908,427	A	6/1999	McKean et al.	6,099,551	A	8/2000	Gabbay
5,911,353	A	6/1999	Bolanos et al.	6,102,271	A	8/2000	Longo et al.
5,915,616	A	6/1999	Viola et al.	6,109,500	A	8/2000	Alli et al.
5,918,791	A	7/1999	Sorrentino et al.	6,117,148	A	9/2000	Ravo et al.
5,919,198	A	7/1999	Graves, Jr. et al.	6,117,158	A	9/2000	Measamer et al.
5,921,956	A	7/1999	Grinberg et al.	6,119,913	A	9/2000	Adams et al.
5,928,256	A	7/1999	Riza	6,120,433	A	9/2000	Mizuno et al.
5,931,847	A	8/1999	Bittner et al.	6,123,241	A	9/2000	Walter et al.
5,931,853	A	8/1999	McEwen et al.	H1904	H	10/2000	Yates et al.
5,937,951	A	8/1999	Izuchukwu et al.	6,126,058	A	10/2000	Adams et al.
5,938,667	A	8/1999	Peyser et al.	6,126,670	A	10/2000	Walker et al.
5,941,442	A	8/1999	Geiste et al.	6,131,789	A	10/2000	Schulze et al.
5,944,172	A	8/1999	Hannula	6,131,790	A	10/2000	Piraka
5,944,715	A	8/1999	Goble et al.	6,132,368	A	10/2000	Cooper
5,947,984	A	9/1999	Whipple	6,139,546	A	10/2000	Koenig et al.
5,948,030	A	9/1999	Miller et al.	6,149,660	A	11/2000	Laufer et al.
5,951,552	A	9/1999	Long et al.	6,152,935	A	11/2000	Kammerer et al.
5,951,574	A	9/1999	Stefanchik et al.	6,155,473	A	12/2000	Tompkins et al.
5,951,581	A	9/1999	Saadat et al.	6,156,056	A	12/2000	Kearns et al.
5,954,259	A	9/1999	Viola et al.	6,159,146	A	12/2000	El Gazayerli
5,964,774	A	10/1999	McKean et al.	6,159,200	A	12/2000	Verdura et al.
5,971,916	A	10/1999	Koren	6,162,208	A	12/2000	Hipps
5,984,949	A	11/1999	Levin	6,165,175	A	12/2000	Wampler et al.
5,988,479	A	11/1999	Palmer	6,165,184	A	12/2000	Verdura et al.
5,997,528	A	12/1999	Bisch et al.	6,165,188	A	12/2000	Saadat et al.
5,997,552	A	12/1999	Person et al.	6,168,605	B1	1/2001	Measamer et al.
6,003,517	A	12/1999	Sheffield et al.	6,171,316	B1	1/2001	Kovac et al.
6,004,319	A	12/1999	Goble et al.	6,171,330	B1	1/2001	Benchetrit
6,010,054	A	1/2000	Johnson et al.	6,174,308	B1	1/2001	Goble et al.
6,010,513	A	1/2000	Törmälä et al.	6,174,309	B1	1/2001	Wrublewski et al.
6,012,494	A	1/2000	Balazs	6,179,195	B1	1/2001	Adams et al.
6,013,076	A	1/2000	Goble et al.	6,179,776	B1	1/2001	Adams et al.
6,015,406	A	1/2000	Goble et al.	6,181,105	B1	1/2001	Cutolo et al.
6,017,322	A	1/2000	Snoke et al.	6,182,673	B1	2/2001	Kindermann et al.
6,017,356	A	1/2000	Frederick et al.	6,187,003	B1	2/2001	Buyssse et al.
6,022,352	A	2/2000	Vandewalle	6,190,386	B1	2/2001	Rydell
6,024,741	A	2/2000	Williamson, IV et al.	6,193,129	B1	2/2001	Bittner et al.
6,024,748	A	2/2000	Manzo et al.	6,197,042	B1	3/2001	Ginn et al.
6,027,501	A	2/2000	Goble et al.	6,200,330	B1	3/2001	Benderev et al.
6,032,849	A	3/2000	Mastri et al.	6,202,914	B1	3/2001	Geiste et al.
6,033,378	A	3/2000	Lundquist et al.	6,206,897	B1	3/2001	Jamiolkowski et al.
6,033,399	A	3/2000	Gines	6,210,403	B1	4/2001	Klicek
6,033,427	A	3/2000	Lee	6,213,999	B1	4/2001	Platt, Jr. et al.
				6,214,028	B1	4/2001	Yoon et al.
				6,220,368	B1	4/2001	Ark et al.
				6,223,835	B1	5/2001	Habedank et al.
				6,224,617	B1	5/2001	Saadat et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

6,228,081	B1	5/2001	Goble	6,450,391	B1	9/2002	Kayan et al.
6,228,083	B1	5/2001	Lands et al.	6,450,989	B2	9/2002	Dubrul et al.
6,228,084	B1	5/2001	Kirwan, Jr.	6,454,781	B1	9/2002	Witt et al.
6,231,565	B1	5/2001	Tovey et al.	6,468,275	B1	10/2002	Wampler et al.
6,234,178	B1	5/2001	Goble et al.	6,471,106	B1	10/2002	Reining
6,241,139	B1	6/2001	Milliman et al.	6,478,210	B2	11/2002	Adams et al.
6,241,140	B1	6/2001	Adams et al.	6,482,200	B2	11/2002	Shippert
6,241,723	B1	6/2001	Heim et al.	6,485,490	B2	11/2002	Wampler et al.
6,248,117	B1	6/2001	Blatter	6,485,667	B1	11/2002	Tan
6,249,076	B1	6/2001	Madden et al.	6,488,196	B1	12/2002	Fenton, Jr.
6,250,532	B1	6/2001	Green et al.	6,488,197	B1	12/2002	Whitman
6,258,107	B1	7/2001	Balázs et al.	6,491,201	B1	12/2002	Whitman
6,261,286	B1	7/2001	Goble et al.	6,491,690	B1	12/2002	Goble et al.
6,264,086	B1	7/2001	McGuckin, Jr.	6,491,701	B2	12/2002	Tierney et al.
6,264,087	B1	7/2001	Whitman	6,492,785	B1	12/2002	Kasten et al.
6,270,508	B1	8/2001	Klieman et al.	6,494,896	B1	12/2002	D'Alessio et al.
6,273,876	B1	8/2001	Klima et al.	6,500,176	B1	12/2002	Truckai et al.
6,273,897	B1	8/2001	Dallessandro et al.	6,500,194	B2	12/2002	Benderev et al.
6,277,114	B1	8/2001	Bullivant et al.	6,503,257	B2	1/2003	Grant et al.
6,293,942	B1	9/2001	Goble et al.	6,503,259	B2	1/2003	Huxel et al.
6,296,640	B1	10/2001	Wampler et al.	6,505,768	B2	1/2003	Whitman
6,302,311	B1	10/2001	Adams et al.	6,510,854	B2	1/2003	Goble
6,305,891	B1	10/2001	Burlingame	6,511,468	B1	1/2003	Cragg et al.
6,306,134	B1	10/2001	Goble et al.	6,517,528	B1	2/2003	Pantages et al.
6,306,149	B1	10/2001	Meade	6,517,535	B2	2/2003	Edwards
6,309,403	B1	10/2001	Minor et al.	6,517,565	B1	2/2003	Whitman et al.
6,315,184	B1	11/2001	Whitman	6,517,566	B1	2/2003	Hovland et al.
6,320,123	B1	11/2001	Reimers	6,522,101	B2	2/2003	Malackowski
6,322,494	B1	11/2001	Bullivant et al.	6,533,157	B1	3/2003	Whitman
6,324,339	B1	11/2001	Hudson et al.	6,533,784	B2	3/2003	Truckai et al.
6,325,799	B1	12/2001	Goble	6,535,764	B2	3/2003	Imran et al.
6,325,810	B1	12/2001	Hamilton et al.	6,543,456	B1	4/2003	Freeman
6,330,965	B1	12/2001	Milliman et al.	6,545,384	B1	4/2003	Pelrine et al.
6,331,181	B1	12/2001	Tierney et al.	6,547,786	B1	4/2003	Goble
6,331,761	B1	12/2001	Kumar et al.	6,550,546	B2	4/2003	Thurler et al.
6,333,029	B1	12/2001	Vyakarnam et al.	6,551,333	B2	4/2003	Kuhns et al.
6,334,860	B1	1/2002	Dorn	6,554,861	B2	4/2003	Knox et al.
6,334,861	B1	1/2002	Chandler et al.	6,558,379	B1	5/2003	Batchelor et al.
6,336,926	B1	1/2002	Goble	6,565,560	B1	5/2003	Goble et al.
6,338,737	B1	1/2002	Toledano	6,569,085	B2	5/2003	Kortenbach et al.
6,343,731	B1	2/2002	Adams et al.	6,569,171	B2	5/2003	DeGuillebon et al.
6,346,077	B1	2/2002	Taylor et al.	6,578,751	B2	6/2003	Hartwick
6,352,503	B1	3/2002	Matsui et al.	6,582,427	B1	6/2003	Goble et al.
6,352,532	B1	3/2002	Kramer et al.	6,583,533	B2	6/2003	Pelrine et al.
6,358,224	B1	3/2002	Tims et al.	6,585,144	B2	7/2003	Adams et al.
6,364,877	B1	4/2002	Goble et al.	6,588,643	B2	7/2003	Bolduc et al.
6,364,888	B1	4/2002	Niemeyer et al.	6,589,164	B1	7/2003	Flaherty
6,370,981	B2	4/2002	Watarai	6,592,538	B1	7/2003	Hotchkiss et al.
6,373,152	B1	4/2002	Wang et al.	6,592,597	B2	7/2003	Grant et al.
6,383,201	B1	5/2002	Dong	6,596,296	B1	7/2003	Nelson et al.
6,387,113	B1	5/2002	Hawkins et al.	6,596,304	B1	7/2003	Bayon et al.
6,387,114	B2	5/2002	Adams	6,596,432	B2	7/2003	Kawakami et al.
6,391,038	B2	5/2002	Vargas et al.	D478,665	S	8/2003	Isaacs et al.
6,398,781	B1	6/2002	Goble et al.	D478,986	S	8/2003	Johnston et al.
6,398,797	B2	6/2002	Bombard et al.	6,601,749	B2	8/2003	Sullivan et al.
6,402,766	B2	6/2002	Bowman et al.	6,602,252	B2	8/2003	Mollenauer
6,406,440	B1	6/2002	Stefanchik	6,602,262	B2	8/2003	Griego et al.
6,409,724	B1	6/2002	Penny et al.	6,605,078	B2	8/2003	Adams
H2037	H	7/2002	Yates et al.	6,605,669	B2	8/2003	Awokola et al.
6,413,274	B1	7/2002	Pedros	6,607,475	B2	8/2003	Doyle et al.
6,416,486	B1	7/2002	Wampler	6,616,686	B2	9/2003	Coleman et al.
6,416,509	B1	7/2002	Goble et al.	6,619,529	B2	9/2003	Green et al.
6,419,695	B1	7/2002	Gabbay	6,620,166	B1	9/2003	Wenstrom, Jr. et al.
RE37,814	E	8/2002	Allgeyer	6,626,834	B2	9/2003	Dunne et al.
6,428,070	B1	8/2002	Takanashi et al.	6,629,630	B2	10/2003	Adams
6,429,611	B1	8/2002	Li	6,629,974	B2	10/2003	Penny et al.
6,436,097	B1	8/2002	Nardella	6,629,988	B2	10/2003	Weadock
6,436,107	B1	8/2002	Wang et al.	6,636,412	B2	10/2003	Smith
6,436,110	B2	8/2002	Bowman et al.	6,638,108	B2	10/2003	Tachi
6,436,122	B1	8/2002	Frank et al.	6,638,285	B2	10/2003	Gabbay
6,439,439	B1	8/2002	Rickard et al.	6,638,297	B1	10/2003	Huitema
6,439,446	B1	8/2002	Perry et al.	RE38,335	E	11/2003	Aust et al.
6,440,146	B2	8/2002	Nicholas et al.	6,641,528	B2	11/2003	Torii
6,443,973	B1	9/2002	Whitman	6,644,532	B2	11/2003	Green et al.
6,447,518	B1	9/2002	Krause et al.	6,645,201	B1	11/2003	Utley et al.
				6,646,307	B1	11/2003	Yu et al.
				6,648,816	B2	11/2003	Irion et al.
				6,652,595	B1	11/2003	Nicolo
				D484,243	S	12/2003	Ryan et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

D484,595 S	12/2003	Ryan et al.	6,820,791 B2	11/2004	Adams
D484,596 S	12/2003	Ryan et al.	6,821,273 B2	11/2004	Mollenauer
6,656,177 B2	12/2003	Truckai et al.	6,821,284 B2	11/2004	Sturtz et al.
6,656,193 B2	12/2003	Grant et al.	6,827,246 B2	12/2004	Sullivan et al.
6,663,641 B1	12/2003	Kovac et al.	6,827,712 B2	12/2004	Tovey et al.
6,666,854 B1	12/2003	Lange	6,827,725 B2	12/2004	Batchelor et al.
6,666,875 B1	12/2003	Sakurai et al.	6,828,902 B2	12/2004	Casden
6,667,825 B2	12/2003	Lu et al.	6,830,174 B2	12/2004	Hillstead et al.
6,669,073 B2	12/2003	Milliman et al.	6,832,998 B2	12/2004	Goble
6,671,185 B2	12/2003	Duval	6,834,001 B2	12/2004	Myono
D484,977 S	1/2004	Ryan et al.	6,835,199 B2	12/2004	McGuckin, Jr. et al.
6,676,660 B2	1/2004	Wampler et al.	6,835,336 B2	12/2004	Watt
6,679,269 B2	1/2004	Swanson	6,837,846 B2	1/2005	Jaffe et al.
6,679,410 B2	1/2004	Würsch et al.	6,840,423 B2	1/2005	Adams et al.
6,681,978 B2	1/2004	Geiste et al.	6,843,403 B2	1/2005	Whitman
6,681,979 B2	1/2004	Whitman	6,843,789 B2	1/2005	Goble
6,682,527 B2	1/2004	Strul	6,846,307 B2	1/2005	Whitman et al.
6,682,528 B2	1/2004	Frazier et al.	6,846,308 B2	1/2005	Whitman et al.
6,685,727 B2	2/2004	Fisher et al.	6,846,309 B2	1/2005	Whitman et al.
6,689,153 B1	2/2004	Skiba	6,849,071 B2	2/2005	Whitman et al.
6,692,507 B2	2/2004	Pugsley et al.	6,858,005 B2	2/2005	Ohline et al.
6,695,198 B2	2/2004	Adams et al.	RE38,708 E	3/2005	Bolanos et al.
6,695,199 B2	2/2004	Whitman	6,861,142 B1	3/2005	Wilkie et al.
6,698,643 B2	3/2004	Whitman	6,863,694 B1	3/2005	Boyce et al.
6,699,235 B2	3/2004	Wallace et al.	6,866,178 B2	3/2005	Adams et al.
6,704,210 B1	3/2004	Myers	6,866,671 B2	3/2005	Tierney et al.
6,705,503 B1	3/2004	Pedicini et al.	6,869,435 B2	3/2005	Blake, III
6,709,445 B2	3/2004	Boebel et al.	6,872,214 B2	3/2005	Sonnenschein et al.
6,712,773 B1	3/2004	Viola	6,874,669 B2	4/2005	Adams et al.
6,716,223 B2	4/2004	Leopold et al.	6,877,647 B2	4/2005	Green et al.
6,716,232 B1	4/2004	Vidal et al.	6,878,106 B1	4/2005	Herrmann
6,716,233 B1	4/2004	Whitman	6,889,116 B2	5/2005	Jinno
6,722,552 B2	4/2004	Fenton, Jr.	6,893,435 B2	5/2005	Goble
6,723,087 B2	4/2004	O'Neill et al.	6,905,057 B2	6/2005	Swayze et al.
6,723,091 B2	4/2004	Goble et al.	6,905,497 B2	6/2005	Truckai et al.
6,726,697 B2	4/2004	Nicholas et al.	6,908,472 B2	6/2005	Wiener et al.
6,729,119 B2	5/2004	Schnipke et al.	6,911,033 B2	6/2005	de Guillebon et al.
6,736,825 B2	5/2004	Blatter et al.	6,913,579 B2	7/2005	Truckai et al.
6,736,854 B2	5/2004	Vadurro et al.	6,913,608 B2	7/2005	Liddicoat et al.
6,740,030 B2	5/2004	Martone et al.	6,913,613 B2	7/2005	Schwarz et al.
6,747,121 B2	6/2004	Gogolewski	6,921,397 B2	7/2005	Corcoran et al.
6,749,560 B1	6/2004	Konstorum et al.	6,921,412 B1	7/2005	Black et al.
6,752,768 B2	6/2004	Burdorff et al.	6,923,803 B2	8/2005	Goble
6,752,816 B2	6/2004	Culp et al.	6,926,716 B2	8/2005	Baker et al.
6,755,195 B1	6/2004	Lemke et al.	6,929,641 B2	8/2005	Goble et al.
6,755,338 B2	6/2004	Hahnen et al.	6,929,644 B2	8/2005	Truckai et al.
6,758,846 B2	7/2004	Goble et al.	6,931,830 B2	8/2005	Liao
6,761,685 B2	7/2004	Adams et al.	6,932,218 B2	8/2005	Kosann et al.
6,767,352 B2	7/2004	Field et al.	6,932,810 B2	8/2005	Ryan
6,767,356 B2	7/2004	Kanner et al.	6,936,042 B2	8/2005	Wallace et al.
6,769,590 B2	8/2004	Vresh et al.	6,939,358 B2	9/2005	Palacios et al.
6,769,594 B2	8/2004	Orban, III	6,942,662 B2	9/2005	Goble et al.
6,770,072 B1	8/2004	Truckai et al.	6,945,444 B2	9/2005	Gresham et al.
6,773,409 B2	8/2004	Truckai et al.	6,953,138 B1	10/2005	Dworak et al.
6,773,438 B1	8/2004	Knodel et al.	6,953,139 B2	10/2005	Milliman et al.
6,777,838 B2	8/2004	Miekka et al.	6,958,035 B2	10/2005	Friedman et al.
6,780,151 B2	8/2004	Grabover et al.	6,959,851 B2	11/2005	Heinrich
6,780,180 B1	8/2004	Goble et al.	6,959,852 B2	11/2005	Shelton, IV et al.
6,783,524 B2	8/2004	Anderson et al.	6,960,107 B1	11/2005	Schaub et al.
6,786,382 B1	9/2004	Hoffman	6,960,163 B2	11/2005	Ewers et al.
6,786,864 B2	9/2004	Matsuura et al.	6,960,220 B2	11/2005	Marino et al.
6,786,896 B1	9/2004	Madhani et al.	6,964,363 B2	11/2005	Wales et al.
6,790,173 B2	9/2004	Saadat et al.	6,966,907 B2	11/2005	Goble
6,793,652 B1	9/2004	Whitman et al.	6,966,909 B2	11/2005	Marshall et al.
6,793,661 B2	9/2004	Hamilton et al.	6,971,988 B2	12/2005	Orban, III
6,793,663 B2	9/2004	Kneifel et al.	6,972,199 B2	12/2005	Leboutz et al.
6,802,843 B2	10/2004	Truckai et al.	6,974,462 B2	12/2005	Sater
6,805,273 B2	10/2004	Bilotti et al.	6,978,921 B2	12/2005	Shelton, IV et al.
6,806,808 B1	10/2004	Watters et al.	6,978,922 B2	12/2005	Bilotti et al.
6,808,525 B2	10/2004	Latterell et al.	6,981,628 B2	1/2006	Wales
6,814,741 B2	11/2004	Bowman et al.	6,981,941 B2	1/2006	Whitman et al.
6,817,508 B1	11/2004	Racenet et al.	6,981,978 B2	1/2006	Gannoe
6,817,509 B2	11/2004	Geiste et al.	6,984,203 B2	1/2006	Tartaglia et al.
6,817,974 B2	11/2004	Cooper et al.	6,984,231 B2	1/2006	Goble et al.
6,818,018 B1	11/2004	Sawhney	6,986,451 B1	1/2006	Mastri et al.
			6,988,649 B2	1/2006	Shelton, IV et al.
			6,988,650 B2	1/2006	Schwemberger et al.
			6,990,796 B2	1/2006	Schnipke et al.
			6,994,708 B2	2/2006	Manzo

(56)

References Cited

U.S. PATENT DOCUMENTS

6,995,729 B2	2/2006	Govari et al.	7,128,254 B2	10/2006	Shelton, IV et al.
6,997,931 B2	2/2006	Sauer et al.	7,128,748 B2	10/2006	Mooradian et al.
7,000,818 B2	2/2006	Shelton, IV et al.	7,131,445 B2	11/2006	Amoah
7,000,819 B2	2/2006	Swayze et al.	7,133,601 B2	11/2006	Phillips et al.
7,001,380 B2	2/2006	Goble	7,134,587 B2	11/2006	Schwemberger et al.
7,001,408 B2	2/2006	Knodel et al.	7,137,981 B2	11/2006	Long
7,008,435 B2	3/2006	Cummins	7,140,527 B2	11/2006	Ehrenfels et al.
7,011,657 B2	3/2006	Truckai et al.	7,140,528 B2	11/2006	Shelton, IV
7,018,357 B2	3/2006	Emmons	7,143,923 B2	12/2006	Shelton, IV et al.
7,018,390 B2	3/2006	Turovskiy et al.	7,143,924 B2	12/2006	Scirica et al.
7,025,743 B2	4/2006	Mann et al.	7,143,925 B2	12/2006	Shelton, IV et al.
7,029,435 B2	4/2006	Nakao	7,143,926 B2	12/2006	Shelton, IV et al.
7,032,798 B2	4/2006	Whitman et al.	7,147,138 B2	12/2006	Shelton, IV
7,032,799 B2	4/2006	Viola et al.	7,147,139 B2	12/2006	Schwemberger et al.
7,033,356 B2	4/2006	Latterell et al.	7,147,140 B2	12/2006	Wukusick et al.
7,036,680 B1	5/2006	Flannery	7,147,637 B2	12/2006	Goble
7,037,344 B2	5/2006	Kagan et al.	7,147,650 B2	12/2006	Lee
7,041,102 B2	5/2006	Truckai et al.	7,150,748 B2	12/2006	Ebbutt et al.
7,041,868 B2	5/2006	Greene et al.	7,153,300 B2	12/2006	Goble
7,043,852 B2	5/2006	Hayashida et al.	7,156,863 B2	1/2007	Sonnenschein et al.
7,044,352 B2	5/2006	Shelton, IV et al.	7,159,750 B2	1/2007	Racenet et al.
7,044,353 B2	5/2006	Mastri et al.	7,160,299 B2	1/2007	Baily
7,048,687 B1	5/2006	Reuss et al.	7,161,036 B2	1/2007	Oikawa et al.
7,048,745 B2	5/2006	Tierney et al.	7,168,604 B2	1/2007	Milliman et al.
7,052,494 B2	5/2006	Goble et al.	7,172,104 B2	2/2007	Scirica et al.
7,055,730 B2	6/2006	Ehrenfels et al.	7,179,223 B2	2/2007	Motoki et al.
7,055,731 B2	6/2006	Shelton, IV et al.	7,179,267 B2	2/2007	Nolan et al.
7,056,284 B2	6/2006	Martone et al.	7,182,239 B1	2/2007	Myers
7,056,330 B2	6/2006	Gayton	7,182,763 B2	2/2007	Nardella
7,059,331 B2	6/2006	Adams et al.	7,183,737 B2	2/2007	Kitagawa
7,059,508 B2	6/2006	Shelton, IV et al.	7,188,758 B2	3/2007	Viola et al.
7,063,712 B2	6/2006	Vargas et al.	7,189,207 B2	3/2007	Viola
7,066,879 B2	6/2006	Fowler et al.	7,195,627 B2	3/2007	Amoah et al.
7,066,944 B2	6/2006	Lauffer et al.	7,199,537 B2	4/2007	Okamura et al.
7,067,038 B2	6/2006	Trokhan et al.	7,204,835 B2	4/2007	Latterell et al.
7,070,083 B2	7/2006	Jankowski	7,207,233 B2	4/2007	Wadge
7,070,559 B2	7/2006	Adams et al.	7,207,471 B2	4/2007	Heinrich et al.
7,070,597 B2	7/2006	Truckai et al.	7,207,472 B2	4/2007	Wukusick et al.
7,071,287 B2	7/2006	Rhine et al.	7,207,556 B2	4/2007	Saitoh et al.
7,075,770 B1	7/2006	Smith	7,208,005 B2	4/2007	Freckler et al.
7,077,856 B2	7/2006	Whitman	7,210,609 B2	5/2007	Leiboff et al.
7,080,769 B2	7/2006	Vresh et al.	7,211,081 B2	5/2007	Goble
7,081,114 B2	7/2006	Rashidi	7,211,084 B2	5/2007	Goble et al.
7,083,073 B2	8/2006	Yoshie et al.	7,213,736 B2	5/2007	Wales et al.
7,083,075 B2	8/2006	Swayze et al.	7,214,224 B2	5/2007	Goble
7,083,571 B2	8/2006	Wang et al.	7,217,285 B2	5/2007	Vargas et al.
7,083,615 B2	8/2006	Peterson et al.	7,220,260 B2	5/2007	Fleming et al.
7,083,619 B2	8/2006	Truckai et al.	7,220,272 B2	5/2007	Weadock
7,083,620 B2	8/2006	Jahns et al.	7,225,963 B2	6/2007	Scirica
7,087,054 B2	8/2006	Truckai et al.	7,225,964 B2	6/2007	Mastri et al.
7,087,071 B2	8/2006	Nicholas et al.	7,234,624 B2	6/2007	Gresham et al.
7,090,637 B2	8/2006	Danitz et al.	7,235,089 B1	6/2007	McGuckin, Jr.
7,090,673 B2	8/2006	Dycus et al.	7,235,302 B2	6/2007	Jing et al.
7,090,683 B2	8/2006	Brock et al.	7,237,708 B1	7/2007	Guy et al.
7,090,684 B2	8/2006	McGuckin, Jr. et al.	7,238,195 B2	7/2007	Viola
7,094,202 B2	8/2006	Nobis et al.	7,241,288 B2	7/2007	Braun
7,094,247 B2	8/2006	Monassevitch et al.	7,246,734 B2	7/2007	Shelton, IV
7,097,089 B2	8/2006	Marczyk	7,247,161 B2	7/2007	Johnston et al.
7,097,644 B2	8/2006	Long	7,252,660 B2	8/2007	Kunz
7,097,650 B2	8/2006	Weller et al.	7,255,696 B2	8/2007	Goble et al.
7,098,794 B2	8/2006	Lindsay et al.	7,256,695 B2	8/2007	Hamel et al.
7,104,741 B2	9/2006	Krohn	7,258,262 B2	8/2007	Mastri et al.
7,108,695 B2	9/2006	Witt et al.	7,258,546 B2	8/2007	Beier et al.
7,108,701 B2	9/2006	Evens et al.	7,260,431 B2	8/2007	Libbus et al.
7,108,709 B2	9/2006	Cummins	7,265,374 B2	9/2007	Lee et al.
7,111,769 B2	9/2006	Wales et al.	7,267,679 B2	9/2007	McGuckin, Jr. et al.
7,112,214 B2	9/2006	Peterson et al.	7,273,483 B2	9/2007	Wiener et al.
RE39,358 E	10/2006	Goble	7,278,562 B2	10/2007	Mastri et al.
7,114,642 B2	10/2006	Whitman	7,278,563 B1	10/2007	Green
7,118,582 B1	10/2006	Wang et al.	7,278,949 B2	10/2007	Bader
7,121,446 B2	10/2006	Arad et al.	7,278,994 B2	10/2007	Goble
7,122,028 B2	10/2006	Looper et al.	7,282,048 B2	10/2007	Goble et al.
7,125,409 B2	10/2006	Truckai et al.	7,293,685 B2	11/2007	Ehrenfels et al.
7,126,303 B2	10/2006	Farritor et al.	7,295,907 B2	11/2007	Lu et al.
7,128,253 B2	10/2006	Mastri et al.	7,296,722 B2	11/2007	Ivanko
			7,296,724 B2	11/2007	Green et al.
			7,297,149 B2	11/2007	Vitali et al.
			7,300,450 B2	11/2007	Vleugels et al.
			7,303,106 B2	12/2007	Milliman et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

7,303,107 B2	12/2007	Milliman et al.	7,441,685 B1	10/2008	Boudreaux
7,303,108 B2	12/2007	Shelton, IV	7,442,201 B2	10/2008	Pugsley et al.
7,303,502 B2	12/2007	Thompson	7,448,525 B2	11/2008	Shelton, IV et al.
7,303,556 B2	12/2007	Metzger	7,451,904 B2	11/2008	Shelton, IV
7,308,998 B2	12/2007	Mastri et al.	7,455,208 B2	11/2008	Wales et al.
7,322,975 B2	1/2008	Goble et al.	7,455,676 B2	11/2008	Holsten et al.
7,322,994 B2	1/2008	Nicholas et al.	7,455,682 B2	11/2008	Viola
7,324,572 B2	1/2008	Chang	7,461,767 B2	12/2008	Viola et al.
7,326,203 B2	2/2008	Papineau et al.	7,462,187 B2	12/2008	Johnston et al.
7,326,213 B2	2/2008	Benderev et al.	7,464,846 B2	12/2008	Shelton, IV et al.
7,328,828 B2	2/2008	Ortiz et al.	7,464,847 B2	12/2008	Viola et al.
7,328,829 B2	2/2008	Arad et al.	7,464,849 B2	12/2008	Shelton, IV et al.
7,330,004 B2	2/2008	DeJonge et al.	7,467,740 B2	12/2008	Shelton, IV et al.
7,331,340 B2	2/2008	Barney	7,467,849 B2	12/2008	Silverbrook et al.
7,334,717 B2	2/2008	Rethy et al.	7,472,814 B2	1/2009	Mastri et al.
7,334,718 B2	2/2008	McAlister et al.	7,472,815 B2	1/2009	Shelton, IV et al.
7,335,199 B2	2/2008	Goble et al.	7,472,816 B2	1/2009	Holsten et al.
7,336,048 B2	2/2008	Lohr	7,473,253 B2	1/2009	Dycus et al.
7,336,184 B2	2/2008	Smith et al.	7,473,263 B2	1/2009	Johnston et al.
7,338,513 B2	3/2008	Lee et al.	7,479,608 B2	1/2009	Smith
7,341,591 B2	3/2008	Grinberg	7,481,347 B2	1/2009	Roy
7,343,920 B2	3/2008	Toby et al.	7,481,348 B2	1/2009	Marczyk
7,344,532 B2	3/2008	Goble et al.	7,481,349 B2	1/2009	Holsten et al.
7,348,763 B1	3/2008	Reinhart et al.	7,481,824 B2	1/2009	Boudreaux et al.
RE40,237 E	4/2008	Bilotti et al.	7,485,133 B2	2/2009	Cannon et al.
7,351,258 B2	4/2008	Ricotta et al.	7,485,142 B2	2/2009	Milo
7,354,447 B2	4/2008	Shelton, IV et al.	7,487,899 B2	2/2009	Shelton, IV et al.
7,354,502 B2	4/2008	Polat et al.	7,490,749 B2	2/2009	Schall et al.
7,357,287 B2	4/2008	Shelton, IV et al.	7,494,039 B2	2/2009	Racenet et al.
7,357,806 B2	4/2008	Rivera et al.	7,494,499 B2	2/2009	Nagase et al.
7,361,195 B2	4/2008	Schwartz et al.	7,500,979 B2	3/2009	Hueil et al.
7,364,060 B2	4/2008	Milliman	7,501,198 B2	3/2009	Barlev et al.
7,364,061 B2	4/2008	Swayze et al.	7,503,474 B2	3/2009	Hillstead et al.
7,377,918 B2	5/2008	Amoah	7,506,790 B2	3/2009	Shelton, IV
7,377,928 B2	5/2008	Zubik et al.	7,506,791 B2	3/2009	Omaitis et al.
7,380,695 B2	6/2008	Doll et al.	7,507,202 B2	3/2009	Schoellhorn
7,380,696 B2	6/2008	Shelton, IV et al.	7,510,107 B2	3/2009	Timm et al.
7,386,730 B2	6/2008	Uchikubo	7,510,566 B2	3/2009	Jacobs et al.
7,388,217 B2	6/2008	Buschbeck et al.	7,513,408 B2	4/2009	Shelton, IV et al.
7,391,173 B2	6/2008	Schena	7,517,356 B2	4/2009	Heinrich
7,396,356 B2	7/2008	Mollenauer	7,524,320 B2	4/2009	Tierney et al.
7,397,364 B2	7/2008	Govari	7,530,984 B2	5/2009	Sonnenschein et al.
7,398,907 B2	7/2008	Racenet et al.	7,530,985 B2	5/2009	Takemoto et al.
7,398,908 B2	7/2008	Holsten et al.	7,546,939 B2	6/2009	Adams et al.
7,401,721 B2	7/2008	Holsten et al.	7,546,940 B2	6/2009	Milliman et al.
7,404,508 B2	7/2008	Smith et al.	7,547,312 B2	6/2009	Bauman et al.
7,404,509 B2	7/2008	Ortiz et al.	7,549,563 B2	6/2009	Mather et al.
7,404,822 B2	7/2008	Via et al.	7,549,564 B2	6/2009	Boudreaux
7,407,074 B2	8/2008	Ortiz et al.	7,549,998 B2	6/2009	Braun
7,407,075 B2	8/2008	Holsten et al.	7,552,854 B2	6/2009	Wixey et al.
7,407,076 B2	8/2008	Racenet et al.	7,556,185 B2	7/2009	Viola
7,407,077 B2	8/2008	Ortiz et al.	7,556,186 B2	7/2009	Milliman
7,407,078 B2	8/2008	Shelton, IV et al.	7,556,647 B2	7/2009	Dreus et al.
7,410,086 B2	8/2008	Ortiz et al.	7,559,449 B2	7/2009	Viola
7,413,563 B2	8/2008	Corcoran et al.	7,559,450 B2	7/2009	Wales et al.
7,416,101 B2	8/2008	Shelton, IV et al.	7,559,452 B2	7/2009	Wales et al.
7,418,078 B2	8/2008	Blanz et al.	7,563,862 B2	7/2009	Sieg et al.
RE40,514 E	9/2008	Mastri et al.	7,565,993 B2	7/2009	Milliman et al.
7,419,080 B2	9/2008	Smith et al.	7,566,300 B2	7/2009	Devierre et al.
7,419,081 B2	9/2008	Ehrenfels et al.	7,567,045 B2	7/2009	Fristedt
7,419,495 B2	9/2008	Menn et al.	7,568,603 B2	8/2009	Shelton, IV et al.
7,422,136 B1	9/2008	Marczyk	7,568,604 B2	8/2009	Ehrenfels et al.
7,422,139 B2	9/2008	Shelton, IV et al.	7,568,619 B2	8/2009	Todd et al.
7,424,965 B2	9/2008	Racenet et al.	7,575,144 B2	8/2009	Ortiz et al.
7,427,607 B2	9/2008	Suzuki	7,588,174 B2	9/2009	Holsten et al.
7,431,188 B1	10/2008	Marczyk	7,588,175 B2	9/2009	Timm et al.
7,431,189 B2	10/2008	Shelton, IV et al.	7,588,176 B2	9/2009	Timm et al.
7,431,694 B2	10/2008	Stefanchik et al.	7,588,177 B2	9/2009	Racenet
7,431,730 B2	10/2008	Viola	7,591,783 B2	9/2009	Boulais et al.
7,434,715 B2	10/2008	Shelton, IV et al.	7,597,229 B2	10/2009	Boudreaux et al.
7,434,717 B2	10/2008	Shelton, IV et al.	7,597,230 B2	10/2009	Racenet et al.
7,438,209 B1	10/2008	Hess et al.	7,600,663 B2	10/2009	Green
7,438,718 B2	10/2008	Milliman et al.	7,604,150 B2	10/2009	Boudreaux
7,439,354 B2	10/2008	Lenges et al.	7,604,151 B2	10/2009	Hess et al.
7,441,684 B2	10/2008	Shelton, IV et al.	7,607,557 B2	10/2009	Shelton, IV et al.
			7,611,038 B2	11/2009	Racenet et al.
			7,611,474 B2	11/2009	Hibner et al.
			7,615,003 B2	11/2009	Stefanchik et al.
			7,615,067 B2	11/2009	Lee et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

7,624,902 B2	12/2009	Marczyk et al.	7,740,159 B2	6/2010	Shelton, IV et al.
7,624,903 B2	12/2009	Green et al.	7,743,960 B2	6/2010	Whitman et al.
7,625,370 B2	12/2009	Hart et al.	7,744,624 B2	6/2010	Bettuchi
7,631,793 B2	12/2009	Rethy et al.	7,744,627 B2	6/2010	Orban, III et al.
7,631,794 B2	12/2009	Rethy et al.	7,744,628 B2	6/2010	Viola
7,635,074 B2	12/2009	Olson et al.	7,748,587 B2	7/2010	Haramiishi et al.
7,637,409 B2	12/2009	Marczyk	7,749,204 B2	7/2010	Dhanaraj et al.
7,638,958 B2	12/2009	Philipp et al.	7,751,870 B2	7/2010	Whitman
7,641,091 B2	1/2010	Olson et al.	7,753,245 B2	7/2010	Boudreaux et al.
7,641,092 B2	1/2010	Kruszynski et al.	7,753,904 B2	7/2010	Shelton, IV et al.
7,641,093 B2	1/2010	Doll et al.	7,758,612 B2	7/2010	Shipp
7,641,095 B2	1/2010	Viola	7,766,209 B2	8/2010	Baxter, III et al.
7,644,783 B2	1/2010	Roberts et al.	7,766,210 B2	8/2010	Shelton, IV et al.
7,644,848 B2	1/2010	Swayze et al.	7,766,821 B2	8/2010	Brunnen et al.
7,645,230 B2	1/2010	Mikkaichi et al.	7,766,894 B2	8/2010	Weitzner et al.
7,648,519 B2	1/2010	Lee et al.	7,770,773 B2	8/2010	Whitman et al.
7,651,017 B2	1/2010	Ortiz et al.	7,770,774 B2	8/2010	Mastri et al.
7,651,498 B2	1/2010	Shifrin et al.	7,770,775 B2	8/2010	Shelton, IV et al.
7,654,431 B2	2/2010	Hueil et al.	7,770,776 B2	8/2010	Chen et al.
7,656,131 B2	2/2010	Embrey et al.	7,771,396 B2	8/2010	Stefanchik et al.
7,658,311 B2	2/2010	Boudreaux	7,772,720 B2	8/2010	McGee et al.
7,658,312 B2	2/2010	Vidal et al.	7,776,060 B2	8/2010	Mooradian et al.
7,662,161 B2	2/2010	Briganti et al.	7,778,004 B2	8/2010	Nerheim et al.
7,665,646 B2	2/2010	Prommersberger	7,780,054 B2	8/2010	Wales
7,665,647 B2	2/2010	Shelton, IV et al.	7,780,055 B2	8/2010	Scirica et al.
7,669,746 B2	3/2010	Shelton, IV	7,780,663 B2	8/2010	Yates et al.
7,669,747 B2	3/2010	Weisenburgh, II et al.	7,780,685 B2	8/2010	Hunt et al.
7,670,334 B2	3/2010	Hueil et al.	7,784,662 B2	8/2010	Wales et al.
7,673,780 B2	3/2010	Shelton, IV et al.	7,784,663 B2	8/2010	Shelton, IV
7,673,781 B2	3/2010	Swayze et al.	7,789,875 B2	9/2010	Brock et al.
7,673,782 B2	3/2010	Hess et al.	7,789,883 B2	9/2010	Takashino et al.
7,673,783 B2	3/2010	Morgan et al.	7,789,889 B2	9/2010	Zubik et al.
7,674,253 B2	3/2010	Fisher et al.	7,793,812 B2 *	9/2010	Moore et al. 227/176.1
7,674,255 B2	3/2010	Braun	7,794,475 B2	9/2010	Hess et al.
7,674,263 B2	3/2010	Ryan	7,798,386 B2	9/2010	Schall et al.
7,682,307 B2	3/2010	Danitz et al.	7,799,039 B2	9/2010	Shelton, IV et al.
7,686,201 B2	3/2010	Csiky	7,799,044 B2	9/2010	Johnston et al.
7,686,826 B2	3/2010	Lee et al.	7,803,151 B2	9/2010	Whitman
7,688,028 B2	3/2010	Phillips et al.	7,806,891 B2	10/2010	Nowlin et al.
7,691,098 B2	4/2010	Wallace et al.	7,810,690 B2	10/2010	Bilotti et al.
7,694,865 B2	4/2010	Scirica	7,810,691 B2	10/2010	Boyden et al.
7,695,485 B2	4/2010	Whitman et al.	7,810,692 B2	10/2010	Hall et al.
7,699,204 B2	4/2010	Viola	7,810,693 B2	10/2010	Broehl et al.
7,699,835 B2	4/2010	Lee et al.	7,815,092 B2	10/2010	Whitman et al.
7,699,844 B2	4/2010	Utley et al.	7,815,565 B2	10/2010	Stefanchik et al.
7,699,846 B2	4/2010	Ryan	7,819,296 B2	10/2010	Hueil et al.
7,699,856 B2	4/2010	Van Wyk et al.	7,819,297 B2	10/2010	Doll et al.
7,699,859 B2	4/2010	Bombard et al.	7,819,298 B2	10/2010	Hall et al.
7,699,860 B2	4/2010	Huitema et al.	7,819,299 B2	10/2010	Shelton, IV et al.
7,703,653 B2	4/2010	Shah et al.	7,819,886 B2	10/2010	Whitfield et al.
7,708,180 B2	5/2010	Murray et al.	7,823,592 B2	11/2010	Bettuchi et al.
7,708,181 B2	5/2010	Cole et al.	7,824,401 B2	11/2010	Manzo et al.
7,708,758 B2	5/2010	Lee et al.	7,824,426 B2	11/2010	Racenet et al.
7,714,239 B2	5/2010	Smith	7,828,189 B2	11/2010	Holsten et al.
7,717,312 B2	5/2010	Beetel	7,828,794 B2	11/2010	Sartor
7,717,313 B2	5/2010	Criscuolo et al.	7,828,808 B2	11/2010	Hinman et al.
7,717,846 B2	5/2010	Zirps et al.	7,832,408 B2	11/2010	Shelton, IV et al.
7,718,180 B2	5/2010	Karp	7,832,611 B2	11/2010	Boyden et al.
7,718,556 B2	5/2010	Matsuda et al.	7,832,612 B2	11/2010	Baxter, III et al.
7,721,930 B2	5/2010	McKenna et al.	7,833,234 B2	11/2010	Bailly et al.
7,721,931 B2	5/2010	Shelton, IV et al.	7,836,400 B2	11/2010	May et al.
7,721,933 B2	5/2010	Ehrenfels et al.	7,837,079 B2	11/2010	Holsten et al.
7,721,934 B2	5/2010	Shelton, IV et al.	7,837,080 B2	11/2010	Schwemberger
7,721,936 B2	5/2010	Shalton, IV et al.	7,837,081 B2	11/2010	Holsten et al.
7,722,527 B2	5/2010	Bouchier et al.	7,837,694 B2	11/2010	Tethrake et al.
7,722,607 B2	5/2010	Dumbauld et al.	7,842,025 B2	11/2010	Coleman et al.
7,722,610 B2	5/2010	Viola et al.	7,842,028 B2	11/2010	Lee
7,726,537 B2	6/2010	Olson et al.	7,845,533 B2	12/2010	Marczyk et al.
7,726,538 B2	6/2010	Holsten et al.	7,845,534 B2	12/2010	Viola et al.
7,726,539 B2	6/2010	Holsten et al.	7,845,535 B2	12/2010	Scirica
7,731,072 B2	6/2010	Timm et al.	7,845,536 B2	12/2010	Viola et al.
7,731,724 B2	6/2010	Huitema et al.	7,845,537 B2	12/2010	Shelton, IV et al.
7,735,703 B2	6/2010	Morgan et al.	7,846,149 B2	12/2010	Jankowski
7,736,374 B2	6/2010	Vaughan et al.	7,850,642 B2	12/2010	Moll et al.
7,738,971 B2	6/2010	Swayze et al.	7,854,736 B2	12/2010	Ryan
			7,857,183 B2	12/2010	Shelton, IV
			7,857,185 B2	12/2010	Swayze et al.
			7,857,186 B2	12/2010	Baxter, III et al.
			7,857,813 B2	12/2010	Schmitz et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

7,861,906 B2	1/2011	Doll et al.	8,002,785 B2	8/2011	Weiss et al.
7,862,579 B2	1/2011	Ortiz et al.	8,002,795 B2	8/2011	Beetel
7,866,525 B2	1/2011	Scirica	8,006,365 B2	8/2011	Levin et al.
7,866,527 B2	1/2011	Hall et al.	8,006,885 B2	8/2011	Marczyk
7,866,528 B2	1/2011	Olson et al.	8,006,889 B2	8/2011	Adams et al.
7,870,989 B2	1/2011	Viola et al.	8,011,550 B2	9/2011	Aranyi et al.
7,871,418 B2	1/2011	Thompson et al.	8,011,551 B2	9/2011	Marczyk et al.
7,879,070 B2	2/2011	Ortiz et al.	8,011,553 B2	9/2011	Mastri et al.
7,883,465 B2	2/2011	Donofrio et al.	8,011,555 B2	9/2011	Tarinelli et al.
7,886,952 B2	2/2011	Scirica et al.	8,016,176 B2	9/2011	Kasvikis et al.
7,887,530 B2	2/2011	Zemlok et al.	8,016,177 B2	9/2011	Bettuchi et al.
7,887,535 B2	2/2011	Lands et al.	8,016,178 B2	9/2011	Olson et al.
7,891,531 B1	2/2011	Ward	8,016,855 B2	9/2011	Whitman et al.
7,891,532 B2	2/2011	Mastri et al.	8,016,858 B2	9/2011	Whitman
7,893,586 B2	2/2011	West et al.	8,016,881 B2	9/2011	Furst
7,896,214 B2	3/2011	Farascioni	8,020,742 B2	9/2011	Marczyk
7,896,215 B2	3/2011	Adams et al.	8,020,743 B2	9/2011	Shelton, IV
7,896,877 B2	3/2011	Hall et al.	8,021,375 B2	9/2011	Aldrich et al.
7,900,805 B2	3/2011	Shelton, IV et al.	8,025,199 B2	9/2011	Whitman et al.
7,905,380 B2	3/2011	Shelton, IV et al.	8,028,883 B2	10/2011	Stopek
7,905,381 B2	3/2011	Baxter, III et al.	8,028,884 B2	10/2011	Sniffin et al.
7,905,889 B2	3/2011	Catanese, III et al.	8,028,885 B2	10/2011	Smith et al.
7,905,902 B2	3/2011	Huitema et al.	8,034,077 B2	10/2011	Smith et al.
7,909,191 B2	3/2011	Baker et al.	8,034,363 B2	10/2011	Li et al.
7,909,220 B2	3/2011	Viola	8,037,591 B2	10/2011	Spivey et al.
7,909,221 B2	3/2011	Viola et al.	8,038,045 B2	10/2011	Bettuchi et al.
7,913,891 B2	3/2011	Doll et al.	8,038,046 B2	10/2011	Smith et al.
7,913,893 B2	3/2011	Mastri et al.	8,038,686 B2	10/2011	Huitema et al.
7,914,543 B2	3/2011	Roth et al.	8,043,207 B2	10/2011	Adams
7,914,551 B2	3/2011	Ortiz et al.	8,043,328 B2	10/2011	Hahnen et al.
7,918,376 B1	4/2011	Knodel et al.	8,047,236 B2	11/2011	Perry
7,918,377 B2	4/2011	Measamer et al.	8,056,787 B2	11/2011	Boudreaux et al.
7,918,848 B2	4/2011	Lau et al.	8,056,788 B2	11/2011	Mastri et al.
7,922,061 B2	4/2011	Shelton, IV et al.	8,057,508 B2	11/2011	Shelton, IV
7,922,063 B2	4/2011	Zemlok et al.	8,062,330 B2	11/2011	Prommersberger et al.
7,922,743 B2	4/2011	Heinrich et al.	8,066,167 B2	11/2011	Measamer et al.
7,926,691 B2	4/2011	Viola et al.	8,066,168 B2	11/2011	Vidal et al.
7,927,328 B2	4/2011	Orszulak et al.	D650,074 S	12/2011	Hunt et al.
7,931,660 B2	4/2011	Aranyi et al.	8,070,743 B2	12/2011	Kagan et al.
7,931,695 B2	4/2011	Ringeisen	8,075,571 B2	12/2011	Vitali et al.
7,934,630 B2	5/2011	Shelton, IV et al.	8,083,118 B2	12/2011	Milliman et al.
7,934,631 B2	5/2011	Balbierz et al.	8,083,119 B2	12/2011	Prommersberger
7,935,773 B2	5/2011	Hadba et al.	8,083,120 B2	12/2011	Shelton, IV et al.
7,938,307 B2	5/2011	Bettuchi	8,084,001 B2	12/2011	Burns et al.
7,941,865 B2	5/2011	Seman, Jr. et al.	8,091,756 B2	1/2012	Viola
7,942,303 B2	5/2011	Shah	8,092,932 B2	1/2012	Phillips et al.
7,942,890 B2	5/2011	D'Agostino et al.	8,097,017 B2	1/2012	Viola
7,944,175 B2	5/2011	Mori et al.	8,100,310 B2	1/2012	Zemlok
7,950,560 B2	5/2011	Zemlok et al.	8,105,350 B2	1/2012	Lee et al.
7,950,561 B2	5/2011	Aranyi	8,108,072 B2	1/2012	Zhao et al.
7,951,071 B2	5/2011	Whitman et al.	8,109,426 B2	2/2012	Milliman et al.
7,951,166 B2	5/2011	Orban et al.	8,113,405 B2	2/2012	Milliman
7,954,682 B2	6/2011	Giordano et al.	8,113,410 B2	2/2012	Hall et al.
7,954,684 B2	6/2011	Boudreaux	8,114,100 B2	2/2012	Smith et al.
7,954,686 B2	6/2011	Baxter, III et al.	8,123,103 B2	2/2012	Milliman
7,954,687 B2	6/2011	Zemlok et al.	8,123,767 B2	2/2012	Bauman et al.
7,955,257 B2	6/2011	Frasier et al.	8,127,975 B2	3/2012	Olson et al.
7,959,050 B2	6/2011	Smith et al.	8,128,624 B2	3/2012	Couture et al.
7,959,051 B2	6/2011	Smith et al.	8,128,645 B2	3/2012	Sonnenschein et al.
7,963,432 B2	6/2011	Knodel et al.	8,132,703 B2	3/2012	Milliman et al.
7,963,963 B2	6/2011	Francischelli et al.	8,132,706 B2	3/2012	Marczyk et al.
7,963,964 B2	6/2011	Santilli et al.	8,136,712 B2	3/2012	Zingman
7,966,799 B2	6/2011	Morgan et al.	8,136,713 B2	3/2012	Hathaway et al.
7,967,180 B2	6/2011	Scirica	8,140,417 B2	3/2012	Shibata
7,967,181 B2	6/2011	Viola et al.	8,141,762 B2	3/2012	Bedi et al.
7,967,839 B2	6/2011	Flock et al.	8,141,763 B2	3/2012	Milliman
7,972,298 B2	7/2011	Wallace et al.	8,146,790 B2	4/2012	Milliman
7,980,443 B2	7/2011	Scheib et al.	8,152,041 B2	4/2012	Kostrzewski
7,988,026 B2	8/2011	Knodel et al.	8,157,145 B2	4/2012	Shelton, IV et al.
7,988,027 B2	8/2011	Olson et al.	8,157,148 B2	4/2012	Scirica
7,988,028 B2	8/2011	Farascioni et al.	8,157,152 B2	4/2012	Holsten et al.
7,992,757 B2	8/2011	Wheeler et al.	8,157,153 B2	4/2012	Shelton, IV et al.
7,997,469 B2	8/2011	Olson et al.	8,161,977 B2	4/2012	Shelton, IV et al.
8,002,696 B2	8/2011	Suzuki	8,162,138 B2	4/2012	Bettenhausen et al.
8,002,784 B2	8/2011	Jinno et al.	8,162,197 B2	4/2012	Mastri et al.
			8,167,185 B2	5/2012	Shelton, IV et al.
			8,167,895 B2	5/2012	D'Agostino et al.
			8,167,898 B1	5/2012	Schaller et al.
			8,172,120 B2	5/2012	Boyden et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

8,172,122 B2	5/2012	Kasvikis et al.	8,323,789 B2	12/2012	Rozhin et al.
8,172,124 B2	5/2012	Shelton, IV et al.	8,328,062 B2	12/2012	Viola
8,177,797 B2	5/2012	Shimoji et al.	8,328,063 B2	12/2012	Milliman et al.
8,180,458 B2	5/2012	Kane et al.	8,328,064 B2	12/2012	Racenet et al.
8,181,840 B2	5/2012	Milliman	8,328,802 B2	12/2012	Deville et al.
8,186,555 B2	5/2012	Shelton, IV et al.	8,328,823 B2	12/2012	Aranyi et al.
8,186,560 B2	5/2012	Hess et al.	8,333,313 B2	12/2012	Boudreaux et al.
8,191,752 B2	6/2012	Scirica	8,333,764 B2	12/2012	Francischelli et al.
8,192,460 B2	6/2012	Orban, III et al.	8,336,753 B2	12/2012	Olson et al.
8,196,795 B2 *	6/2012	Moore et al. 227/176.1	8,348,123 B2	1/2013	Scirica et al.
8,196,796 B2	6/2012	Shelton, IV et al.	8,348,127 B2	1/2013	Marczyk
8,201,721 B2	6/2012	Zemlok et al.	8,348,129 B2	1/2013	Bedi et al.
8,205,780 B2	6/2012	Sorrentino et al.	8,348,131 B2	1/2013	Omaits et al.
8,205,781 B2	6/2012	Baxter, III et al.	8,348,972 B2	1/2013	Soltz et al.
8,210,411 B2	7/2012	Yates et al.	8,353,437 B2	1/2013	Boudreaux
8,210,414 B2	7/2012	Bettuchi et al.	8,353,438 B2	1/2013	Baxter, III et al.
8,210,415 B2	7/2012	Ward	8,353,439 B2	1/2013	Baxter, III et al.
8,210,416 B2	7/2012	Milliman et al.	8,357,144 B2	1/2013	Whitman et al.
8,211,125 B2	7/2012	Spivey	8,360,296 B2	1/2013	Zingman
8,214,019 B2	7/2012	Govari et al.	8,360,297 B2	1/2013	Shelton, IV et al.
8,215,531 B2	7/2012	Shelton, IV et al.	8,360,298 B2	1/2013	Farascioni et al.
8,215,533 B2	7/2012	Viola et al.	8,360,299 B2	1/2013	Zemlok et al.
8,220,468 B2	7/2012	Cooper et al.	8,365,973 B1	2/2013	White et al.
8,220,688 B2	7/2012	Laurent et al.	8,365,976 B2	2/2013	Hess et al.
8,220,690 B2	7/2012	Hess et al.	8,366,559 B2	2/2013	Papenfuss et al.
8,221,424 B2	7/2012	Cha	8,371,491 B2	2/2013	Huitema et al.
8,225,799 B2	7/2012	Bettuchi	8,371,492 B2	2/2013	Aranyi et al.
8,226,715 B2	7/2012	Hwang et al.	8,371,493 B2	2/2013	Aranyi et al.
8,231,040 B2	7/2012	Zemlok et al.	8,372,094 B2	2/2013	Bettuchi et al.
8,231,041 B2	7/2012	Marczyk et al.	8,376,865 B2	2/2013	Forster et al.
8,231,042 B2	7/2012	Hessler et al.	8,377,044 B2	2/2013	Coe et al.
8,231,043 B2	7/2012	Tarinelli et al.	8,393,513 B2	3/2013	Jankowski
8,236,010 B2	8/2012	Ortiz et al.	8,393,514 B2	3/2013	Shelton, IV et al.
8,241,271 B2	8/2012	Milliman et al.	8,397,971 B2	3/2013	Yates et al.
8,241,308 B2	8/2012	Kortenbach et al.	8,403,138 B2	3/2013	Weissaupt et al.
8,241,322 B2	8/2012	Whitman et al.	8,403,198 B2	3/2013	Sorrentino et al.
8,245,898 B2	8/2012	Smith et al.	8,403,945 B2	3/2013	Whitfield et al.
8,245,899 B2	8/2012	Swensgard et al.	8,408,439 B2	4/2013	Huang et al.
8,245,900 B2	8/2012	Scirica	8,408,442 B2	4/2013	Racenet et al.
8,245,901 B2	8/2012	Stopek	8,409,079 B2	4/2013	Okamoto et al.
8,246,637 B2	8/2012	Viola et al.	8,409,222 B2	4/2013	Whitfield et al.
8,256,654 B2	9/2012	Bettuchi et al.	8,413,870 B2	4/2013	Pastorelli et al.
8,256,655 B2	9/2012	Sniffin et al.	8,413,871 B2	4/2013	Racenet et al.
8,257,251 B2	9/2012	Shelton, IV et al.	8,413,872 B2	4/2013	Patel
8,257,356 B2	9/2012	Bleich et al.	8,414,577 B2	4/2013	Boudreaux et al.
8,257,391 B2	9/2012	Orban, III et al.	8,424,737 B2	4/2013	Scirica
8,267,300 B2	9/2012	Boudreaux	8,424,739 B2	4/2013	Racenet et al.
8,267,924 B2	9/2012	Zemlok et al.	8,424,740 B2	4/2013	Shelton, IV et al.
8,267,946 B2	9/2012	Whitfield et al.	8,424,741 B2	4/2013	McGuckin, Jr. et al.
8,267,951 B2	9/2012	Whayne et al.	8,430,898 B2	4/2013	Wiener et al.
8,269,121 B2	9/2012	Smith	8,439,246 B1	5/2013	Knodel et al.
8,272,553 B2	9/2012	Mastri et al.	8,444,036 B2	5/2013	Shelton, IV
8,272,554 B2	9/2012	Whitman et al.	8,444,549 B2	5/2013	Viola et al.
8,276,801 B2	10/2012	Zemlok et al.	8,453,904 B2	6/2013	Eskaros et al.
8,276,802 B2	10/2012	Kostrzewski	8,453,907 B2	6/2013	Laurent et al.
8,281,973 B2	10/2012	Wenchell et al.	8,453,908 B2	6/2013	Bedi et al.
8,286,845 B2	10/2012	Perry et al.	8,453,912 B2	6/2013	Mastri et al.
8,287,561 B2	10/2012	Nunez et al.	8,453,914 B2	6/2013	Laurent et al.
8,292,151 B2	10/2012	Viola	8,459,520 B2	6/2013	Giordano et al.
8,292,155 B2	10/2012	Shelton, IV et al.	8,459,525 B2	6/2013	Yates et al.
8,292,157 B2	10/2012	Smith et al.	8,464,922 B2	6/2013	Marczyk
8,292,888 B2	10/2012	Whitman	8,464,923 B2	6/2013	Shelton, IV
8,298,677 B2	10/2012	Wiesner et al.	8,464,924 B2	6/2013	Gresham et al.
8,308,040 B2	11/2012	Huang et al.	8,464,925 B2	6/2013	Hull et al.
8,308,042 B2	11/2012	Aranyi	8,474,677 B2	7/2013	Woodard, Jr. et al.
8,308,046 B2	11/2012	Prommersberger	8,475,453 B2	7/2013	Marczyk et al.
8,308,659 B2	11/2012	Scheibe et al.	8,475,474 B2	7/2013	Bombard et al.
8,313,496 B2	11/2012	Sauer et al.	8,479,969 B2	7/2013	Shelton, IV
8,313,509 B2	11/2012	Kostrzewski	8,485,412 B2	7/2013	Shelton, IV et al.
8,317,070 B2	11/2012	Hueil et al.	8,485,413 B2	7/2013	Scheib et al.
8,317,071 B1	11/2012	Knodel	8,490,853 B2	7/2013	Criscuolo et al.
8,317,074 B2	11/2012	Ortiz et al.	8,496,156 B2	7/2013	Sniffin et al.
8,319,002 B2	11/2012	Daniels et al.	8,496,683 B2	7/2013	Prommersberger et al.
8,322,455 B2	12/2012	Shelton, IV et al.	8,499,993 B2	8/2013	Shelton, IV et al.
8,322,589 B2	12/2012	Boudreaux	8,500,762 B2	8/2013	Sholev et al.
			8,506,557 B2	8/2013	Zemlok et al.
			8,517,239 B2	8/2013	Scheib et al.
			8,517,241 B2	8/2013	Nicholas et al.
			8,517,243 B2	8/2013	Giordano et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

8,517,244 B2	8/2013	Shelton, IV et al.	8,763,877 B2	7/2014	Schall et al.
8,523,881 B2	9/2013	Cabiri et al.	8,777,004 B2	7/2014	Shelton, IV et al.
8,529,588 B2	9/2013	Ahlberg et al.	8,783,541 B2	7/2014	Shelton, IV et al.
8,529,600 B2	9/2013	Woodard, Jr. et al.	8,783,542 B2	7/2014	Riestenberg et al.
8,534,528 B2	9/2013	Shelton, IV	8,783,543 B2	7/2014	Shelton, IV et al.
8,535,304 B2	9/2013	Sklar et al.	8,789,739 B2	7/2014	Swensgard
8,540,128 B2	9/2013	Shelton, IV et al.	8,789,740 B2	7/2014	Baxter, III et al.
8,540,129 B2	9/2013	Baxter, III et al.	8,789,741 B2	7/2014	Baxter, III et al.
8,540,130 B2	9/2013	Moore et al.	8,794,497 B2	8/2014	Zingman
8,540,131 B2	9/2013	Swayze	8,800,838 B2	8/2014	Shelton, IV
8,540,133 B2	9/2013	Bedi et al.	8,800,841 B2	8/2014	Ellerhorst et al.
8,540,733 B2	9/2013	Whitman et al.	8,801,734 B2	8/2014	Shelton, IV et al.
8,556,151 B2	10/2013	Viola	8,801,735 B2	8/2014	Shelton, IV et al.
8,561,870 B2	10/2013	Baxter, III et al.	8,814,024 B2	8/2014	Woodard, Jr. et al.
8,561,873 B2	10/2013	Ingmanson et al.	8,820,605 B2	9/2014	Shelton, IV
8,567,656 B2	10/2013	Shelton, IV et al.	8,827,133 B2	9/2014	Shelton, IV et al.
8,573,461 B2	11/2013	Shelton, IV et al.	8,827,903 B2	9/2014	Shelton, IV et al.
8,573,465 B2	11/2013	Shelton, IV et al.	8,833,632 B2	9/2014	Swensgard
8,579,937 B2	11/2013	Gresham	8,840,003 B2	9/2014	Morgan et al.
8,584,919 B2	11/2013	Hueil et al.	8,840,603 B2	9/2014	Shelton, IV et al.
8,585,721 B2	11/2013	Kirsch	8,844,789 B2	9/2014	Shelton, IV et al.
8,590,762 B2	11/2013	Hess et al.	8,851,354 B2	10/2014	Swensgard et al.
8,602,287 B2	12/2013	Yates et al.	8,857,693 B2	10/2014	Schuckmann et al.
8,602,288 B2	12/2013	Shelton, IV et al.	8,857,694 B2	10/2014	Shelton, IV et al.
8,608,044 B2	12/2013	Hueil et al.	8,858,571 B2	10/2014	Shelton, IV et al.
8,608,045 B2	12/2013	Smith et al.	8,858,590 B2	10/2014	Shelton, IV et al.
8,608,046 B2	12/2013	Laurent et al.	8,864,007 B2	10/2014	Widenhouse et al.
8,616,431 B2	12/2013	Timm et al.	8,864,009 B2	10/2014	Shelton, IV et al.
8,622,274 B2	1/2014	Yates et al.	2001/0025183 A1	9/2001	Shahidi
8,622,275 B2	1/2014	Baxter, III et al.	2001/0044637 A1	11/2001	Jacobs et al.
8,631,987 B2	1/2014	Shelton, IV et al.	2002/0022836 A1	2/2002	Goble et al.
8,632,462 B2	1/2014	Yoo et al.	2002/0029036 A1	3/2002	Goble et al.
8,632,525 B2	1/2014	Kerr et al.	2002/0095175 A1	7/2002	Brock et al.
8,632,535 B2	1/2014	Shelton, IV et al.	2002/0103494 A1	8/2002	Pacey
8,632,563 B2	1/2014	Nagase et al.	2002/0117534 A1	8/2002	Green et al.
8,636,187 B2	1/2014	Hueil et al.	2002/0134811 A1	9/2002	Napier et al.
8,636,736 B2	1/2014	Yates et al.	2002/0165541 A1	11/2002	Whitman
8,647,258 B2	2/2014	Aranyi et al.	2003/0023316 A1	1/2003	Brown et al.
8,652,120 B2	2/2014	Giordano et al.	2003/0078647 A1	4/2003	Vallana et al.
8,652,151 B2	2/2014	Lehman et al.	2003/0084983 A1	5/2003	Rangachari et al.
8,657,174 B2	2/2014	Yates et al.	2003/0093103 A1	5/2003	Malackowski et al.
8,657,176 B2	2/2014	Shelton, IV et al.	2003/0096158 A1	5/2003	Takano et al.
8,657,178 B2	2/2014	Hueil et al.	2003/0105478 A1	6/2003	Whitman et al.
8,668,129 B2	3/2014	Olson	2003/0130677 A1	7/2003	Whitman et al.
8,668,130 B2	3/2014	Hess et al.	2003/0139741 A1	7/2003	Goble et al.
8,672,206 B2	3/2014	Aranyi et al.	2003/0153908 A1	8/2003	Goble et al.
8,672,207 B2	3/2014	Shelton, IV et al.	2003/0163085 A1	8/2003	Tanner et al.
8,672,208 B2	3/2014	Hess et al.	2003/0181900 A1	9/2003	Long
8,679,454 B2	3/2014	Guire et al.	2003/0195387 A1	10/2003	Kortenbach et al.
8,684,253 B2	4/2014	Giordano et al.	2003/0205029 A1	11/2003	Chapolini et al.
8,695,866 B2	4/2014	Leimbach et al.	2003/0216732 A1	11/2003	Truckai et al.
8,696,665 B2	4/2014	Hunt et al.	2003/0220660 A1	11/2003	Kortenbach et al.
8,701,958 B2	4/2014	Shelton, IV et al.	2003/0236505 A1	12/2003	Bonadio et al.
8,701,959 B2	4/2014	Shah	2004/0002726 A1	1/2004	Nunez et al.
8,708,213 B2	4/2014	Shelton, IV et al.	2004/0006335 A1	1/2004	Garrison
8,720,766 B2	5/2014	Hess et al.	2004/0006340 A1	1/2004	Latterell et al.
8,721,666 B2	5/2014	Schroeder et al.	2004/0006372 A1	1/2004	Racenet et al.
8,727,197 B2	5/2014	Hess et al.	2004/0006861 A1	1/2004	Haytayan
8,733,613 B2	5/2014	Huitema et al.	2004/0030333 A1	2/2004	Goble
8,734,478 B2	5/2014	Widenhouse et al.	2004/0034357 A1	2/2004	Beane et al.
8,740,034 B2	6/2014	Morgan et al.	2004/0034369 A1	2/2004	Sauer et al.
8,740,037 B2	6/2014	Shelton, IV et al.	2004/0044364 A1	3/2004	DeVries et al.
8,740,038 B2	6/2014	Shelton, IV et al.	2004/0068161 A1	4/2004	Couvillon, Jr.
8,746,529 B2	6/2014	Shelton, IV et al.	2004/0068224 A1	4/2004	Couvillon, Jr. et al.
8,746,530 B2	6/2014	Giordano et al.	2004/0068307 A1	4/2004	Goble
8,746,535 B2	6/2014	Shelton, IV et al.	2004/0070369 A1	4/2004	Sakakibara
8,747,238 B2	6/2014	Shelton, IV et al.	2004/0073222 A1	4/2004	Koseki
8,752,699 B2	6/2014	Morgan et al.	2004/0078037 A1	4/2004	Batchelor et al.
8,752,747 B2	6/2014	Shelton, IV et al.	2004/0093024 A1	5/2004	Lousararian et al.
8,752,749 B2 *	6/2014	Moore et al. 227/176.1	2004/0094597 A1	5/2004	Whitman et al.
8,757,465 B2	6/2014	Woodard, Jr. et al.	2004/0097987 A1	5/2004	Pugsley et al.
8,758,235 B2	6/2014	Jaworek	2004/0098040 A1	5/2004	Taniguchi et al.
8,758,391 B2	6/2014	Swayze et al.	2004/0101822 A1	5/2004	Wiesner et al.
8,758,438 B2	6/2014	Boyce et al.	2004/0102783 A1	5/2004	Sutterlin, III et al.
8,763,875 B2	7/2014	Morgan et al.	2004/0108357 A1	6/2004	Milliman et al.
			2004/0111081 A1	6/2004	Whitman et al.
			2004/0115022 A1	6/2004	Albertson et al.
			2004/0116952 A1	6/2004	Sakurai et al.
			2004/0147909 A1	7/2004	Johnston et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

2004/0164123	A1	8/2004	Racenet et al.	2005/0261676	A1	11/2005	Hall et al.
2004/0167572	A1	8/2004	Roth et al.	2005/0261677	A1	11/2005	Hall et al.
2004/0173659	A1	9/2004	Green et al.	2005/0263563	A1	12/2005	Racenet et al.
2004/0181219	A1	9/2004	Goble et al.	2005/0267455	A1	12/2005	Eggers et al.
2004/0186470	A1	9/2004	Goble et al.	2005/0274768	A1	12/2005	Cummins et al.
2004/0193189	A1	9/2004	Kortenbach et al.	2005/0283188	A1	12/2005	Loshakove et al.
2004/0199181	A1	10/2004	Knodel et al.	2006/0004407	A1	1/2006	Hiles et al.
2004/0222268	A1	11/2004	Bilotti et al.	2006/0008787	A1	1/2006	Hayman et al.
2004/0225186	A1	11/2004	Horne, Jr. et al.	2006/0011699	A1	1/2006	Olson et al.
2004/0230214	A1	11/2004	Donofrio et al.	2006/0015009	A1	1/2006	Jaffe et al.
2004/0232201	A1	11/2004	Wenchell et al.	2006/0020247	A1	1/2006	Kagan et al.
2004/0236352	A1	11/2004	Wang et al.	2006/0020258	A1	1/2006	Strauss et al.
2004/0243147	A1	12/2004	Lipow	2006/0020336	A1	1/2006	Liddicoat
2004/0243151	A1	12/2004	Demmy et al.	2006/0025811	A1	2/2006	Shelton, IV
2004/0243163	A1	12/2004	Casiano et al.	2006/0025812	A1	2/2006	Shelton, IV
2004/0243176	A1	12/2004	Hahnen et al.	2006/0025813	A1	2/2006	Shelton et al.
2004/0247415	A1	12/2004	Mangone, Jr.	2006/0041188	A1	2/2006	Dirusso et al.
2004/0254566	A1	12/2004	Pllicchi et al.	2006/0047275	A1	3/2006	Goble
2004/0254608	A1	12/2004	Huitema et al.	2006/0047303	A1	3/2006	Ortiz et al.
2004/0260315	A1	12/2004	Dell et al.	2006/0047307	A1	3/2006	Ortiz et al.
2004/0267310	A1	12/2004	Racenet et al.	2006/0049229	A1	3/2006	Milliman et al.
2005/0010213	A1	1/2005	Stad et al.	2006/0052825	A1	3/2006	Ransick et al.
2005/0032511	A1	2/2005	Malone et al.	2006/0060630	A1	3/2006	Shelton, IV et al.
2005/0033357	A1	2/2005	Braun	2006/0064086	A1	3/2006	Odom
2005/0054946	A1	3/2005	Krzyzanowski	2006/0079115	A1	4/2006	Aranyi et al.
2005/0059997	A1	3/2005	Bauman et al.	2006/0079735	A1	4/2006	Martone et al.
2005/0070929	A1	3/2005	Dallessandro et al.	2006/0085031	A1	4/2006	Bettuchi
2005/0075561	A1	4/2005	Golden	2006/0085033	A1	4/2006	Criscuolo et al.
2005/0080454	A1	4/2005	Drews et al.	2006/0086032	A1	4/2006	Valencic et al.
2005/0085693	A1	4/2005	Belson et al.	2006/0087746	A1	4/2006	Lipow
2005/0090817	A1	4/2005	Phan	2006/0089535	A1	4/2006	Raz et al.
2005/0096683	A1	5/2005	Ellins et al.	2006/0100643	A1	5/2006	Laufer et al.
2005/0103819	A1	5/2005	Racenet et al.	2006/0108393	A1	5/2006	Heinrich et al.
2005/0107814	A1	5/2005	Johnston et al.	2006/0111711	A1	5/2006	Goble
2005/0107824	A1	5/2005	Hillstead et al.	2006/0111723	A1	5/2006	Chapolini et al.
2005/0113820	A1	5/2005	Goble et al.	2006/0122636	A1	6/2006	Bailly et al.
2005/0119525	A1	6/2005	Takemoto	2006/0142772	A1	6/2006	Ralph et al.
2005/0119669	A1	6/2005	Demmy	2006/0149163	A1	7/2006	Hibner et al.
2005/0124855	A1	6/2005	Jaffe et al.	2006/0161185	A1	7/2006	Saadat et al.
2005/0125009	A1	6/2005	Perry et al.	2006/0167471	A1	7/2006	Phillips
2005/0125897	A1	6/2005	Wyslucha et al.	2006/0173470	A1	8/2006	Oray et al.
2005/0131173	A1	6/2005	McDaniel et al.	2006/0178556	A1	8/2006	Hasser et al.
2005/0131211	A1	6/2005	Bayley et al.	2006/0180634	A1	8/2006	Shelton, IV et al.
2005/0131390	A1	6/2005	Heinrich et al.	2006/0185682	A1	8/2006	Marczyk
2005/0131436	A1	6/2005	Johnston et al.	2006/0200123	A1	9/2006	Ryan
2005/0131437	A1	6/2005	Johnston et al.	2006/0201989	A1	9/2006	Ojeda
2005/0131457	A1	6/2005	Douglas et al.	2006/0212069	A1	9/2006	Shelton, IV
2005/0137454	A1	6/2005	Saadat et al.	2006/0217729	A1	9/2006	Eskridge et al.
2005/0137455	A1	6/2005	Ewers et al.	2006/0226196	A1	10/2006	Hueil et al.
2005/0143759	A1	6/2005	Kelly	2006/0235368	A1	10/2006	Oz
2005/0143769	A1	6/2005	White et al.	2006/0235469	A1	10/2006	Viola
2005/0145675	A1	7/2005	Hartwick et al.	2006/0241655	A1	10/2006	Viola
2005/0154258	A1	7/2005	Tartaglia et al.	2006/0241692	A1	10/2006	McGuckin, Jr. et al.
2005/0154406	A1	7/2005	Bombard et al.	2006/0244460	A1	11/2006	Weaver
2005/0165419	A1	7/2005	Sauer et al.	2006/0252993	A1	11/2006	Freed et al.
2005/0165435	A1	7/2005	Johnston et al.	2006/0253069	A1	11/2006	Li et al.
2005/0169974	A1	8/2005	Tenerz et al.	2006/0258904	A1	11/2006	Stefanchik et al.
2005/0171522	A1	8/2005	Christopherson	2006/0258910	A1	11/2006	Stefanchik et al.
2005/0177181	A1	8/2005	Kagan et al.	2006/0259073	A1	11/2006	Miyamoto et al.
2005/0182298	A1	8/2005	Ikeda et al.	2006/0264927	A1	11/2006	Ryan
2005/0187545	A1	8/2005	Hooven et al.	2006/0264929	A1	11/2006	Goble et al.
2005/0187572	A1	8/2005	Johnston et al.	2006/0271042	A1	11/2006	Latterell et al.
2005/0187576	A1	8/2005	Whitman et al.	2006/0271102	A1	11/2006	Bosshard et al.
2005/0189397	A1	9/2005	Jankowski	2006/0278680	A1	12/2006	Viola et al.
2005/0192609	A1	9/2005	Whitman et al.	2006/0278681	A1	12/2006	Viola et al.
2005/0192628	A1	9/2005	Viola	2006/0284730	A1	12/2006	Schmid et al.
2005/0203550	A1	9/2005	Laufer et al.	2006/0287576	A1	12/2006	Tsuji et al.
2005/0216055	A1	9/2005	Scirica et al.	2006/0289602	A1	12/2006	Wales et al.
2005/0228224	A1	10/2005	Okada et al.	2006/0291981	A1	12/2006	Viola et al.
2005/0240178	A1	10/2005	Morley et al.	2007/0010838	A1	1/2007	Shelton, IV et al.
2005/0240222	A1	10/2005	Shipp	2007/0023476	A1	2/2007	Whitman et al.
2005/0245965	A1	11/2005	Orban, III et al.	2007/0023477	A1	2/2007	Whitman et al.
2005/0251128	A1	11/2005	Amoah	2007/0027468	A1	2/2007	Wales et al.
2005/0256452	A1	11/2005	DeMarchi et al.	2007/0027469	A1	2/2007	Smith et al.
2005/0256522	A1	11/2005	Francischelli et al.	2007/0027472	A1	2/2007	Hiles et al.
				2007/0027551	A1	2/2007	Farnsworth et al.
				2007/0034668	A1	2/2007	Holsten et al.
				2007/0049966	A1	3/2007	Bonadio et al.
				2007/0051375	A1	3/2007	Milliman

(56)

References Cited

U.S. PATENT DOCUMENTS

2007/0055219 A1	3/2007	Whitman et al.	2008/0172088 A1	7/2008	Smith et al.
2007/0066981 A1	3/2007	Meagher	2008/0183193 A1	7/2008	Omori et al.
2007/0070574 A1	3/2007	Nerheim et al.	2008/0185419 A1	8/2008	Smith et al.
2007/0073341 A1	3/2007	Smith	2008/0190989 A1	8/2008	Crews et al.
2007/0078484 A1	4/2007	Talarico et al.	2008/0197167 A1	8/2008	Viola et al.
2007/0083193 A1	4/2007	Werneth et al.	2008/0200762 A1	8/2008	Stokes et al.
2007/0084897 A1	4/2007	Shelton, IV et al.	2008/0200835 A1	8/2008	Monson et al.
2007/0093869 A1	4/2007	Bloom et al.	2008/0200933 A1	8/2008	Bakos et al.
2007/0102472 A1	5/2007	Shelton, IV	2008/0200949 A1	8/2008	Hiles et al.
2007/0106113 A1	5/2007	Ravo	2008/0228029 A1	9/2008	Mikkaichi et al.
2007/0106317 A1	5/2007	Shelton, IV et al.	2008/0245841 A1	10/2008	Smith et al.
2007/0118175 A1	5/2007	Butler et al.	2008/0251568 A1	10/2008	Zemlok et al.
2007/0129605 A1	6/2007	Schaaf	2008/0251569 A1	10/2008	Smith et al.
2007/0135686 A1	6/2007	Pruitt, Jr. et al.	2008/0255413 A1	10/2008	Zemlok et al.
2007/0135803 A1	6/2007	Belson	2008/0255607 A1	10/2008	Zemlok
2007/0155010 A1	7/2007	Farnsworth et al.	2008/0262654 A1	10/2008	Omori et al.
2007/0158358 A1	7/2007	Mason, II et al.	2008/0283570 A1	11/2008	Boyden et al.
2007/0170225 A1	7/2007	Shelton, IV et al.	2008/0287944 A1	11/2008	Pearson et al.
2007/0173687 A1	7/2007	Shima et al.	2008/0290134 A1	11/2008	Bettuchi et al.
2007/0173806 A1	7/2007	Orszulak et al.	2008/0294179 A1	11/2008	Balbierz et al.
2007/0173813 A1	7/2007	Odom	2008/0296346 A1	12/2008	Shelton, IV et al.
2007/0175950 A1	8/2007	Shelton, IV et al.	2008/0297287 A1	12/2008	Shachar et al.
2007/0175951 A1	8/2007	Shelton, IV et al.	2008/0308602 A1	12/2008	Timm et al.
2007/0175955 A1	8/2007	Shelton, IV et al.	2008/0308603 A1	12/2008	Shelton, IV et al.
2007/0179528 A1	8/2007	Soltz et al.	2008/0308608 A1	12/2008	Prommersberger
2007/0181632 A1	8/2007	Milliman	2008/0314960 A1	12/2008	Marczyk et al.
2007/0194079 A1	8/2007	Hueil et al.	2008/0315829 A1	12/2008	Jones et al.
2007/0194082 A1	8/2007	Morgan et al.	2009/0001121 A1	1/2009	Hess et al.
2007/0203510 A1	8/2007	Bettuchi	2009/0001122 A1	1/2009	Prommersberger et al.
2007/0213750 A1	9/2007	Weadock	2009/0001130 A1	1/2009	Hess et al.
2007/0219571 A1	9/2007	Balbierz et al.	2009/0005807 A1	1/2009	Hess et al.
2007/0221700 A1	9/2007	Ortiz et al.	2009/0005809 A1	1/2009	Hess et al.
2007/0225562 A1	9/2007	Spivey et al.	2009/0012534 A1	1/2009	Madhani et al.
2007/0233163 A1	10/2007	Bombard et al.	2009/0012556 A1	1/2009	Boudreaux et al.
2007/0239028 A1	10/2007	Houser et al.	2009/0018553 A1	1/2009	McLean et al.
2007/0243227 A1	10/2007	Gertner	2009/0020958 A1	1/2009	Soul
2007/0244471 A1	10/2007	Malackowski	2009/0048589 A1	2/2009	Takashino et al.
2007/0246505 A1	10/2007	Pace-Florida et al.	2009/0048612 A1	2/2009	Farritor et al.
2007/0249999 A1	10/2007	Sklar et al.	2009/0054908 A1	2/2009	Zand et al.
2007/0260278 A1	11/2007	Wheeler et al.	2009/0076506 A1	3/2009	Baker
2007/0270784 A1	11/2007	Smith et al.	2009/0078736 A1	3/2009	Van Lue
2007/0270884 A1	11/2007	Smith et al.	2009/0082789 A1	3/2009	Milliman et al.
2007/0276409 A1	11/2007	Ortiz et al.	2009/0088774 A1	4/2009	Swarup et al.
2007/0279011 A1	12/2007	Jones et al.	2009/0090763 A1	4/2009	Zemlok et al.
2007/0286892 A1	12/2007	Herzberg et al.	2009/0092651 A1	4/2009	Shah et al.
2007/0287993 A1	12/2007	Hinman et al.	2009/0093728 A1	4/2009	Hyde et al.
2007/0288044 A1	12/2007	Jinno et al.	2009/0099876 A1	4/2009	Whitman
2007/0299427 A1	12/2007	Yeung et al.	2009/0108048 A1	4/2009	Zemlok et al.
2008/0015598 A1	1/2008	Prommersberger	2009/0112229 A1	4/2009	Omori et al.
2008/0029570 A1	2/2008	Shelton et al.	2009/0114701 A1	5/2009	Zemlok et al.
2008/0029573 A1	2/2008	Shelton et al.	2009/0143805 A1	6/2009	Palmer et al.
2008/0029574 A1	2/2008	Shelton et al.	2009/0143855 A1	6/2009	Weber et al.
2008/0029575 A1	2/2008	Shelton et al.	2009/0149871 A9	6/2009	Kagan et al.
2008/0030170 A1	2/2008	Dacquay et al.	2009/0157067 A1	6/2009	Kane et al.
2008/0035701 A1	2/2008	Racenet et al.	2009/0157087 A1	6/2009	Wei et al.
2008/0041916 A1	2/2008	Milliman et al.	2009/0171147 A1	7/2009	Lee et al.
2008/0041917 A1	2/2008	Racenet et al.	2009/0188964 A1	7/2009	Orlov
2008/0078802 A1	4/2008	Hess et al.	2009/0198272 A1	8/2009	Kerver et al.
2008/0082114 A1	4/2008	McKenna et al.	2009/0204108 A1	8/2009	Steffen
2008/0082125 A1	4/2008	Murray et al.	2009/0206125 A1	8/2009	Huitema et al.
2008/0082126 A1	4/2008	Murray et al.	2009/0206126 A1	8/2009	Huitema et al.
2008/0083808 A1	4/2008	Scirica	2009/0206131 A1	8/2009	Weisenburgh, II et al.
2008/0083813 A1	4/2008	Zemlok et al.	2009/0206133 A1	8/2009	Morgan et al.
2008/0085296 A1	4/2008	Powell et al.	2009/0206137 A1	8/2009	Hall et al.
2008/0086078 A1	4/2008	Powell et al.	2009/0206139 A1	8/2009	Hall et al.
2008/0114315 A1	5/2008	Voegelé et al.	2009/0206141 A1	8/2009	Huitema et al.
2008/0114385 A1	5/2008	Byrum et al.	2009/0206142 A1	8/2009	Huitema et al.
2008/0128469 A1	6/2008	Dallessandro et al.	2009/0213685 A1	8/2009	Mak et al.
2008/0129253 A1	6/2008	Shiue et al.	2009/0242610 A1	10/2009	Shelton, IV et al.
2008/0140115 A1	6/2008	Stopek	2009/0255974 A1	10/2009	Viola
2008/0154299 A1	6/2008	Livneh	2009/0255975 A1	10/2009	Zemlok et al.
2008/0169328 A1	7/2008	Shelton	2009/0255976 A1	10/2009	Marczyk et al.
2008/0169332 A1	7/2008	Shelton et al.	2009/0255977 A1	10/2009	Zemlok
2008/0169333 A1	7/2008	Shelton et al.	2009/0255978 A1	10/2009	Viola et al.
2008/0172087 A1	7/2008	Fuchs et al.	2009/0270895 A1	10/2009	Churchill et al.
			2009/0277949 A1	11/2009	Viola et al.
			2009/0292283 A1	11/2009	Odom
			2009/0308907 A1	12/2009	Nalagatla et al.
			2010/0010511 A1	1/2010	Harris et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

2010/0012704 A1	1/2010	Tarinelli Racenet et al.	2011/0155784 A1	6/2011	Shelton, IV et al.
2010/0023024 A1	1/2010	Zeiner et al.	2011/0155786 A1	6/2011	Shelton, IV
2010/0036370 A1	2/2010	Mirel et al.	2011/0155787 A1	6/2011	Baxter, III et al.
2010/0049084 A1	2/2010	Nock et al.	2011/0163146 A1	7/2011	Ortiz et al.
2010/0057087 A1	3/2010	Cha	2011/0174099 A1	7/2011	Ross et al.
2010/0057107 A1	3/2010	Sorrentino et al.	2011/0174861 A1	7/2011	Shelton, IV et al.
2010/0069942 A1	3/2010	Shelton, IV	2011/0174862 A1	7/2011	Shelton, IV et al.
2010/0072254 A1	3/2010	Aranyi et al.	2011/0178536 A1	7/2011	Kostrzewski
2010/0076475 A1	3/2010	Yates et al.	2011/0192882 A1	8/2011	Hess et al.
2010/0076483 A1	3/2010	Imuta	2011/0210156 A1	9/2011	Smith et al.
2010/0076489 A1	3/2010	Stopek et al.	2011/0253765 A1	10/2011	Nicholas et al.
2010/0087840 A1	4/2010	Ebersole et al.	2011/0275901 A1	11/2011	Shelton, IV
2010/0094289 A1	4/2010	Taylor et al.	2011/0276083 A1	11/2011	Shelton, IV et al.
2010/0096431 A1	4/2010	Smith et al.	2011/0278343 A1	11/2011	Knodel et al.
2010/0108740 A1	5/2010	Pastorelli et al.	2011/0282446 A1	11/2011	Schulte et al.
2010/0108741 A1	5/2010	Hessler et al.	2011/0288573 A1	11/2011	Yates et al.
2010/0133317 A1	6/2010	Shelton, IV et al.	2011/0290851 A1	12/2011	Shelton, IV
2010/0145146 A1	6/2010	Melder	2011/0290853 A1	12/2011	Shelton, IV et al.
2010/0147921 A1	6/2010	Olson	2011/0290854 A1	12/2011	Timm et al.
2010/0147922 A1	6/2010	Olson	2011/0290856 A1	12/2011	Shelton, IV et al.
2010/0147923 A1	6/2010	D'Agostino et al.	2011/0295242 A1	12/2011	Spivey et al.
2010/0163598 A1	7/2010	Belzer	2011/0295269 A1	12/2011	Swensgard et al.
2010/0179022 A1	7/2010	Shirokoshi	2011/0295295 A1	12/2011	Shelton, IV et al.
2010/0179540 A1	7/2010	Marczyk et al.	2012/0004636 A1	1/2012	Lo
2010/0186219 A1	7/2010	Smith	2012/0022523 A1	1/2012	Smith et al.
2010/0193566 A1	8/2010	Scheib et al.	2012/0022630 A1	1/2012	Wübbeling
2010/0200637 A1	8/2010	Beetel	2012/0029272 A1	2/2012	Shelton, IV et al.
2010/0204717 A1	8/2010	Knodel	2012/0046692 A1	2/2012	Smith et al.
2010/0222901 A1	9/2010	Swayze et al.	2012/0071711 A1	3/2012	Shelton, IV et al.
2010/0230465 A1	9/2010	Smith et al.	2012/0074200 A1	3/2012	Schmid et al.
2010/0243707 A1	9/2010	Olson et al.	2012/0080332 A1	4/2012	Shelton, IV et al.
2010/0243708 A1	9/2010	Aranyi et al.	2012/0080336 A1	4/2012	Shelton, IV et al.
2010/0249519 A1	9/2010	Park et al.	2012/0080337 A1	4/2012	Shelton, IV et al.
2010/0258611 A1	10/2010	Smith et al.	2012/0080338 A1	4/2012	Shelton, IV et al.
2010/0268030 A1	10/2010	Viola et al.	2012/0080340 A1	4/2012	Shelton, IV et al.
2010/0276471 A1	11/2010	Whitman	2012/0080344 A1	4/2012	Shelton, IV
2010/0292540 A1	11/2010	Hess et al.	2012/0080475 A1	4/2012	Smith et al.
2010/0294827 A1	11/2010	Boyden et al.	2012/0080478 A1	4/2012	Morgan et al.
2010/0305552 A1	12/2010	Shelton, IV et al.	2012/0080479 A1	4/2012	Shelton, IV
2010/0312261 A1	12/2010	Suzuki et al.	2012/0080482 A1	4/2012	Schall et al.
2010/0320252 A1	12/2010	Viola et al.	2012/0080484 A1	4/2012	Morgan et al.
2010/0331856 A1	12/2010	Carlson et al.	2012/0080485 A1	4/2012	Woodard, Jr. et al.
2010/0331880 A1	12/2010	Stopek	2012/0080486 A1	4/2012	Woodard, Jr. et al.
2011/0003528 A1	1/2011	Lam	2012/0080488 A1	4/2012	Shelton, IV et al.
2011/0006099 A1	1/2011	Hall et al.	2012/0080491 A1	4/2012	Shelton, IV et al.
2011/0006101 A1	1/2011	Hall et al.	2012/0080493 A1	4/2012	Shelton, IV et al.
2011/0011916 A1	1/2011	Levine	2012/0080498 A1	4/2012	Shelton, IV et al.
2011/0017799 A1	1/2011	Whitman et al.	2012/0080499 A1	4/2012	Schall et al.
2011/0017801 A1	1/2011	Zemlok et al.	2012/0080502 A1	4/2012	Morgan et al.
2011/0022032 A1	1/2011	Zemlok et al.	2012/0083835 A1	4/2012	Shelton, IV et al.
2011/0024477 A1	2/2011	Hall et al.	2012/0083836 A1	4/2012	Shelton, IV et al.
2011/0024478 A1	2/2011	Shelton, IV	2012/0138658 A1	6/2012	Ullrich et al.
2011/0024479 A1	2/2011	Swensgard et al.	2012/0150192 A1	6/2012	Dachs, II et al.
2011/0034918 A1	2/2011	Reschke	2012/0175398 A1	7/2012	Sandborn et al.
2011/0036887 A1	2/2011	Zemlok et al.	2012/0187179 A1	7/2012	Gleiman
2011/0036890 A1	2/2011	Ma	2012/0199632 A1	8/2012	Spivey et al.
2011/0036891 A1	2/2011	Zemlok et al.	2012/0209289 A1	8/2012	Duque et al.
2011/0045047 A1	2/2011	Bennett et al.	2012/0223123 A1	9/2012	Baxter, III et al.
2011/0060363 A1	3/2011	Hess et al.	2012/0234890 A1	9/2012	Aronhalt et al.
2011/0068148 A1	3/2011	Hall et al.	2012/0234891 A1	9/2012	Aronhalt et al.
2011/0084112 A1	4/2011	Kostrzewski	2012/0234892 A1	9/2012	Aronhalt et al.
2011/0087276 A1	4/2011	Bedi et al.	2012/0234895 A1	9/2012	O'Connor et al.
2011/0087279 A1	4/2011	Shah et al.	2012/0234897 A1	9/2012	Shelton, IV et al.
2011/0095068 A1	4/2011	Patel	2012/0234898 A1	9/2012	Shelton, IV et al.
2011/0101065 A1	5/2011	Milliman	2012/0234899 A1	9/2012	Scheib et al.
2011/0114697 A1	5/2011	Baxter, III et al.	2012/0238823 A1	9/2012	Hagerty et al.
2011/0114700 A1	5/2011	Baxter, III et al.	2012/0238824 A1	9/2012	Widenhouse et al.
2011/0118754 A1	5/2011	Dachs, II et al.	2012/0239009 A1	9/2012	Mollere et al.
2011/0118778 A1	5/2011	Burbank	2012/0239010 A1	9/2012	Shelton, IV et al.
2011/0125176 A1	5/2011	Yates et al.	2012/0241491 A1	9/2012	Aldridge et al.
2011/0125177 A1	5/2011	Yates et al.	2012/0241492 A1	9/2012	Shelton, IV et al.
2011/0132964 A1	6/2011	Weisenburgh, II et al.	2012/0241493 A1	9/2012	Baxter, III et al.
2011/0144430 A1	6/2011	Spivey et al.	2012/0241496 A1	9/2012	Mandakolathur Vasudevan et al.
2011/0144640 A1	6/2011	Heinrich et al.	2012/0241497 A1	9/2012	Mandakolathur Vasudevan et al.
2011/0147433 A1	6/2011	Shelton, IV et al.	2012/0241498 A1	9/2012	Gonzalez et al.
			2012/0241499 A1	9/2012	Baxter, III et al.
			2012/0241500 A1	9/2012	Timmer et al.
			2012/0241501 A1	9/2012	Swayze et al.
			2012/0241502 A1	9/2012	Aldridge et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

2012/0241503	A1	9/2012	Baxter, III et al.	2013/0206814	A1	8/2013	Morgan et al.
2012/0241505	A1	9/2012	Alexander, III et al.	2013/0214030	A1	8/2013	Aronhalt et al.
2012/0248169	A1	10/2012	Widenhouse et al.	2013/0221063	A1	8/2013	Aronhalt et al.
2012/0253298	A1	10/2012	Henderson et al.	2013/0221064	A1	8/2013	Aronhalt et al.
2012/0265176	A1	10/2012	Braun	2013/0221065	A1	8/2013	Aronhalt et al.
2012/0273550	A1	11/2012	Scirica	2013/0233906	A1	9/2013	Hess et al.
2012/0283707	A1	11/2012	Giordano et al.	2013/0248576	A1	9/2013	Laurent et al.
2012/0283748	A1	11/2012	Ortiz et al.	2013/0248577	A1	9/2013	Leimbach et al.
2012/0289979	A1	11/2012	Eskaros et al.	2013/0256365	A1	10/2013	Shelton, IV et al.
2012/0292367	A1	11/2012	Morgan et al.	2013/0256366	A1	10/2013	Shelton, IV et al.
2012/0296333	A1	11/2012	Twomey	2013/0256367	A1	10/2013	Scheib et al.
2012/0298719	A1	11/2012	Shelton, IV et al.	2013/0256368	A1	10/2013	Timm et al.
2012/0298722	A1	11/2012	Hess et al.	2013/0256369	A1	10/2013	Schmid et al.
2012/0310255	A1	12/2012	Brisson et al.	2013/0256371	A1	10/2013	Shelton, IV et al.
2012/0310256	A1	12/2012	Brisson	2013/0256372	A1	10/2013	Baxter, III et al.
2012/0312860	A1	12/2012	Ming et al.	2013/0256373	A1	10/2013	Schmid et al.
2012/0318842	A1	12/2012	Anim et al.	2013/0256374	A1	10/2013	Shelton, IV et al.
2012/0318843	A1	12/2012	Henderson et al.	2013/0256375	A1	10/2013	Shelton, IV et al.
2012/0318844	A1	12/2012	Shelton, IV et al.	2013/0256376	A1	10/2013	Barton et al.
2012/0325892	A1	12/2012	Kostrzewski	2013/0256377	A1	10/2013	Schmid et al.
2013/0012931	A1	1/2013	Spivey et al.	2013/0256378	A1	10/2013	Schmid et al.
2013/0018361	A1	1/2013	Bryant	2013/0256379	A1	10/2013	Schmid et al.
2013/0020375	A1	1/2013	Shelton, IV et al.	2013/0256380	A1	10/2013	Schmid et al.
2013/0020376	A1	1/2013	Shelton, IV et al.	2013/0256382	A1	10/2013	Swayze et al.
2013/0023861	A1	1/2013	Shelton, IV et al.	2013/0256383	A1	10/2013	Aronhalt et al.
2013/0026208	A1	1/2013	Shelton, IV et al.	2013/0261648	A1	10/2013	Laurent et al.
2013/0026210	A1	1/2013	Shelton, IV et al.	2013/0270322	A1	10/2013	Scheib et al.
2013/0037596	A1	2/2013	Bear et al.	2013/0277412	A1	10/2013	Gresham et al.
2013/0048697	A1	2/2013	Shelton, IV et al.	2013/0310873	A1	11/2013	Stopek et al.
2013/0056518	A1	3/2013	Swensgard	2013/0313303	A1	11/2013	Shelton, IV et al.
2013/0056521	A1	3/2013	Swensgard	2013/0313304	A1	11/2013	Shelton, IV et al.
2013/0062391	A1	3/2013	Boudreaux et al.	2013/0313306	A1	11/2013	Shelton, IV et al.
2013/0075448	A1	3/2013	Schmid et al.	2013/0324981	A1	12/2013	Smith et al.
2013/0075449	A1	3/2013	Schmid et al.	2013/0324982	A1	12/2013	Smith et al.
2013/0075450	A1	3/2013	Schmid et al.	2013/0327809	A1	12/2013	Shelton, IV et al.
2013/0079814	A1	3/2013	Hess et al.	2013/0327810	A1	12/2013	Swayze et al.
2013/0087597	A1	4/2013	Shelton, IV et al.	2013/0334278	A1	12/2013	Kerr et al.
2013/0087599	A1	4/2013	Krumanaker et al.	2013/0334283	A1	12/2013	Swayze et al.
2013/0087602	A1	4/2013	Olson et al.	2013/0334284	A1	12/2013	Swayze et al.
2013/0098970	A1	4/2013	Racenet et al.	2013/0334285	A1	12/2013	Swayze et al.
2013/0103024	A1	4/2013	Monson et al.	2013/0334286	A1	12/2013	Swayze et al.
2013/0116668	A1	5/2013	Shelton, IV et al.	2013/0334287	A1	12/2013	Shelton, IV
2013/0116669	A1	5/2013	Shelton, IV et al.	2013/0334288	A1	12/2013	Shelton, IV
2013/0119108	A1	5/2013	Altman et al.	2013/0341374	A1	12/2013	Shelton, IV et al.
2013/0123822	A1	5/2013	Wellman et al.	2014/0000411	A1	1/2014	Shelton, IV et al.
2013/0126581	A1	5/2013	Yates et al.	2014/0001231	A1	1/2014	Shelton, IV et al.
2013/0126582	A1	5/2013	Shelton, IV et al.	2014/0001234	A1	1/2014	Shelton, IV et al.
2013/0146641	A1	6/2013	Shelton, IV et al.	2014/0001235	A1	1/2014	Shelton, IV
2013/0146642	A1	6/2013	Shelton, IV et al.	2014/0001236	A1	1/2014	Shelton, IV et al.
2013/0146643	A1	6/2013	Schmid et al.	2014/0001237	A1	1/2014	Shelton, IV et al.
2013/0150832	A1	6/2013	Belson et al.	2014/0001238	A1	1/2014	Shelton, IV et al.
2013/0153634	A1	6/2013	Carter et al.	2014/0001239	A1	1/2014	Shelton, IV et al.
2013/0153636	A1	6/2013	Shelton, IV et al.	2014/0001240	A1	1/2014	Shelton, IV et al.
2013/0153641	A1	6/2013	Shelton, IV et al.	2014/0005640	A1	1/2014	Shelton, IV et al.
2013/0161374	A1	6/2013	Swayze et al.	2014/0005653	A1	1/2014	Shelton, IV et al.
2013/0161375	A1	6/2013	Huitema et al.	2014/0005661	A1	1/2014	Shelton, IV et al.
2013/0168435	A1	7/2013	Huang et al.	2014/0005662	A1	1/2014	Shelton, IV
2013/0172929	A1	7/2013	Hess et al.	2014/0005676	A1	1/2014	Shelton, IV et al.
2013/0175317	A1	7/2013	Yates et al.	2014/0005678	A1	1/2014	Shelton, IV et al.
2013/0175321	A1	7/2013	Shelton, IV et al.	2014/0005679	A1	1/2014	Shelton, IV et al.
2013/0175322	A1	7/2013	Yates et al.	2014/0005680	A1	1/2014	Shelton, IV et al.
2013/0181033	A1	7/2013	Shelton, IV et al.	2014/0005693	A1	1/2014	Shelton, IV et al.
2013/0181034	A1	7/2013	Shelton, IV et al.	2014/0005694	A1	1/2014	Shelton, IV et al.
2013/0184718	A1	7/2013	Smith et al.	2014/0005695	A1	1/2014	Shelton, IV
2013/0184719	A1	7/2013	Shelton, IV et al.	2014/0005702	A1	1/2014	Timm et al.
2013/0186932	A1	7/2013	Shelton, IV et al.	2014/0005708	A1	1/2014	Shelton, IV
2013/0186933	A1	7/2013	Shelton, IV et al.	2014/0005718	A1	1/2014	Shelton, IV et al.
2013/0186934	A1	7/2013	Shelton, IV et al.	2014/0008414	A1	1/2014	Shelton, IV et al.
2013/0186936	A1	7/2013	Shelton, IV	2014/0014705	A1	1/2014	Baxter, III
2013/0190733	A1	7/2013	Giordano et al.	2014/0042205	A1	2/2014	Baxter, III et al.
2013/0190757	A1	7/2013	Yates et al.	2014/0048582	A1	2/2014	Shelton, IV et al.
2013/0193188	A1	8/2013	Shelton, IV et al.	2014/0061279	A1	3/2014	Laurent et al.
2013/0193189	A1	8/2013	Swensgard et al.	2014/0097227	A1	4/2014	Aronhalt et al.
2013/0197556	A1	8/2013	Shelton, IV et al.	2014/0107640	A1	4/2014	Yates et al.
2013/0200132	A1	8/2013	Moore et al.	2014/0128850	A1	5/2014	Kerr et al.
				2014/0151433	A1	6/2014	Shelton, IV et al.
				2014/0151434	A1	6/2014	Shelton, IV et al.
				2014/0166722	A1	6/2014	Hess et al.
				2014/0166724	A1	6/2014	Schellin et al.

(56)

References Cited

FOREIGN PATENT DOCUMENTS

U.S. PATENT DOCUMENTS					
			AU	2012200178	B2 7/2013
			CA	2458946	A1 3/2003
2014/0166725	A1	6/2014 Schellin et al.	CA	2512960	A1 1/2006
2014/0166726	A1	6/2014 Schellin et al.	CA	2514274	A1 1/2006
2014/0171966	A1	6/2014 Giordano et al.	CA	2639177	A1 2/2009
2014/0175152	A1	6/2014 Hess et al.	CN	2488482	Y 5/2002
2014/0175154	A1	6/2014 Shelton, IV et al.	CN	1523725	A 8/2004
2014/0175155	A1	6/2014 Shelton, IV et al.	CN	1634601	A 7/2005
2014/0175156	A1	6/2014 Hess et al.	CN	1726874	A 2/2006
2014/0191014	A1	7/2014 Shelton, IV	CN	1868411	A 11/2006
2014/0191015	A1	7/2014 Shelton, IV	CN	1915180	A 2/2007
2014/0197223	A1	7/2014 Hess et al.	CN	101011286	A 8/2007
2014/0205637	A1	7/2014 Widenhouse et al.	CN	101095621	A 1/2008
2014/0207166	A1	7/2014 Shelton, IV et al.	CN	101023879	B 3/2013
2014/0224686	A1	8/2014 Aronhalt et al.	DE	273689	C 5/1914
2014/0224857	A1	8/2014 Schmid	DE	1775926	A 1/1972
2014/0236184	A1	8/2014 Leimbach et al.	DE	3036217	A1 4/1982
2014/0243865	A1	8/2014 Swayze et al.	DE	3212828	A1 11/1982
2014/0246471	A1	9/2014 Jaworek et al.	DE	3210466	A1 9/1983
2014/0246472	A1	9/2014 Kimsey et al.	DE	3709067	A1 9/1988
2014/0246473	A1	9/2014 Auld	DE	9412228	U 9/1994
2014/0246474	A1	9/2014 Hall et al.	DE	19509116	A1 9/1996
2014/0246475	A1	9/2014 Hall et al.	DE	19851291	A1 1/2000
2014/0246476	A1	9/2014 Hall et al.	DE	19924311	A1 11/2000
2014/0246477	A1	9/2014 Koch, Jr. et al.	DE	69328576	T2 1/2001
2014/0246478	A1	9/2014 Baber et al.	DE	20016423	U1 2/2001
2014/0246479	A1	9/2014 Baber et al.	DE	10052679	A1 5/2001
2014/0249557	A1	9/2014 Koch, Jr. et al.	DE	20112837	U1 10/2001
2014/0252066	A1	9/2014 Shelton, IV et al.	DE	20121753	U1 4/2003
2014/0252067	A1	9/2014 Moore et al.	DE	10314072	A1 10/2004
2014/0252068	A1	9/2014 Shelton, IV et al.	DE	202007003114	U1 6/2007
2014/0252069	A1	9/2014 Moore et al.	EP	0000756	A1 2/1979
2014/0259591	A1	9/2014 Shelton, IV et al.	EP	0122046	A1 10/1984
2014/0263537	A1	9/2014 Leimbach et al.	EP	0070230	B1 10/1985
2014/0263538	A1	9/2014 Leimbach et al.	EP	0156774	A2 10/1985
2014/0263539	A1	9/2014 Leimbach et al.	EP	0387980	B1 10/1985
2014/0263541	A1	9/2014 Leimbach et al.	EP	0033548	B1 5/1986
2014/0263542	A1	9/2014 Leimbach et al.	EP	0077262	B1 8/1986
2014/0263543	A1	9/2014 Leimbach et al.	EP	0129442	B1 11/1987
2014/0263551	A1	9/2014 Hall et al.	EP	0276104	A2 7/1988
2014/0263552	A1	9/2014 Hall et al.	EP	0178940	B1 1/1991
2014/0263553	A1	9/2014 Hall et al.	EP	0178941	B1 1/1991
2014/0263554	A1	9/2014 Leimbach et al.	EP	0169044	B1 6/1991
2014/0263555	A1	9/2014 Leimbach et al.	EP	0248844	B1 1/1993
2014/0263564	A1	9/2014 Leimbach et al.	EP	0539762	A1 5/1993
2014/0263565	A1	9/2014 Lytle, IV et al.	EP	0545029	A1 6/1993
2014/0263571	A1	9/2014 Morgan et al.	EP	0277959	B1 10/1993
2014/0263572	A1	9/2014 Shelton, IV et al.	EP	0233940	B1 11/1993
2014/0277017	A1	9/2014 Leimbach et al.	EP	0261230	B1 11/1993
2014/0284371	A1	9/2014 Morgan et al.	EP	0639349	A2 2/1994
2014/0284373	A1	9/2014 Shelton, IV et al.	EP	0324636	B1 3/1994
2014/0291378	A1	10/2014 Shelton, IV et al.	EP	0593920	A1 4/1994
2014/0291379	A1	10/2014 Schellin et al.	EP	0594148	A1 4/1994
2014/0291380	A1	10/2014 Weaner et al.	EP	0427949	B1 6/1994
2014/0291381	A1	10/2014 Weaner et al.	EP	0523174	B1 6/1994
2014/0291382	A1	10/2014 Lloyd et al.	EP	0600182	A2 6/1994
2014/0291383	A1	10/2014 Spivey et al.	EP	0310431	B1 11/1994
2014/0296873	A1	10/2014 Morgan et al.	EP	0375302	B1 11/1994
2014/0296874	A1	10/2014 Morgan et al.	EP	0376562	B1 11/1994
2014/0299648	A1	10/2014 Shelton, IV et al.	EP	0630612	A1 12/1994
2014/0299649	A1	10/2014 Shelton, IV et al.	EP	0634144	A1 1/1995
2014/0303645	A1	10/2014 Morgan et al.	EP	0646356	A2 4/1995
2014/0303646	A1	10/2014 Morgan et al.	EP	0646357	A1 4/1995
2014/0305986	A1	10/2014 Hall et al.	EP	0505036	B1 5/1995
2014/0305987	A1	10/2014 Parihar et al.	EP	0653189	A2 5/1995
2014/0305988	A1	10/2014 Boudreaux et al.	EP	0669104	A1 8/1995
2014/0305989	A1	10/2014 Parihar et al.	EP	0511470	B1 10/1995
2014/0305990	A1	10/2014 Shelton, IV et al.	EP	0674876	A2 10/1995
2014/0305991	A1	10/2014 Parihar et al.	EP	0679367	A2 11/1995
2014/0305992	A1	10/2014 Kimsey et al.	EP	0392547	B1 12/1995
2014/0305993	A1	10/2014 Timm et al.	EP	0685204	A1 12/1995
2014/0305994	A1	10/2014 Parihar et al.	EP	0364216	B1 1/1996
2014/0305995	A1	10/2014 Shelton, IV et al.	EP	0699418	A1 3/1996
2014/0309665	A1	10/2014 Parihar et al.	EP	0702937	A1 3/1996
2014/0309666	A1	10/2014 Shelton, IV et al.	EP	0705571	A1 4/1996
			EP	0711611	A2 5/1996
			EP	0484677	B2 6/1996

(56)

References Cited

FOREIGN PATENT DOCUMENTS

EP	0541987	B1	7/1996	EP	1402837	A1	3/2004
EP	0667119	B1	7/1996	EP	0705570	B1	4/2004
EP	0737446	A1	10/1996	EP	0959784	B1	4/2004
EP	0748614	A1	12/1996	EP	1407719	A2	4/2004
EP	0708618	B1	3/1997	EP	1086713	B1	5/2004
EP	0770355	A1	5/1997	EP	0996378	B1	6/2004
EP	0503662	B1	6/1997	EP	1426012	A1	6/2004
EP	0447121	B1	7/1997	EP	0833593	B2	7/2004
EP	0621009	B1	7/1997	EP	1442694	A1	8/2004
EP	0625077	B1	7/1997	EP	0888749	B1	9/2004
EP	0633749	B1	8/1997	EP	0959786	B1	9/2004
EP	0710090	B1	8/1997	EP	1459695	A1	9/2004
EP	0578425	B1	9/1997	EP	1254636	B1	10/2004
EP	0625335	B1	11/1997	EP	1473819	A1	11/2004
EP	0552423	B1	1/1998	EP	1477119	A1	11/2004
EP	0592244	B1	1/1998	EP	1479345	A1	11/2004
EP	0648476	B1	1/1998	EP	1479347	A1	11/2004
EP	0649290	B1	3/1998	EP	1479348	A1	11/2004
EP	0598618	B1	9/1998	EP	0754437	B2	12/2004
EP	0676173	B1	9/1998	EP	1025807	B1	12/2004
EP	0678007	B1	9/1998	EP	1001710	B1	1/2005
EP	0869104	A1	10/1998	EP	1520521	A1	4/2005
EP	0603472	B1	11/1998	EP	1520522	A1	4/2005
EP	0605351	B1	11/1998	EP	1520523	A1	4/2005
EP	0878169	A1	11/1998	EP	1520525	A1	4/2005
EP	0879742	A1	11/1998	EP	1522264	A1	4/2005
EP	0695144	B1	12/1998	EP	1523942	A2	4/2005
EP	0722296	B1	12/1998	EP	1550408	A1	7/2005
EP	0760230	B1	2/1999	EP	1557129	A1	7/2005
EP	0623316	B1	3/1999	EP	1064883	B1	8/2005
EP	0650701	B1	3/1999	EP	1067876	B1	8/2005
EP	0537572	B1	6/1999	EP	0870473	B1	9/2005
EP	0923907	A1	6/1999	EP	1157666	B1	9/2005
EP	0640317	A1	9/1999	EP	0880338	B1	10/2005
EP	0843906	B1	3/2000	EP	1158917	B1	11/2005
EP	0552050	B1	5/2000	EP	1344498	B1	11/2005
EP	0833592	B1	5/2000	EP	0906764	B1	12/2005
EP	0832605	B1	6/2000	EP	1330989	B1	12/2005
EP	0830094	B1	9/2000	EP	0771176	B2	1/2006
EP	1034747	A1	9/2000	EP	1621138	A2	2/2006
EP	1034748	A1	9/2000	EP	1621139	A2	2/2006
EP	0694290	B1	11/2000	EP	1621141	A2	2/2006
EP	1050278	A1	11/2000	EP	1621145	A2	2/2006
EP	1053719	A1	11/2000	EP	1621151	A2	2/2006
EP	1053720	A1	11/2000	EP	1034746	B1	3/2006
EP	1055399	A1	11/2000	EP	1201196	B1	3/2006
EP	1055400	A1	11/2000	EP	1632191	A2	3/2006
EP	1080694	A1	3/2001	EP	1647231	A1	4/2006
EP	1090592	A1	4/2001	EP	1065981	B1	5/2006
EP	1095627	A1	5/2001	EP	1082944	B1	5/2006
EP	1256318	B1	5/2001	EP	1230899	B1	5/2006
EP	0806914	B1	9/2001	EP	1652481	A2	5/2006
EP	0768840	B1	12/2001	EP	1382303	B1	6/2006
EP	0908152	B1	1/2002	EP	1253866	B1	7/2006
EP	0872213	B1	5/2002	EP	1032318	B1	8/2006
EP	0862386	B1	6/2002	EP	1045672	B1	8/2006
EP	0949886	B1	9/2002	EP	1617768	B1	8/2006
EP	1238634	A2	9/2002	EP	1693015	A2	8/2006
EP	0858295	B1	12/2002	EP	1400214	B1	9/2006
EP	0656188	B1	1/2003	EP	1702567	A2	9/2006
EP	0717960	B1	2/2003	EP	1129665	B1	11/2006
EP	1284120	A1	2/2003	EP	1400206	B1	11/2006
EP	1287788	A1	3/2003	EP	1721568	A1	11/2006
EP	0717966	B1	4/2003	EP	1256317	B1	12/2006
EP	0869742	B1	5/2003	EP	1285633	B1	12/2006
EP	0829235	B1	6/2003	EP	1728473	A1	12/2006
EP	0887046	B1	7/2003	EP	1728475	A2	12/2006
EP	0852480	B1	8/2003	EP	1736105	A1	12/2006
EP	0891154	B1	9/2003	EP	1011494	B1	1/2007
EP	0813843	B1	10/2003	EP	1479346	B1	1/2007
EP	0873089	B1	10/2003	EP	1484024	B1	1/2007
EP	0856326	B1	11/2003	EP	1749485	A1	2/2007
EP	1374788	A1	1/2004	EP	1754445	A2	2/2007
EP	0741996	B1	2/2004	EP	1759812	A1	3/2007
EP	0814712	B1	2/2004	EP	1767157	A1	3/2007
				EP	1767163	A1	3/2007
				EP	1769756	A1	4/2007
				EP	1769758	A1	4/2007
				EP	1581128	B1	5/2007

(56)	References Cited			EP	2098170	A2	9/2009
	FOREIGN PATENT DOCUMENTS			EP	2110082	A1	10/2009
				EP	2111803	A2	10/2009
				EP	1762190	B8	11/2009
EP	1780825	A1	5/2007	EP	1813208	B1	11/2009
EP	1785097	A2	5/2007	EP	1908426	B1	11/2009
EP	1790293	A2	5/2007	EP	2116195	A1	11/2009
EP	1790294	A1	5/2007	EP	1607050	B1	12/2009
EP	1563793	B1	6/2007	EP	1815804	B1	12/2009
EP	1800610	A1	6/2007	EP	1875870	B1	12/2009
EP	1300117	B1	8/2007	EP	1878395	B1	1/2010
EP	1813199	A1	8/2007	EP	2151204	A1	2/2010
EP	1813200	A2	8/2007	EP	2165656	A2	3/2010
EP	1813201	A1	8/2007	EP	2165660	A2	3/2010
EP	1813202	A1	8/2007	EP	1566150	B1	4/2010
EP	1813203	A2	8/2007	EP	1813206	B1	4/2010
EP	1813207	A1	8/2007	EP	1769754	B1	6/2010
EP	1813209	A1	8/2007	EP	1854416	B1	6/2010
EP	1330991	B1	9/2007	EP	2198787	A1	6/2010
EP	1837041	A1	9/2007	EP	1647286	B1	9/2010
EP	0922435	B1	10/2007	EP	1825821	B1	9/2010
EP	1487359	B1	10/2007	EP	1535565	B1	10/2010
EP	1599146	B1	10/2007	EP	1702570	B1	10/2010
EP	1839596	A1	10/2007	EP	1785098	B1	10/2010
EP	2110083	A2	10/2007	EP	2005896	B1	10/2010
EP	1679096	B1	11/2007	EP	2030578	B1	11/2010
EP	1857057	A2	11/2007	EP	2036505	B1	11/2010
EP	1402821	B1	12/2007	EP	2245993	A2	11/2010
EP	1872727	A1	1/2008	EP	1627605	B1	12/2010
EP	1550410	B1	2/2008	EP	2027811	B1	12/2010
EP	1671593	B1	2/2008	EP	2130498	B1	12/2010
EP	1897502	A1	3/2008	EP	1994890	B1	1/2011
EP	1611856	B1	4/2008	EP	2005900	B1	1/2011
EP	1908417	A2	4/2008	EP	2286738	A2	2/2011
EP	1330201	B1	6/2008	EP	1690502	B1	3/2011
EP	1702568	B1	7/2008	EP	2292153	A1	3/2011
EP	1943955	A2	7/2008	EP	1769755	B1	4/2011
EP	1943957	A2	7/2008	EP	2090240	B1	4/2011
EP	1943959	A1	7/2008	EP	2305135	A1	4/2011
EP	1943962	A2	7/2008	EP	2314254	A2	4/2011
EP	1943964	A1	7/2008	EP	1813205	B1	6/2011
EP	1943976	A2	7/2008	EP	2090243	B1	6/2011
EP	1593337	B1	8/2008	EP	2329773	A1	6/2011
EP	1970014	A1	9/2008	EP	2353545	A1	8/2011
EP	1980213	A2	10/2008	EP	2361562	A1	8/2011
EP	1759645	B1	11/2008	EP	1836986	B1	11/2011
EP	1990014	A2	11/2008	EP	1908414	B1	11/2011
EP	1552795	B1	12/2008	EP	2153781	B1	11/2011
EP	1693008	B1	12/2008	EP	2389928	A2	11/2011
EP	1759640	B1	12/2008	EP	1847225	B1	12/2011
EP	1997439	A2	12/2008	EP	2399538	A2	12/2011
EP	2000102	A2	12/2008	EP	1785102	B1	1/2012
EP	2005894	A2	12/2008	EP	2090253	B1	3/2012
EP	2005901	A1	12/2008	EP	2430986	A2	3/2012
EP	2008595	A2	12/2008	EP	2457519	A1	5/2012
EP	1736104	B1	3/2009	EP	2462880	A2	6/2012
EP	1749486	B1	3/2009	EP	1813204	B1	7/2012
EP	1782743	B1	3/2009	EP	2189121	B1	7/2012
EP	2039302	A2	3/2009	EP	2005895	B1	8/2012
EP	2039308	A2	3/2009	EP	2090248	B1	8/2012
EP	2039316	A2	3/2009	EP	2481359	A1	8/2012
EP	1721576	B1	4/2009	EP	1935351	B1	9/2012
EP	1733686	B1	4/2009	EP	2497431	A1	9/2012
EP	2044890	A1	4/2009	EP	1616549	B1	10/2012
EP	1550409	B1	6/2009	EP	2030579	B1	10/2012
EP	1550413	B1	6/2009	EP	2090252	B1	10/2012
EP	1719461	B1	6/2009	EP	2517637	A1	10/2012
EP	1834594	B1	6/2009	EP	2517638	A1	10/2012
EP	1709911	B1	7/2009	EP	2517642	A2	10/2012
EP	2077093	A2	7/2009	EP	2517645	A2	10/2012
EP	1745748	B1	8/2009	EP	2517649	A2	10/2012
EP	2090231	A1	8/2009	EP	2517651	A2	10/2012
EP	2090237	A1	8/2009	EP	1884206	B1	3/2013
EP	2090241	A1	8/2009	EP	2090238	B1	4/2013
EP	2090244	A2	8/2009	EP	1982657	B1	7/2013
EP	2090245	A1	8/2009	EP	2090234	B1	9/2013
EP	2090254	A1	8/2009	EP	2633830	A1	9/2013
EP	2090256	A2	8/2009	EP	2644124	A1	10/2013
EP	2095777	A2	9/2009	EP	2644209	A2	10/2013

(56)	References Cited			JP	2003-164066	6/2003
	FOREIGN PATENT DOCUMENTS			JP	2003-521301 A	7/2003
				JP	2004-162035 A	6/2004
				JP	2004-229976 A	8/2004
EP	2700367 A1	2/2014		JP	2004-524076 A	8/2004
EP	1772105 B1	5/2014		JP	2004-531280 A	10/2004
ES	2396594 T3	2/2013		JP	2004-532084 A	10/2004
FR	459743 A	11/1913		JP	2004-532676 A	10/2004
FR	999646 A	2/1952		JP	2004-329624 A	11/2004
FR	1112936 A	3/1956		JP	2004-337617 A	12/2004
FR	2598905 A1	11/1987		JP	2004-344663	12/2004
FR	2765794 A	1/1999		JP	2005-028147 A	2/2005
FR	2815842	10/2000		JP	2005-28148 A	2/2005
GB	939929 A	10/1963		JP	2005-028149 A	2/2005
GB	1210522 A	10/1970		JP	2005-505309 A	2/2005
GB	1217159 A	12/1970		JP	2005505322 T	2/2005
GB	1339394 A	12/1973		JP	2005-103280 A	4/2005
GB	2024012 A	1/1980		JP	2005-103281 A	4/2005
GB	2109241 A	6/1983		JP	2005-511131 A	4/2005
GB	2272159 A	5/1994		JP	2005103293 A	4/2005
GB	2284242 A	5/1995		JP	2005131163 A	5/2005
GB	2336214 A	10/1999		JP	2005131164 A	5/2005
GB	2425903 A	11/2006		JP	2005131173 A	5/2005
GR	93100110 A	11/1993		JP	2005131211 A	5/2005
JP	50-33988 U	4/1975		JP	2005131212 A	5/2005
JP	S 58500053 A	1/1983		JP	2005-137919 A	6/2005
JP	60-100955 A	6/1985		JP	2005-144183 A	6/2005
JP	61-98249 A	5/1986		JP	2005-516714 A	6/2005
JP	S 61502036 A	9/1986		JP	2005137423 A	6/2005
JP	S 63-59764 A	3/1988		JP	2005152416 A	6/2005
JP	63-203149	8/1988		JP	2005-521109 A	7/2005
JP	H 02-279149 A	11/1990		JP	2005-523105 A	8/2005
JP	3-12126 A	1/1991		JP	4461008 B2	8/2005
JP	H 05-084252 A	4/1993		JP	2005524474 A	8/2005
JP	5-212039 A	8/1993		JP	2005-296412 A	10/2005
JP	6007357 A	1/1994		JP	2005-328882 A	12/2005
JP	H 6-30945 A	2/1994		JP	2005-335432 A	12/2005
JP	H 06-26812 U	4/1994		JP	2005-342267 A	12/2005
JP	H 6-121798 A	5/1994		JP	2006-034975 A	2/2006
JP	H 06-197901 A	7/1994		JP	2006-34977 A	2/2006
JP	H 06-237937 A	8/1994		JP	2006-034978 A	2/2006
JP	7-31623 A	2/1995		JP	2006-034980 A	2/2006
JP	7051273 A	2/1995		JP	2006-506106 A	2/2006
JP	7-124166 A	5/1995		JP	2006-187649 A	7/2006
JP	H 7-163574 A	6/1995		JP	2006-218297 A	8/2006
JP	07-171163	7/1995		JP	2006-223872 A	8/2006
JP	7-255735 A	10/1995		JP	2006-281405 A	10/2006
JP	H 7-285089 A	10/1995		JP	2006-334417 A	12/2006
JP	8-33642 A	2/1996		JP	2006-346445 A	12/2006
JP	8033641 A	2/1996		JP	2007-61628 A	3/2007
JP	8-164141 A	6/1996		JP	2007-098130 A	4/2007
JP	H 08-182684 A	7/1996		JP	2007-105481 A	4/2007
JP	H 08-507708 A	8/1996		JP	3906843 B2	4/2007
JP	8229050 A	9/1996		JP	2007-117725 A	5/2007
JP	H 09-501081 A	2/1997		JP	2007-130471 A	5/2007
JP	H 09-501577 A	2/1997		JP	2007-222615 A	6/2007
JP	H 09-164144 A	6/1997		JP	2007-203051 A	8/2007
JP	H 10-118090 A	5/1998		JP	2007-203057 A	8/2007
JP	S 63-147449 A	6/1998		JP	2007-524435 A	8/2007
JP	10-512469 A	12/1998		JP	2007-229448 A	9/2007
JP	2000-14632	1/2000		JP	4001860 B2	10/2007
JP	2000033071 A	2/2000		JP	2007-325922 A	12/2007
JP	2000-112002 A	4/2000		JP	2008-68073 A	3/2008
JP	2000-166932 A	6/2000		JP	2008-206967 A	9/2008
JP	2000171730 A	6/2000		JP	2008-212637 A	9/2008
JP	2000287987 A	10/2000		JP	2008-212638 A	9/2008
JP	2000325303 A	11/2000		JP	2008-259860 A	10/2008
JP	2001-046384 A	2/2001		JP	2008-264535 A	11/2008
JP	2001-87272 A	4/2001		JP	2008-283459 A	11/2008
JP	2001-514541 A	9/2001		JP	2009-502351 A	1/2009
JP	2001-517473 A	10/2001		JP	2009-506799 A	2/2009
JP	2001286477 A	10/2001		JP	2009-72599 A	4/2009
JP	2002-51974 A	2/2002		JP	2009-106752 A	5/2009
JP	2002143078 A	5/2002		JP	2009-189836 A	8/2009
JP	2002-528161 A	9/2002		JP	2009-539420 A	11/2009
JP	2002369820 A	12/2002		JP	2010-098844 A	4/2010
JP	2003-500153 A	1/2003		JP	4549018 B2	9/2010
JP	2003-504104 A	2/2003		JP	4783373 B2	7/2011
JP	2003-135473 A	5/2003		JP	5140421 B2	2/2013

(56)	References Cited			WO	WO 96/31155	A1	10/1996
	FOREIGN PATENT DOCUMENTS			WO	WO 96/35464	A1	11/1996
				WO	WO 96/39085	A1	12/1996
				WO	WO 96/39086	A1	12/1996
JP	5162595	B2	3/2013	WO	WO 96/39087	A1	12/1996
JP	2013-128791	A	7/2013	WO	WO 96/39088	A1	12/1996
JP	5333899	B2	11/2013	WO	WO 96/39089	A1	12/1996
RU	1814161	A1	5/1993	WO	WO 97/00646	A1	1/1997
RU	2008830	C1	3/1994	WO	WO 97/00647	A1	1/1997
RU	2052979	C1	1/1996	WO	WO 97/01989	A1	1/1997
RU	2098025	C1	12/1997	WO	WO 97/06582	A1	2/1997
RU	2141279	C1	11/1999	WO	WO 97/10763	A1	3/1997
RU	2144791	C1	1/2000	WO	WO 97/10764	A1	3/1997
RU	2181566	C2	4/2002	WO	WO 97/11648	A2	4/1997
RU	2187249	C2	8/2002	WO	WO 97/11649	A1	4/1997
RU	2189091	C2	9/2002	WO	WO 97/15237	A1	5/1997
RU	32984	U1	10/2003	WO	WO 97/24073	A1	7/1997
RU	2225170	C2	3/2004	WO	WO 97/24993	A1	7/1997
RU	42750	U1	12/2004	WO	WO 97/30644	A1	8/1997
RU	61114	U1	2/2007	WO	WO 97/34533	A1	9/1997
SU	189517	A	1/1967	WO	WO 97/37598	A1	10/1997
SU	328636	A	9/1972	WO	WO 97/39688	A2	10/1997
SU	674747	A1	7/1979	WO	WO 98/01080	A1	1/1998
SU	886900	A1	12/1981	WO	WO 98/17180	A1	4/1998
SU	1009439	A	4/1983	WO	WO 98/27880	A1	7/1998
SU	1022703	A1	6/1983	WO	WO 98/30153	A1	7/1998
SU	1333319	A2	8/1987	WO	WO 98/47436	A1	10/1998
SU	1377053	A1	2/1988	WO	WO 99/03407	A1	1/1999
SU	1509051	A1	9/1989	WO	WO 99/03408	A1	1/1999
SU	1561964	A1	5/1990	WO	WO 99/03409	A1	1/1999
SU	1708312	A1	1/1992	WO	WO 99/12483	A1	3/1999
SU	1722476	A1	3/1992	WO	WO 99/12487	A1	3/1999
SU	1752361	A1	8/1992	WO	WO 99/12488	A1	3/1999
WO	WO 82/02824	A1	9/1982	WO	WO 99/15086	A1	4/1999
WO	WO 86/02254	A1	4/1986	WO	WO 99/15091	A1	4/1999
WO	WO 91/15157	A1	10/1991	WO	WO 99/23933	A2	5/1999
WO	WO 92/20295	A1	11/1992	WO	WO 99/23959	A1	5/1999
WO	WO 92/21300	A1	12/1992	WO	WO 99/25261	A1	5/1999
WO	WO 93/08755	A1	5/1993	WO	WO 99/29244	A1	6/1999
WO	WO 93/13718	A1	7/1993	WO	WO 99/34744	A1	7/1999
WO	WO 93/14690	A1	8/1993	WO	WO 99/45849	A1	9/1999
WO	WO 93/15648	A1	8/1993	WO	WO 99/48430	A1	9/1999
WO	WO 93/15850	A1	8/1993	WO	WO 99/51158	A1	10/1999
WO	WO 93/19681	A1	10/1993	WO	WO 00/24322	A1	5/2000
WO	WO 94/00060	A1	1/1994	WO	WO 00/24330	A1	5/2000
WO	WO 94/11057	A1	5/1994	WO	WO 00/41638	A1	7/2000
WO	WO 94/12108	A1	6/1994	WO	WO 00/48506	A1	8/2000
WO	WO 94/18893	A1	9/1994	WO	WO 00/53112	A2	9/2000
WO	WO 94/20030	A1	9/1994	WO	WO 00/54653	A1	9/2000
WO	WO 94/22378	A1	10/1994	WO	WO 00/57796	A1	10/2000
WO	WO 94/23659	A1	10/1994	WO	WO 00/64365	A1	11/2000
WO	WO 94/24943	A1	11/1994	WO	WO 00/72762	A1	12/2000
WO	WO 94/24947	A1	11/1994	WO	WO 00/72765	A1	12/2000
WO	WO 95/02369	A1	1/1995	WO	WO 01/03587	A1	1/2001
WO	WO 95/03743	A1	2/1995	WO	WO 01/05702	A1	1/2001
WO	WO 95/06817	A1	3/1995	WO	WO 01/10482	A1	2/2001
WO	WO 95/09576	A1	4/1995	WO	WO 01/35845	A1	5/2001
WO	WO 95/09577	A1	4/1995	WO	WO 01/54594	A1	8/2001
WO	WO 95/14436	A1	6/1995	WO	WO 01/58371	A1	8/2001
WO	WO 95/17855	A1	7/1995	WO	WO 01/62158	A2	8/2001
WO	WO 95/18383	A1	7/1995	WO	WO 01/62161	A1	8/2001
WO	WO 95/18572	A1	7/1995	WO	WO 01/62162	A1	8/2001
WO	WO 95/19739	A1	7/1995	WO	WO 01/62164	A2	8/2001
WO	WO 95/20360	A1	8/1995	WO	WO 01/62169	A2	8/2001
WO	WO 95/23557	A1	9/1995	WO	WO 01/78605	A2	10/2001
WO	WO 95/24865	A1	9/1995	WO	WO 01/80757	A2	11/2001
WO	WO 95/25471	A3	9/1995	WO	WO 01/91646	A1	12/2001
WO	WO 95/26562	A1	10/1995	WO	WO 02/00121	A1	1/2002
WO	WO 95/29639	A1	11/1995	WO	WO 02/07608	A2	1/2002
WO	WO 96/04858	A1	2/1996	WO	WO 02/07618	A1	1/2002
WO	WO 96/18344	A2	6/1996	WO	WO 02/17799	A1	3/2002
WO	WO 96/19151	A1	6/1996	WO	WO 02/19920	A1	3/2002
WO	WO 96/19152	A1	6/1996	WO	WO 02/19932	A1	3/2002
WO	WO 96/20652	A1	7/1996	WO	WO 02/26143	A1	4/2002
WO	WO 96/21119	A1	7/1996	WO	WO 02/30297	A2	4/2002
WO	WO 96/22055	A1	7/1996	WO	WO 02/32322	A2	4/2002
WO	WO 96/23448	A1	8/1996	WO	WO 02/36028	A1	5/2002
WO	WO 96/24301	A1	8/1996	WO	WO 02/43571	A2	6/2002
WO	WO 96/27337	A1	9/1996	WO	WO 02/058568	A1	8/2002

(56)

References Cited

FOREIGN PATENT DOCUMENTS

WO WO 02/060328 A1 8/2002
 WO WO 02/067785 A2 9/2002
 WO WO 02/085218 A2 10/2002
 WO WO 02/087586 A1 11/2002
 WO WO 02/098302 A1 12/2002
 WO WO 03/000138 A2 1/2003
 WO WO 03/001329 A2 1/2003
 WO WO 03/001986 A2 1/2003
 WO WO 03/013363 A1 2/2003
 WO WO 03/013372 A2 2/2003
 WO WO 03/015604 A2 2/2003
 WO WO 03/020106 A2 3/2003
 WO WO 03/020139 A2 3/2003
 WO WO 03/024339 A1 3/2003
 WO WO 03/079909 A3 3/2003
 WO WO 03/030743 A2 4/2003
 WO WO 03/037193 A1 5/2003
 WO WO 03/047436 A3 6/2003
 WO WO 03/055402 A1 7/2003
 WO WO 03/057048 A1 7/2003
 WO WO 03/057058 A1 7/2003
 WO WO 03/063694 A1 8/2003
 WO WO 03/077769 A1 9/2003
 WO WO 03/079911 A1 10/2003
 WO WO 03/082126 A1 10/2003
 WO WO 03/086206 A1 10/2003
 WO WO 03/088845 A2 10/2003
 WO WO 03/090630 A2 11/2003
 WO WO 03/094743 A1 11/2003
 WO WO 03/094745 A1 11/2003
 WO WO 03/094746 A1 11/2003
 WO WO 03/094747 A1 11/2003
 WO WO 03/101313 A1 12/2003
 WO WO 03/105698 A2 12/2003
 WO WO 03/105702 A2 12/2003
 WO WO 2004/006980 A2 1/2004
 WO WO 2004/011037 A2 2/2004
 WO WO 2004/019769 A1 3/2004
 WO WO 2004/019803 A1 3/2004
 WO WO 2004/021868 A2 3/2004
 WO WO 2004/028585 A2 4/2004
 WO WO 2004/030554 A1 4/2004
 WO WO 2004/032754 A2 4/2004
 WO WO 2004/032760 A2 4/2004
 WO WO 2004/032762 A1 4/2004
 WO WO 2004/032763 A2 4/2004
 WO WO 2004/032783 A1 4/2004
 WO WO 2004/034875 A2 4/2004
 WO WO 2004/047626 A1 6/2004
 WO WO 2004/047653 A2 6/2004
 WO WO 2004/049956 A2 6/2004
 WO WO 2004/052426 A2 6/2004
 WO WO 2004/056276 A1 7/2004
 WO WO 2004/056277 A1 7/2004
 WO WO 2004/062516 A1 7/2004
 WO WO 2004/064600 A2 8/2004
 WO WO 2004/078050 A2 9/2004
 WO WO 2004/078051 A2 9/2004
 WO WO 2004/078236 A2 9/2004
 WO WO 2004/086987 A1 10/2004
 WO WO 2004/096015 A2 11/2004
 WO WO 2004/096057 A2 11/2004
 WO WO 2004/103157 A2 12/2004
 WO WO 2004/105593 A1 12/2004
 WO WO 2004/105621 A1 12/2004
 WO WO 2004/112618 A2 12/2004
 WO WO 2004/112652 A2 12/2004
 WO WO 2005/027983 A2 3/2005
 WO WO 2005/037329 A2 4/2005
 WO WO 2005/042041 A1 5/2005
 WO WO 2005/044078 A2 5/2005
 WO WO 2005/055846 A1 6/2005
 WO WO 2005/072634 A2 8/2005
 WO WO 2005/078892 A1 8/2005
 WO WO 2005/079675 A2 9/2005

WO WO 2005/096954 A2 10/2005
 WO WO 2005/112806 A2 12/2005
 WO WO 2005/112808 A1 12/2005
 WO WO 2005/115251 A1 12/2005
 WO WO 2005/115253 A2 12/2005
 WO WO 2005/117735 A1 12/2005
 WO WO 2005/122936 A1 12/2005
 WO WO 2006/023486 A1 3/2006
 WO WO 2006/023578 A2 3/2006
 WO WO 2006/027014 A1 3/2006
 WO WO 2006/028314 A1 3/2006
 WO WO 2006/044490 A2 4/2006
 WO WO 2006/044581 A2 4/2006
 WO WO 2006/044810 A2 4/2006
 WO WO 2006/051252 A1 5/2006
 WO WO 2006/059067 A1 6/2006
 WO WO 2006/083748 A1 8/2006
 WO WO 2006/092563 A1 9/2006
 WO WO 2006/092565 A1 9/2006
 WO WO 2006/115958 A1 11/2006
 WO WO 2006/125940 A1 11/2006
 WO WO 2006/132992 A2 12/2006
 WO WO 2007/002180 A2 1/2007
 WO WO 2007/016290 A2 2/2007
 WO WO 2007/018898 A2 2/2007
 WO WO 2007/089603 A2 8/2007
 WO WO 2007/098220 A2 8/2007
 WO WO 2007/121579 A1 11/2007
 WO WO 2007/131110 A2 11/2007
 WO WO 2007/137304 A2 11/2007
 WO WO 2007/139734 A2 12/2007
 WO WO 2007/142625 A2 12/2007
 WO WO 2007/145825 A2 12/2007
 WO WO 2007/146987 A2 12/2007
 WO WO 2007/147439 A1 12/2007
 WO WO 2008/020964 A2 2/2008
 WO WO 2008/021969 A2 2/2008
 WO WO 2008/039249 A1 4/2008
 WO WO 2008/039270 A1 4/2008
 WO WO 2008/045383 A2 4/2008
 WO WO 2008/057281 A2 5/2008
 WO WO 2008/070763 A1 6/2008
 WO WO 2008/089404 A2 7/2008
 WO WO 2008/101080 A1 8/2008
 WO WO 2008/101228 A2 8/2008
 WO WO 2008/109125 A1 9/2008
 WO WO 2008/124748 A1 10/2008
 WO WO 2009/023851 A1 2/2009
 WO WO 2009/033057 A2 3/2009
 WO WO 2009/046394 A1 4/2009
 WO WO 2009/067649 A2 5/2009
 WO WO 2009/091497 A2 7/2009
 WO WO 2009/137761 A2 11/2009
 WO WO 2009/143092 A1 11/2009
 WO WO 2009/143331 A1 11/2009
 WO WO 2010/028332 A2 3/2010
 WO WO 2010/030434 A1 3/2010
 WO WO 2010/050771 A2 5/2010
 WO WO 2010/054404 A1 5/2010
 WO WO 2010/063795 A1 6/2010
 WO WO 2010/098871 A2 9/2010
 WO WO 2011/008672 A2 1/2011
 WO WO 2011/044343 A2 4/2011
 WO WO 2011/060311 A2 5/2011
 WO WO 2012/021671 A1 2/2012
 WO WO 2012/044551 A1 4/2012
 WO WO 2012/044554 A1 4/2012
 WO WO 2012/044606 A2 4/2012
 WO WO 2012/044820 A1 4/2012
 WO WO 2012/044844 A2 4/2012
 WO WO 2012/044853 A1 4/2012
 WO WO 2012/068156 A2 5/2012
 WO WO 2012/148667 A2 11/2012

(56)

References Cited

FOREIGN PATENT DOCUMENTS

WO WO 2012/148703 A2 11/2012
 WO WO 2013/043707 A2 3/2013
 WO WO 2013/043717 A1 3/2013

OTHER PUBLICATIONS

U.S. Appl. No. 14/521,748, filed Oct. 23, 2014.
 European Search Report, Application No. 09250367.1, dated Apr. 14, 2009 (7 pages).
 European Examination Report, Application No. 09250367.1, dated Mar. 4, 2010 (8 pages).
 International Search Report for PCT/US2012/039302, dated Sep. 4, 2012 (5 pages).
 Disclosed Anonymously, "Motor-Driven Surgical Stapler Improvements," Research Disclosure Database No. 526041, Published: Feb. 2008.
 C.C. Thompson et al., "Peroral Endoscopic Reduction of Dilated Gastrojejunal Anastomosis After Roux-en-Y Gastric Bypass: A Possible New Option for Patients with Weight Regain," *Surg Endosc* (2006) vol. 20, pp. 1744-1748.
 B.R. Coolman, DVM, MS et al., "Comparison of Skin Staples With Sutures for Anastomosis of the Small Intestine in Dogs," Abstract; <http://www.blackwell-synergy.com/doi/abs/10.1053/jvet.2000.7539?cookieSet=1&journalCode=vsu> which redirects to <http://www3.interscience.wiley.com/journal/119040681/abstract?CRETRY=1&SRETRY=0>; [online] accessed: Sep. 22, 2008 (2 pages).
 The Sodem Aseptic Battery Transfer Kit, Sodem Systems, (2000), 3 pages.
 "Biomedical Coatings," Fort Wayne Metals, Research Products Corporation, obtained online at www.fwmetals.com on Jun. 21, 2010 (1 page).
 Van Meer et al., "A Disposable Plastic Compact Wrist for Smart Minimally Invasive Surgical Tools," *LAAS/CNRS* (Aug. 2005).
 Breedveld et al., "A New, Easily Miniaturized Sterrable Endoscope," *IEEE Engineering in Medicine and Biology Magazine* (Nov./Dec. 2005).
 D. Tuite, Ed., "Get the Lowdown on Ultracapacitors," Nov. 15, 2007; [online] URL: <http://electronicsdesign.com/Articles/Print.cfm?ArticleID=17465>, accessed Jan. 15, 2008 (5 pages).
 Datasheet for Panasonic TK Relays Ultra Low Profile 2 A Polarized Relay, Copyright Matsushita Electric Works, Ltd. (Known of at least as early as Aug. 17, 2010), 5 pages.
 ASTM procedure D2240-00, "Standard Test Method for Rubber Property—Durometer Hardness," (Published Aug. 2000).
 ASTM procedure D2240-05, "Standard Test Method for Rubber Property—Durometer Hardness," (Published Apr. 2010).
 Covidien Brochure, "Endo GIA™ Reloads with Tri-Staple™ Technology," (2010), 1 page.
 Covidien Brochure, "Endo GIA™ Reloads with Tri-Staple™ Technology and Endo GIA™ Ultra Universal Staplers," (2010), 2 pages.
 Covidien Brochure, "Endo GIA™ Black Reload with Tri-Staple™ Technology," (2012), 2 pages.
 Covidien Brochure, "Endo GIA™ Curved Tip Reload with Tri-Staple™ Technology," (2012), 2 pages.
 Covidien Brochure, "Endo GIA™ Reloads with Tri-Staple™ Technology," (2010), 2 pages.
 Covidien Brochure, "Endo GIA™ Ultra Universal Stapler," (2010), 2 pages.
 Miyata et al., "Biomolecule-Sensitive Hydrogels," *Advanced Drug Delivery Reviews*, 54 (2002) pp. 79-98.
 Jeong et al., "Thermosensitive Sol-Gel Reversible Hydrogels," *Advanced Drug Delivery Reviews*, 54 (2002) pp. 37-51.
 Byrne et al., "Molecular Imprinting Within Hydrogels," *Advanced Drug Delivery Reviews*, 54 (2002) pp. 149-161.

Qiu et al., "Environment-Sensitive Hydrogels for Drug Delivery," *Advanced Drug Delivery Reviews*, 53 (2001) pp. 321-339.
 Hoffman, "Hydrogels for Biomedical Applications," *Advanced Drug Delivery Reviews*, 43 (2002) pp. 3-12.
 Hoffman, "Hydrogels for Biomedical Applications," *Advanced Drug Delivery Reviews*, 54 (2002) pp. 3-12.
 Peppas, "Physiologically Responsive Hydrogels," *Journal of Bioactive and Compatible Polymers*, vol. 6 (Jul. 1991) pp. 241-246.
 Ebara, "Carbohydrate-Derived Hydrogels and Microgels," *Engineered Carbohydrate-Based Materials for Biomedical Applications: Polymers, Surfaces, Dendrimers, Nanoparticles, and Hydrogels*, Edited by Ravin Narain, 2011, pp. 337-345.
 Peppas, Editor "Hydrogels in Medicine and Pharmacy," vol. I, Fundamentals, CRC Press, 1986.
 Matsuda, "Thermodynamics of Formation of Porous Polymeric Membrane from Solutions," *Polymer Journal*, vol. 23, No. 5, pp. 435-444 (1991).
 Young, "Microcellular foams via phase separation," *Journal of Vacuum Science & Technology A* 4(3), (May/Jun. 1986).
 Chen et al., "Elastomeric Biomaterials for Tissue Engineering," *Progress in Polymer Science* 38 (2013), pp. 584-671.
 Pitt et al., "Attachment of Hyaluronan to Metallic Surfaces," *J. Biomed. Mater. Res.* 68A: pp. 95-106, 2004.
 Schellhammer et al., "Poly-Lactic-Acid for Coating of Endovascular Stents: Preliminary Results in Canine Experimental Av-Fistulae," *Mat.-wiss. u. Werkstofftech.*, 32, pp. 193-199 (2001).
 Solorio et al., "Gelatin Microspheres Crosslinked with Genipin for Local Delivery of Growth Factors," *J. Tissue Eng. Regen. Med.* (2010), 4(7): pp. 514-523.
 U.S. Appl. No. 14/187,383, filed Feb. 24, 2014.
 U.S. Appl. No. 14/187,386, filed Feb. 24, 2014.
 U.S. Appl. No. 14/187,390, filed Feb. 24, 2014.
 U.S. Appl. No. 14/187,385, filed Feb. 24, 2014.
 U.S. Appl. No. 14/187,384, filed Feb. 24, 2014.
 U.S. Appl. No. 14/187,389, filed Feb. 24, 2014.
 U.S. Appl. No. 14/275,232, filed May 12, 2014.
 U.S. Appl. No. 14/311,976, filed Jun. 23, 2014.
 U.S. Appl. No. 14/498,070, filed Sep. 26, 2014.
 U.S. Appl. No. 14/498,087, filed Sep. 26, 2014.
 U.S. Appl. No. 14/498,105, filed Sep. 26, 2014.
 U.S. Appl. No. 14/498,107, filed Sep. 26, 2014.
 U.S. Appl. No. 14/498,121, filed Sep. 26, 2014.
 U.S. Appl. No. 14/498,145, filed Sep. 26, 2014.
 U.S. Appl. No. 14/318,996, filed Jun. 30, 2014.
 U.S. Appl. No. 14/319,006, filed Jun. 30, 2014.
 U.S. Appl. No. 14/319,014, filed Jun. 30, 2014.
 U.S. Appl. No. 14/318,991, filed Jun. 30, 2014.
 U.S. Appl. No. 14/319,004, filed Jun. 30, 2014.
 U.S. Appl. No. 14/319,008, filed Jun. 30, 2014.
 U.S. Appl. No. 14/318,997, filed Jun. 30, 2014.
 U.S. Appl. No. 14/319,002, filed Jun. 30, 2014.
 U.S. Appl. No. 14/319,013, filed Jun. 30, 2014.
 U.S. Appl. No. 14/319,016, filed Jun. 30, 2014.
 U.S. Appl. No. 13/974,166, filed Aug. 23, 2013.
 U.S. Appl. No. 14/138,481, filed Dec. 23, 2013.
 U.S. Appl. No. 13/974,215, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,202, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,205, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,224, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,169, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,206, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,227, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,174, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,177, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,182, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,208, filed Aug. 23, 2013.
 U.S. Appl. No. 13/974,209, filed Aug. 23, 2013.
 U.S. Appl. No. 12/031,573, filed Feb. 14, 2008.

* cited by examiner

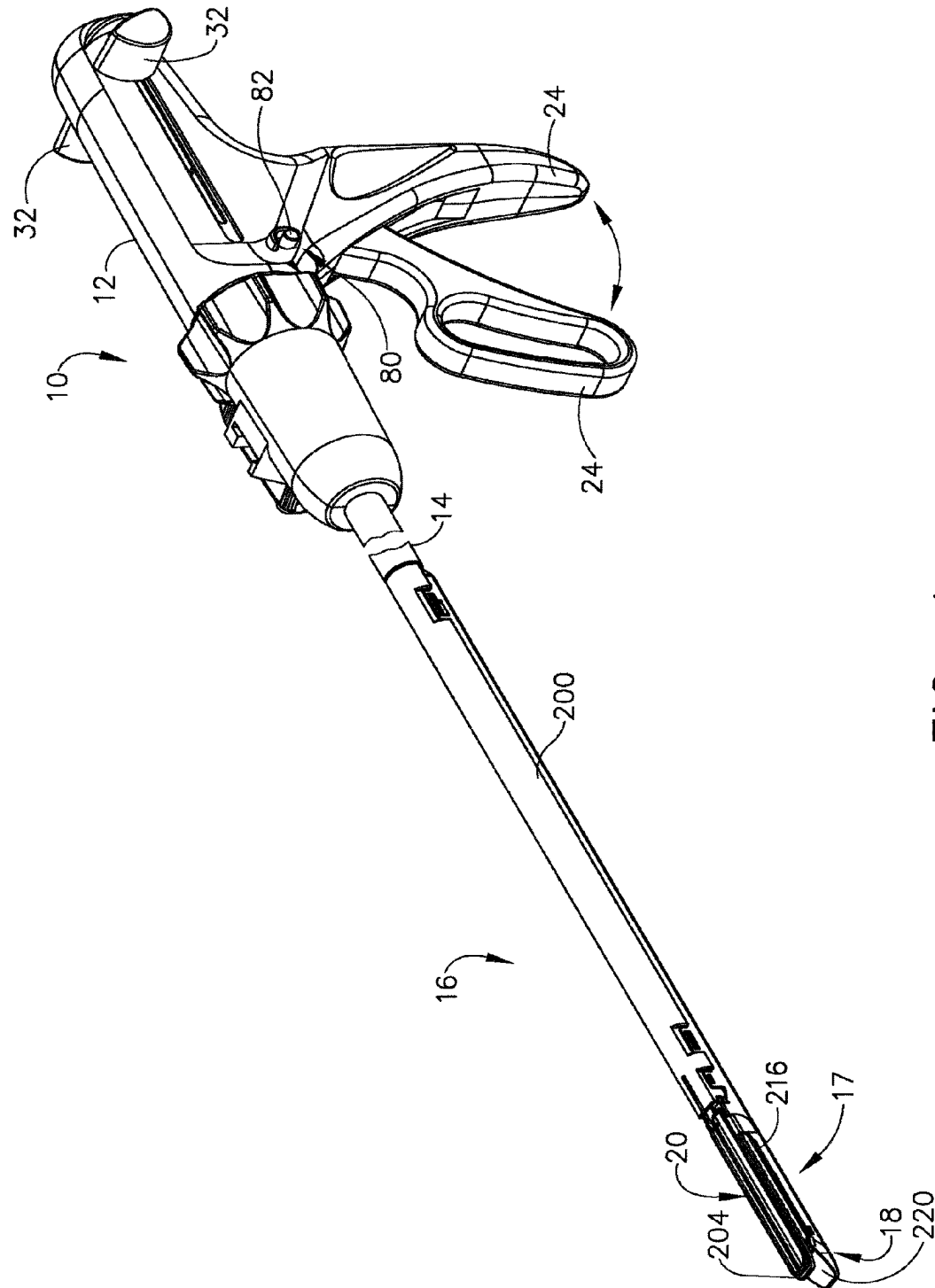


FIG. 1

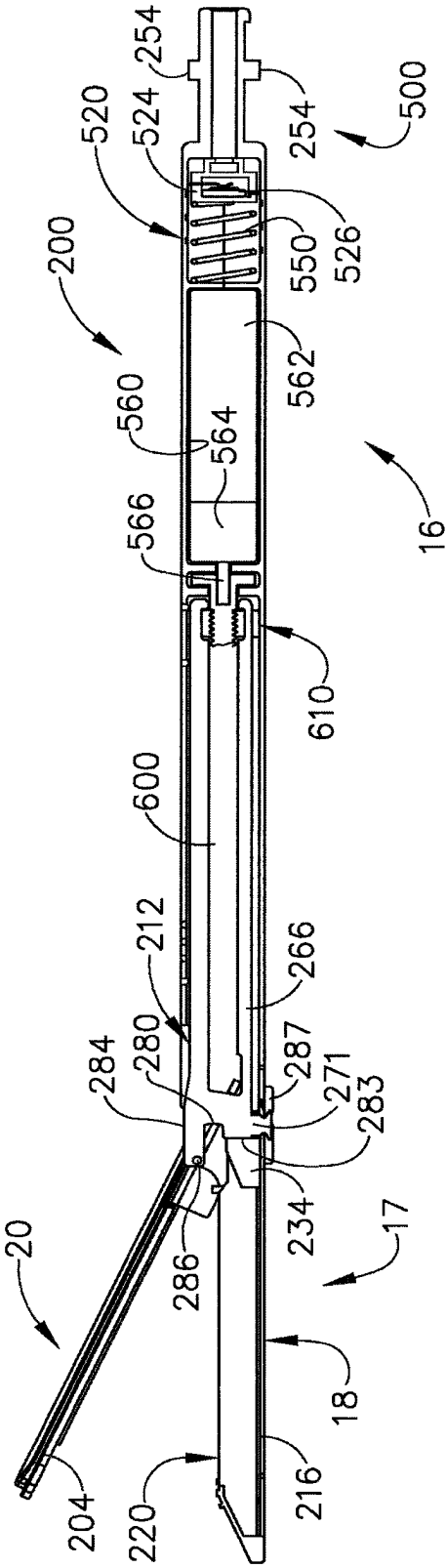
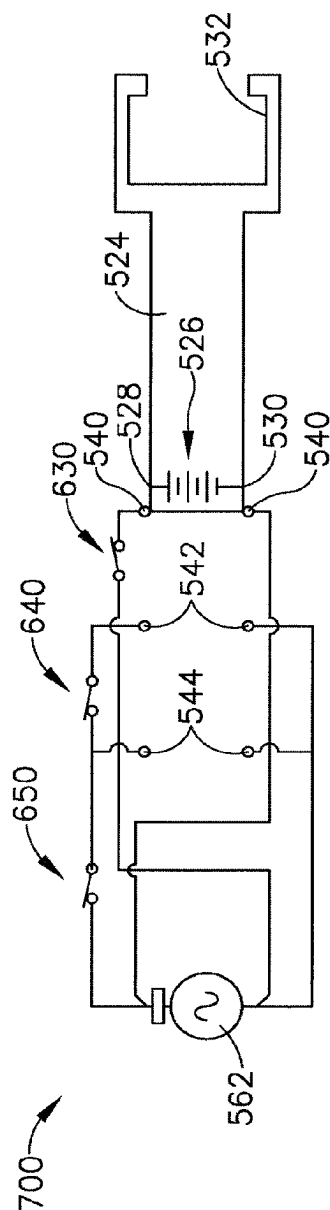
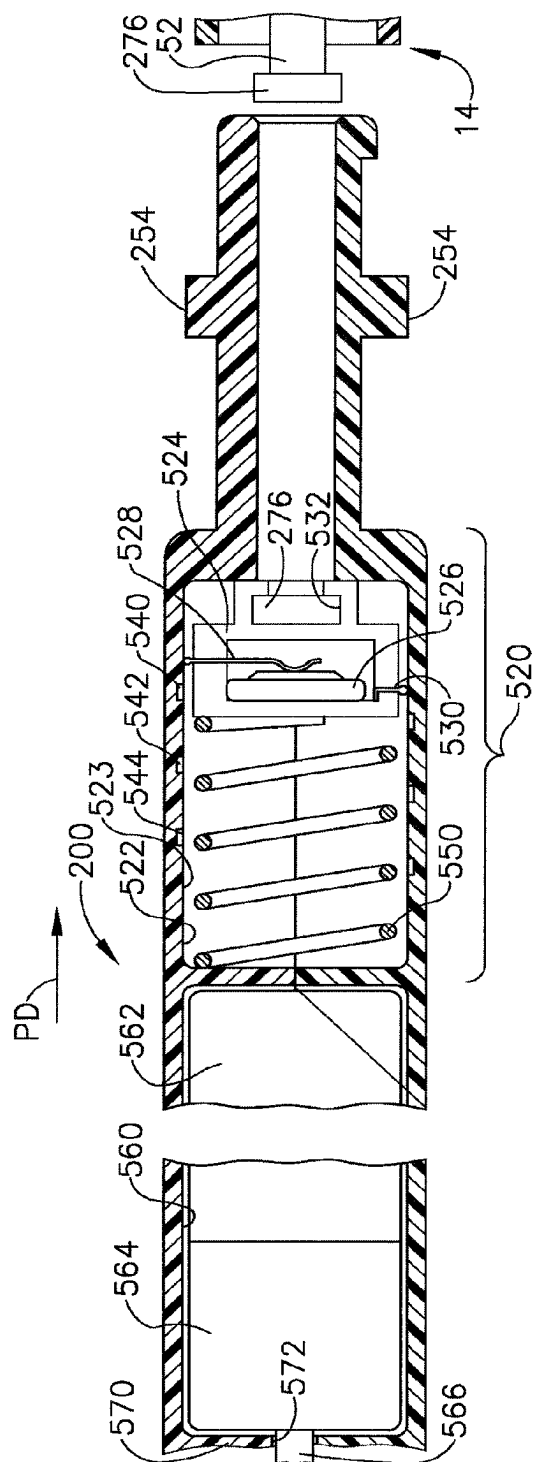
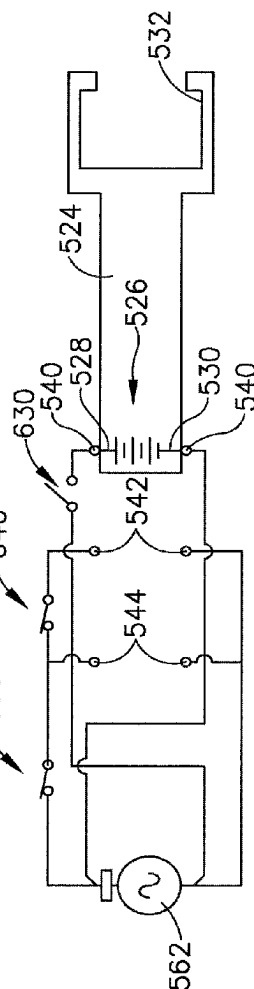
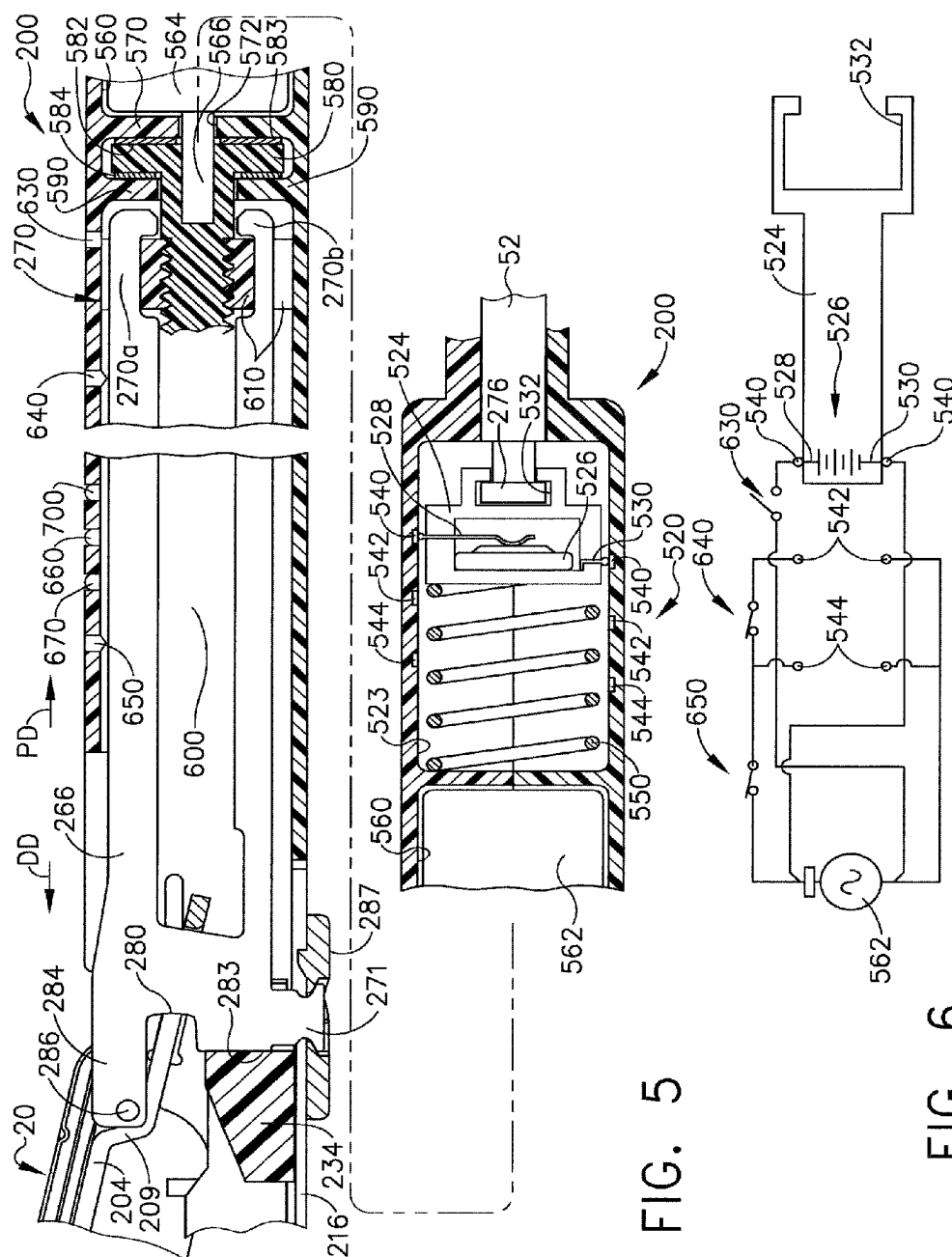
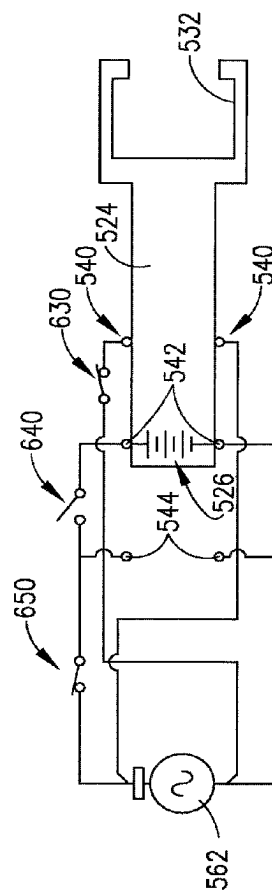
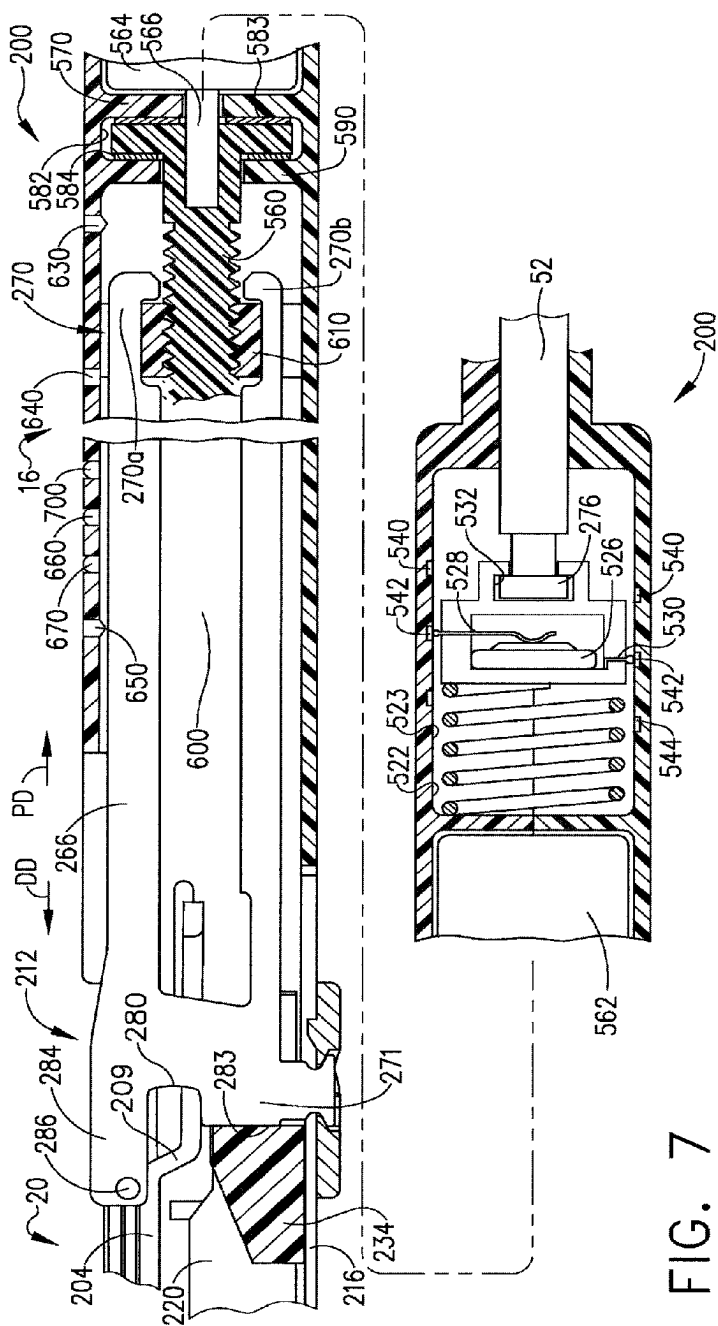
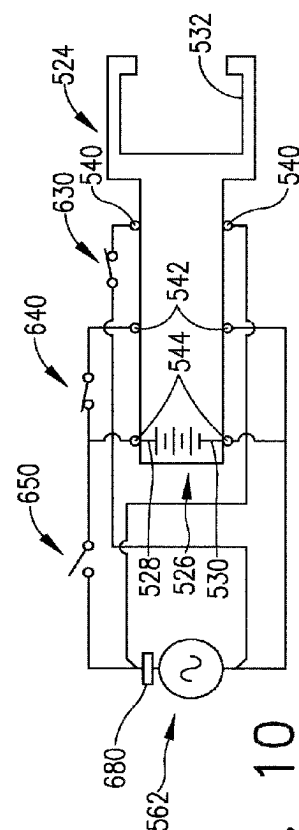
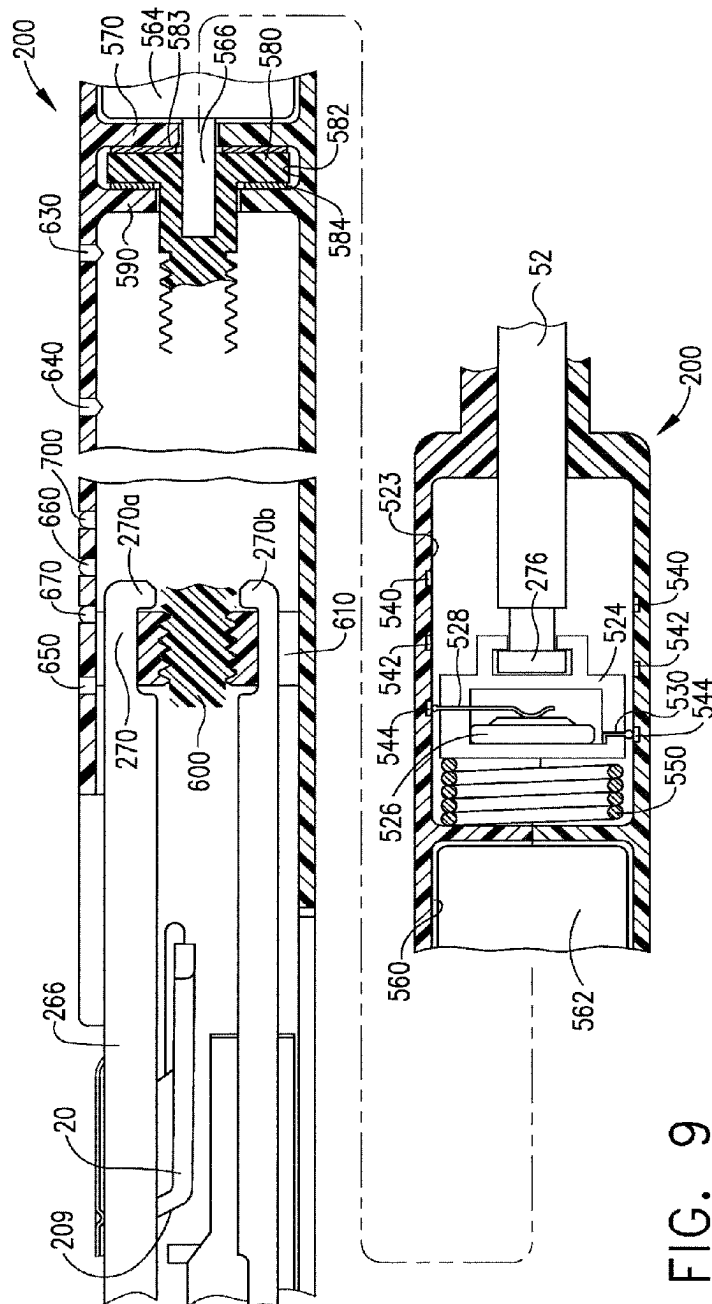


FIG. 2









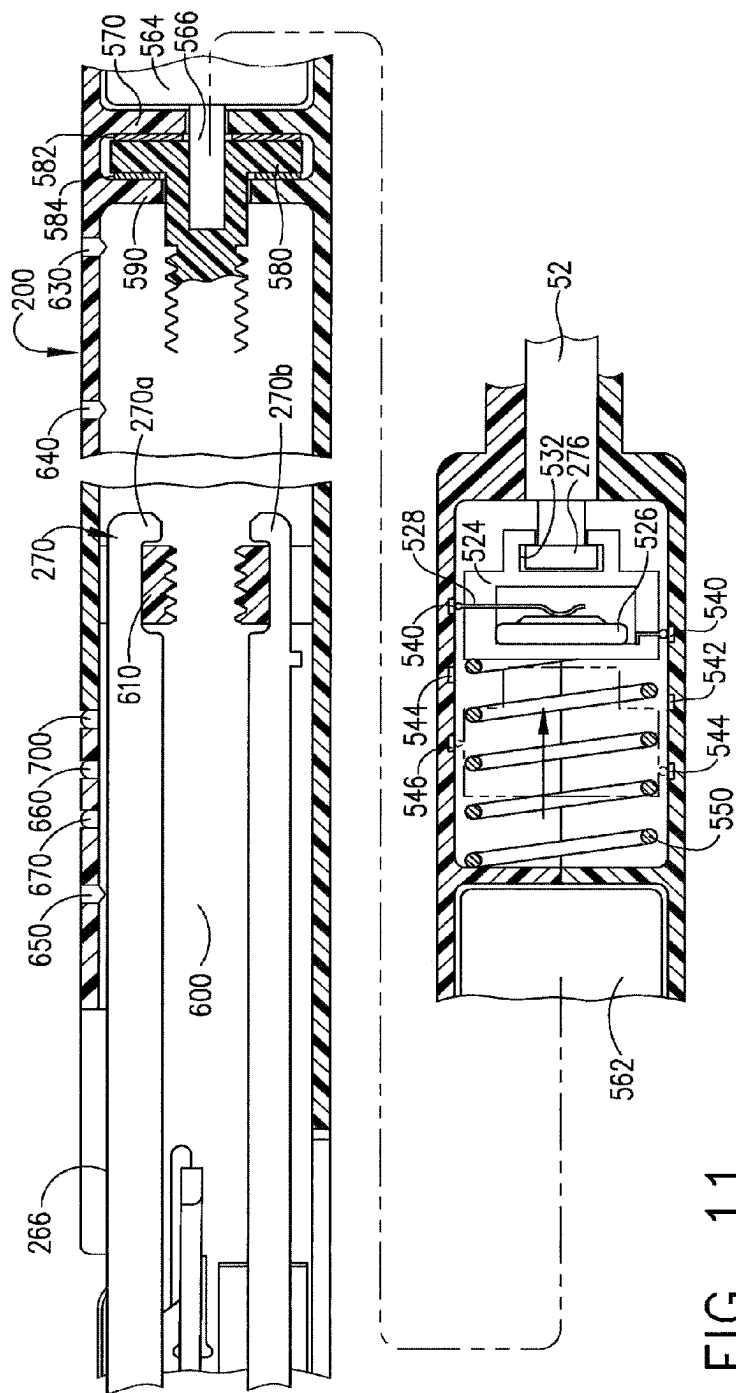


FIG. 11

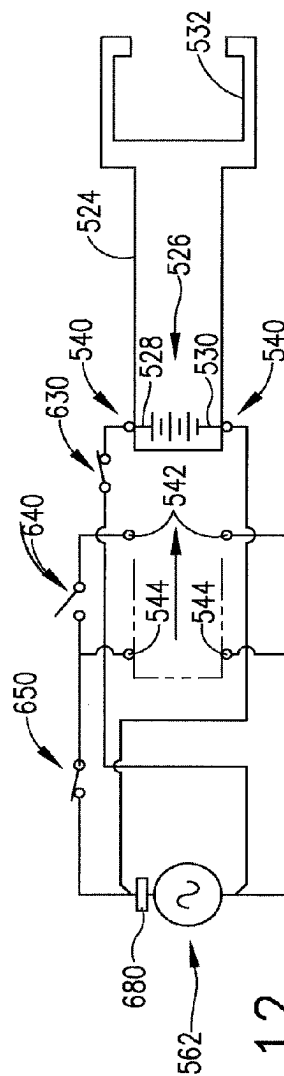


FIG. 12

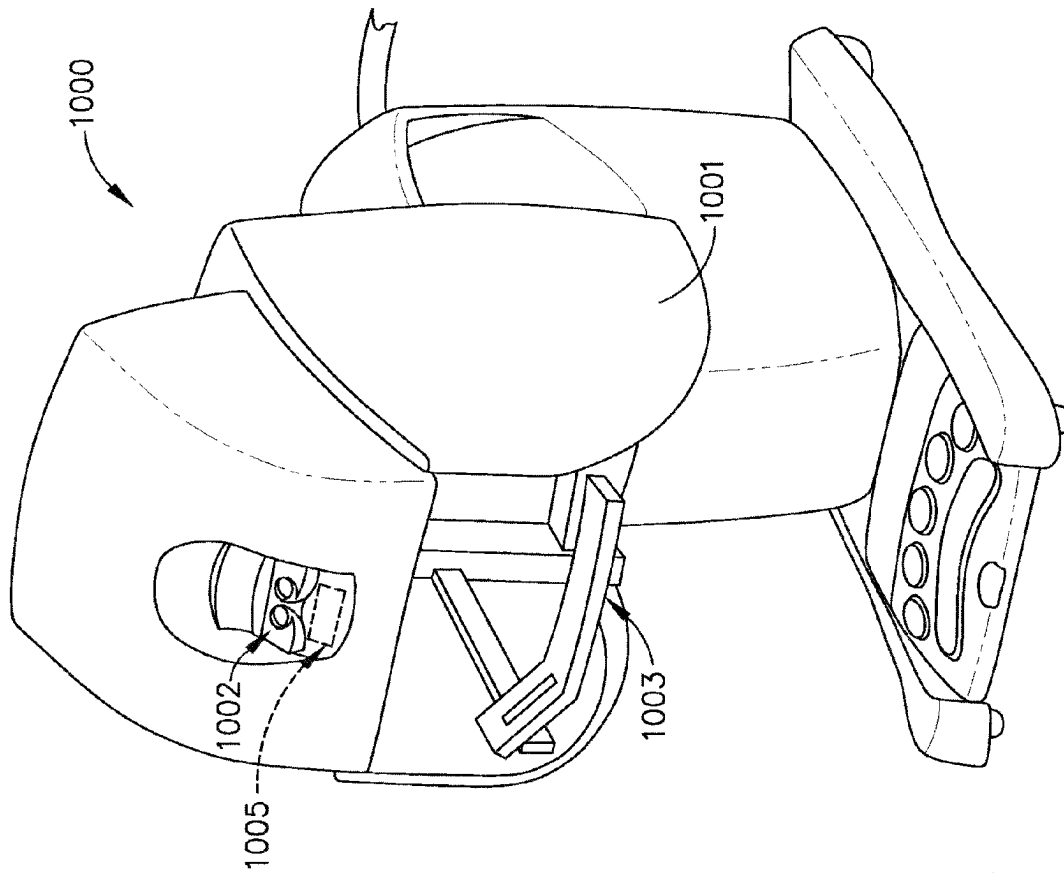


FIG. 13

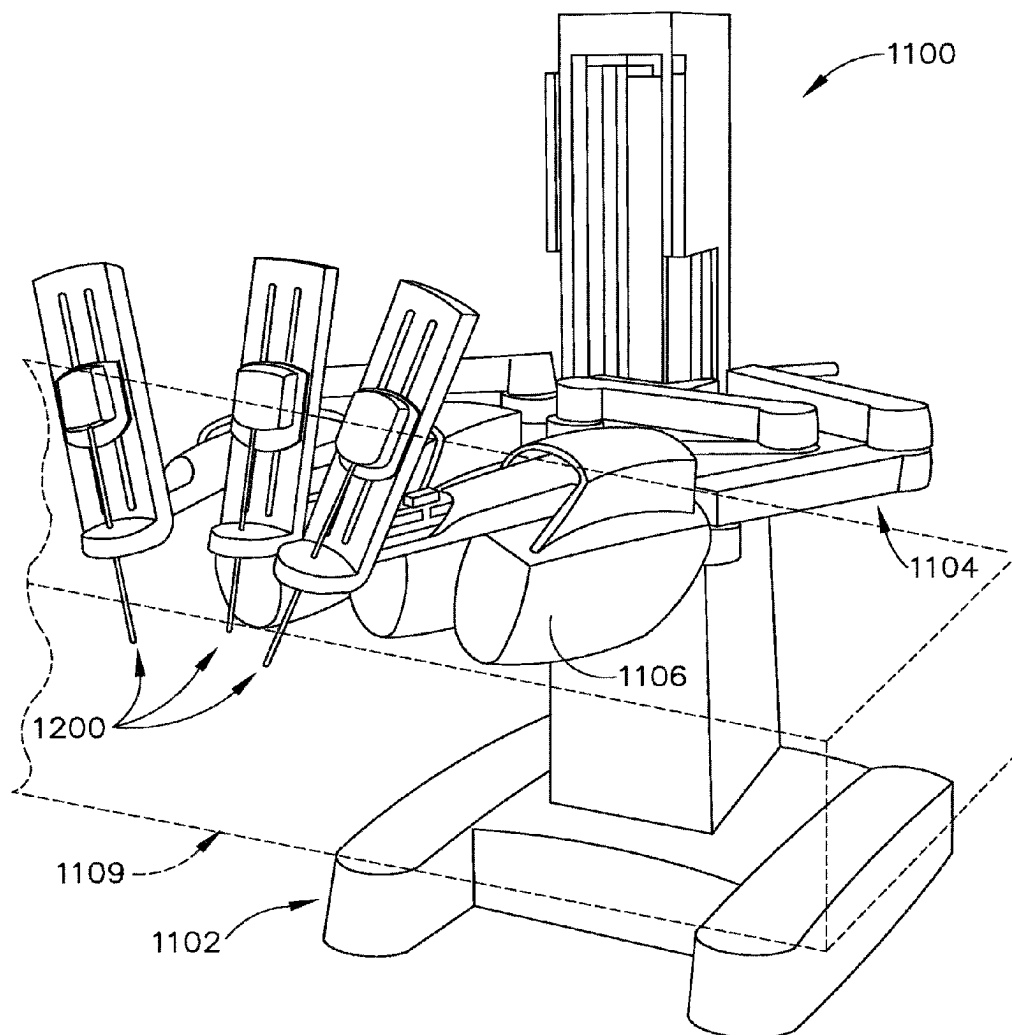
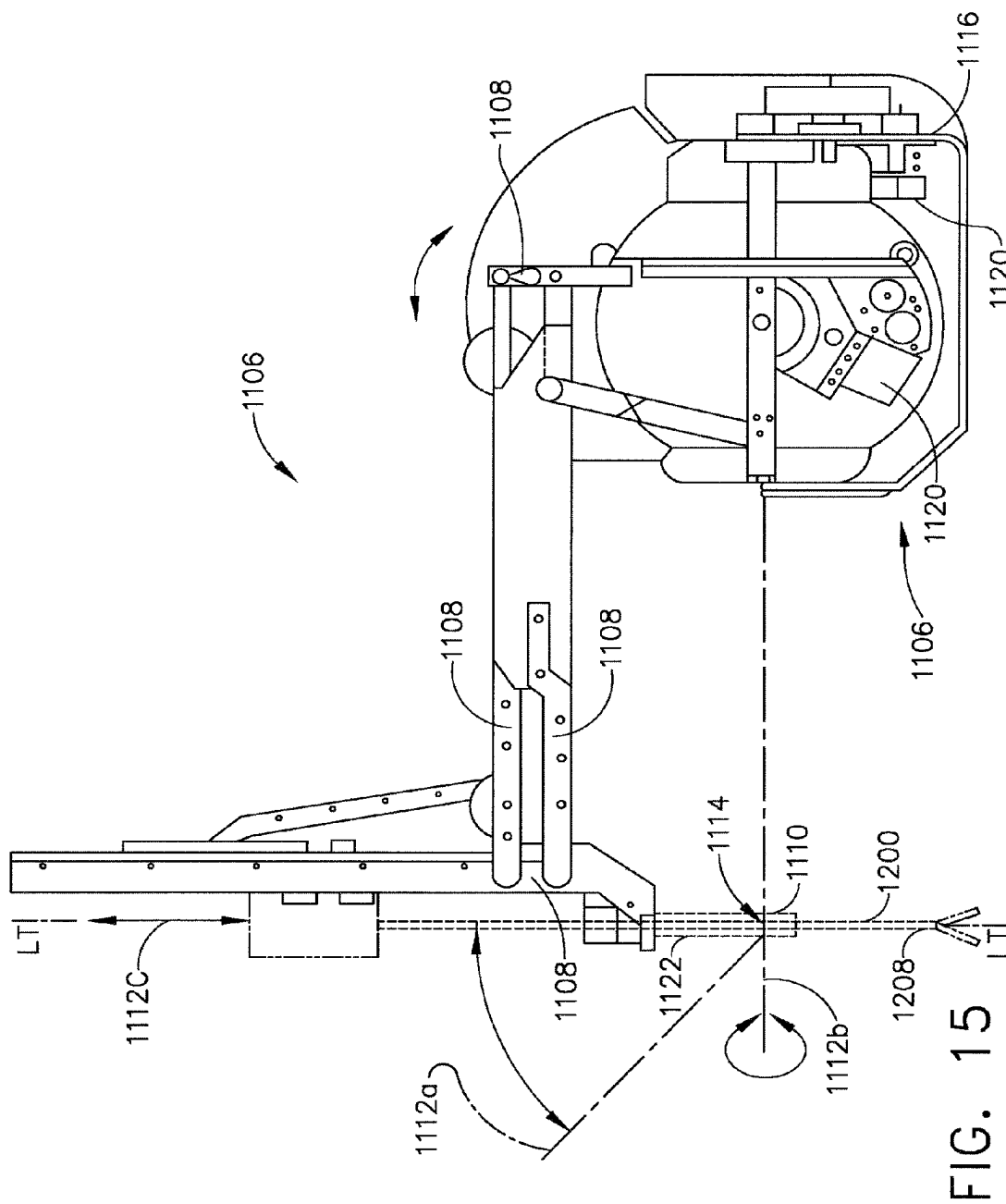


FIG. 14



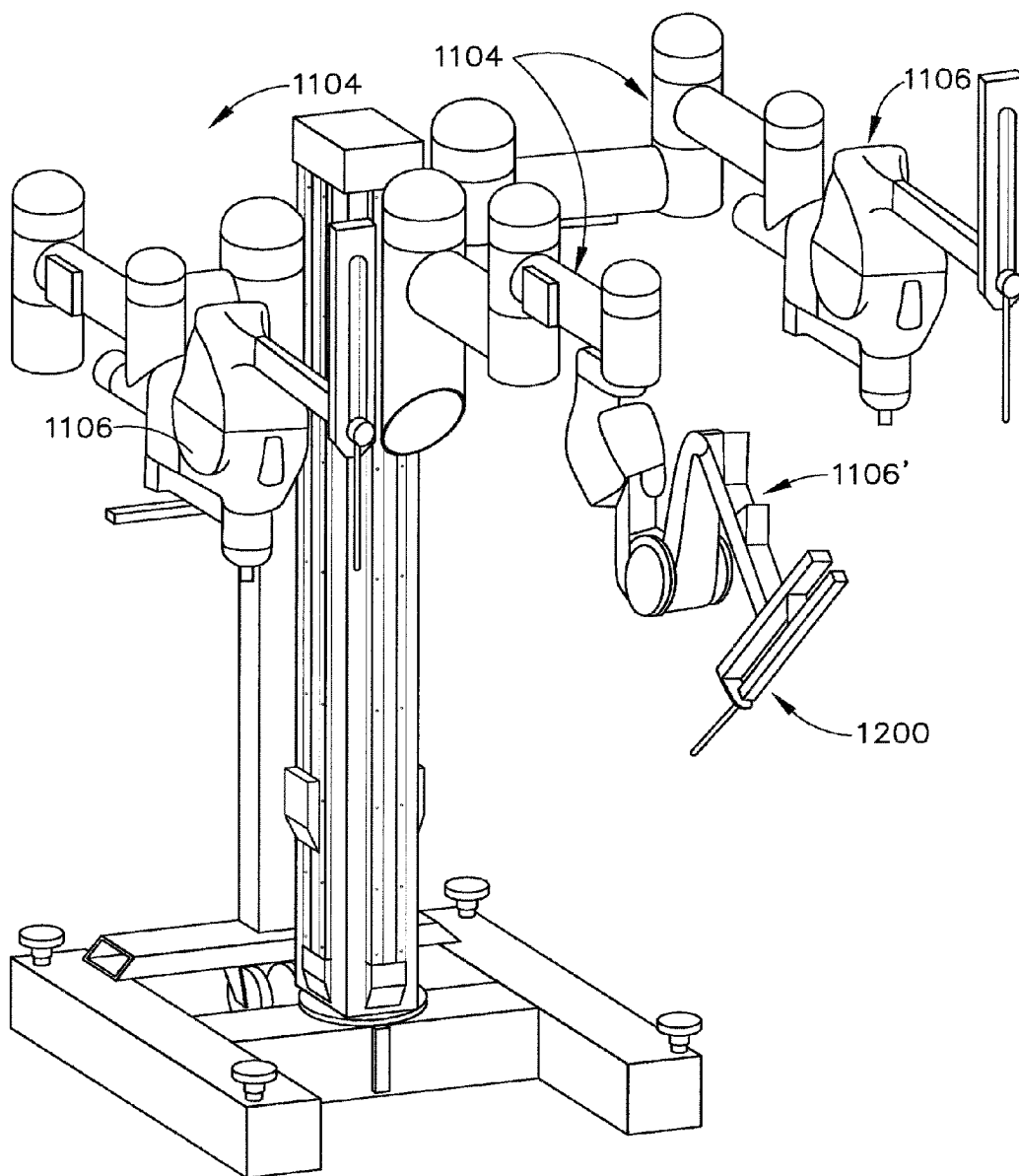
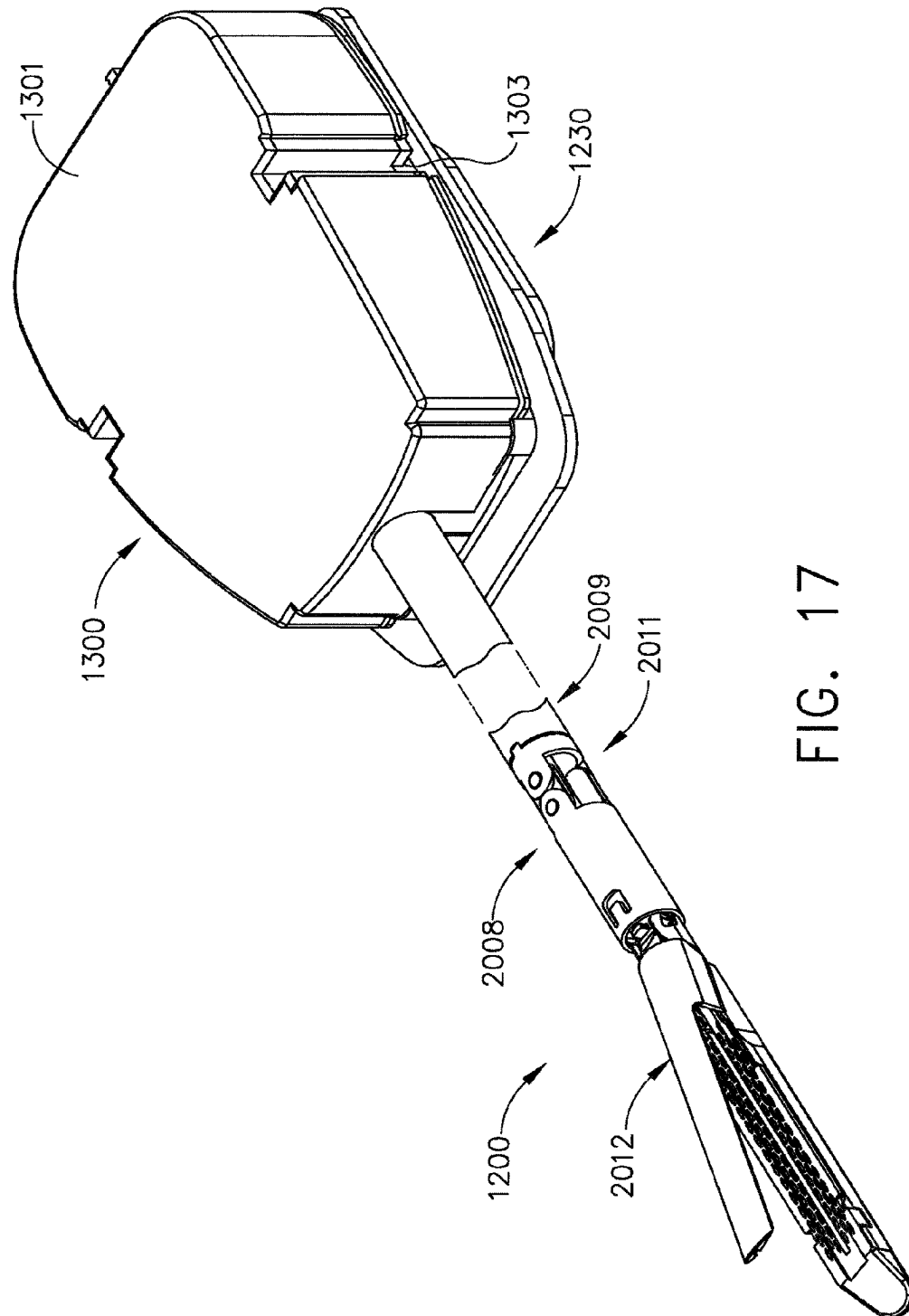


FIG. 16



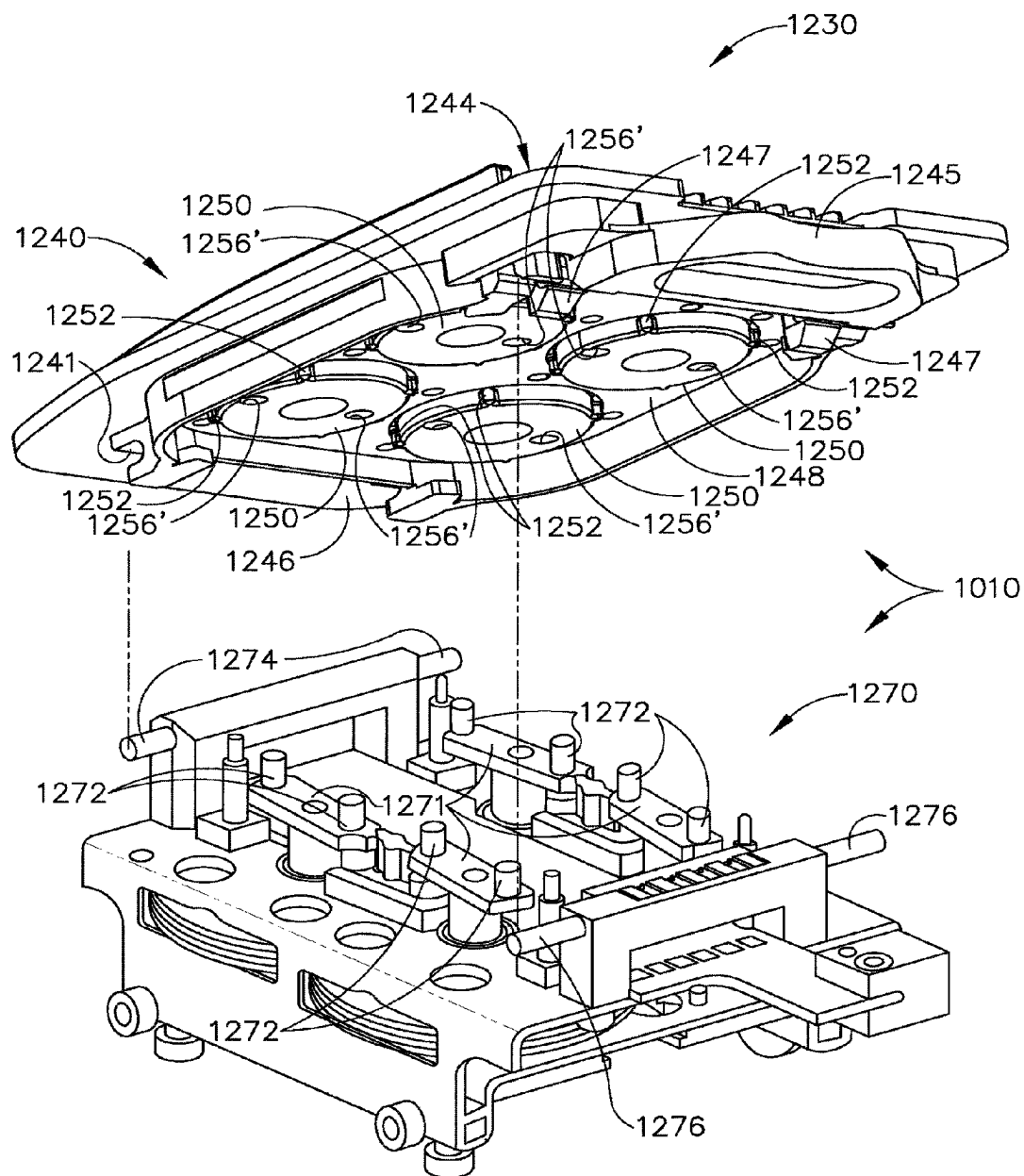


FIG. 18

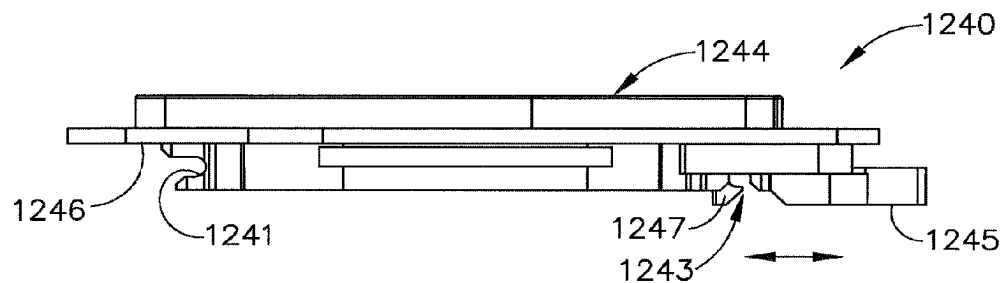


FIG. 19

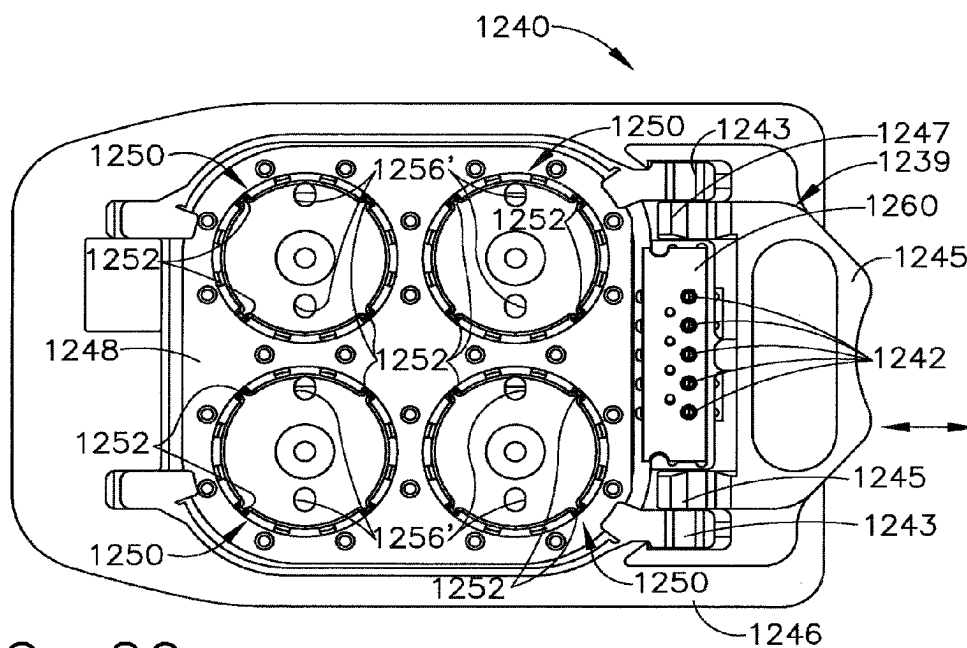


FIG. 20

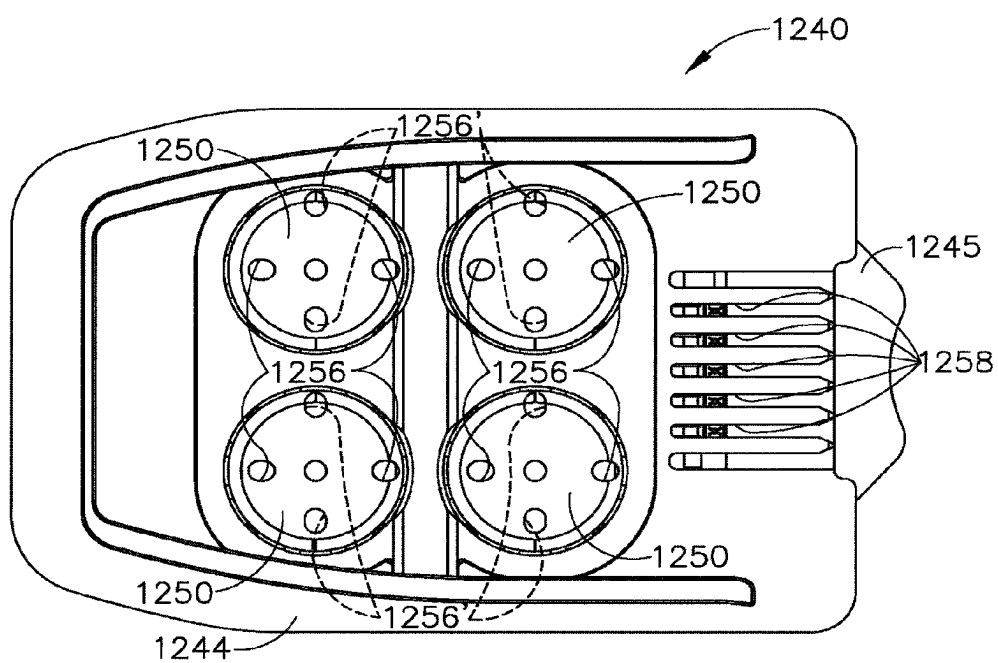


FIG. 21

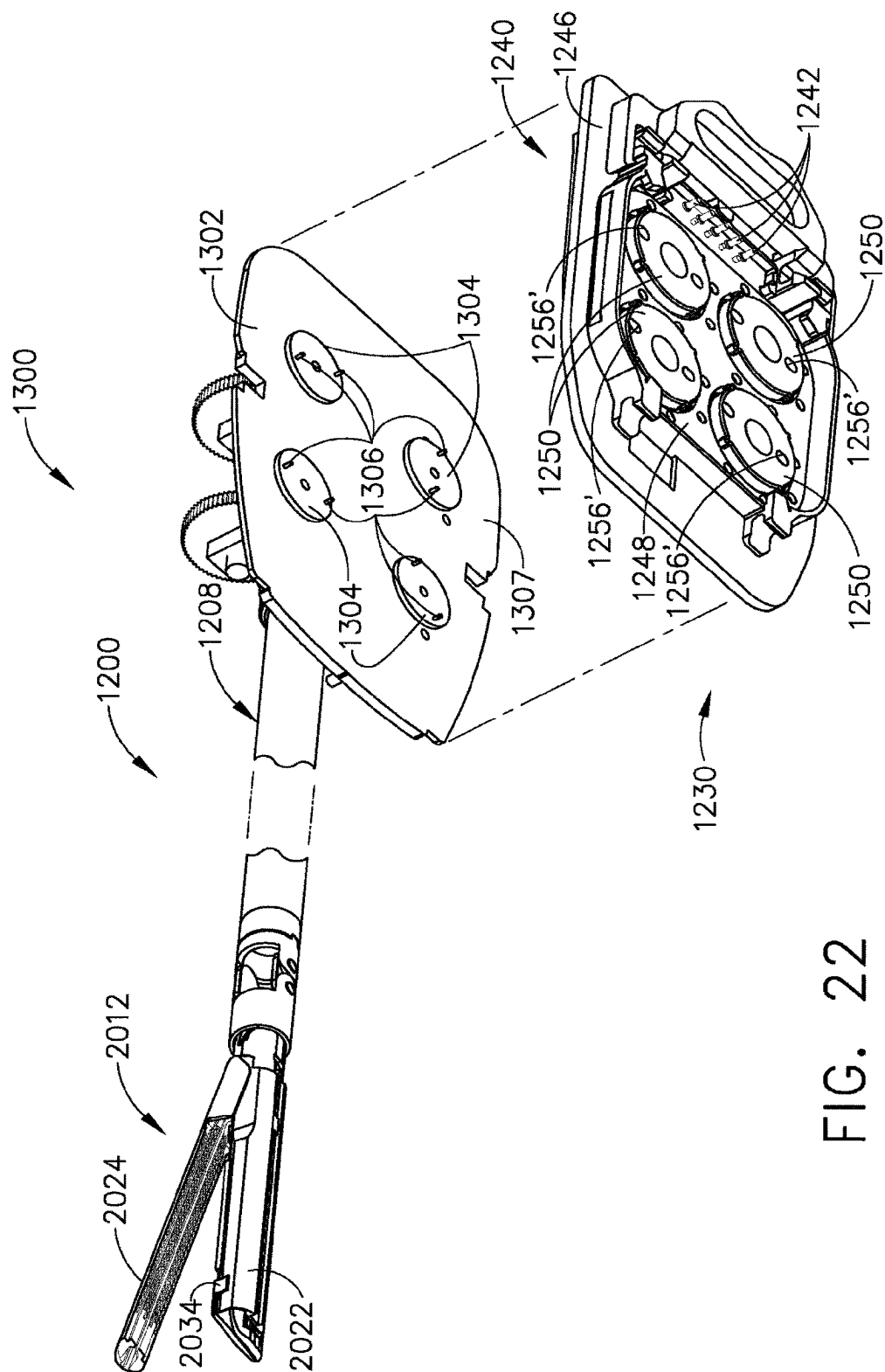
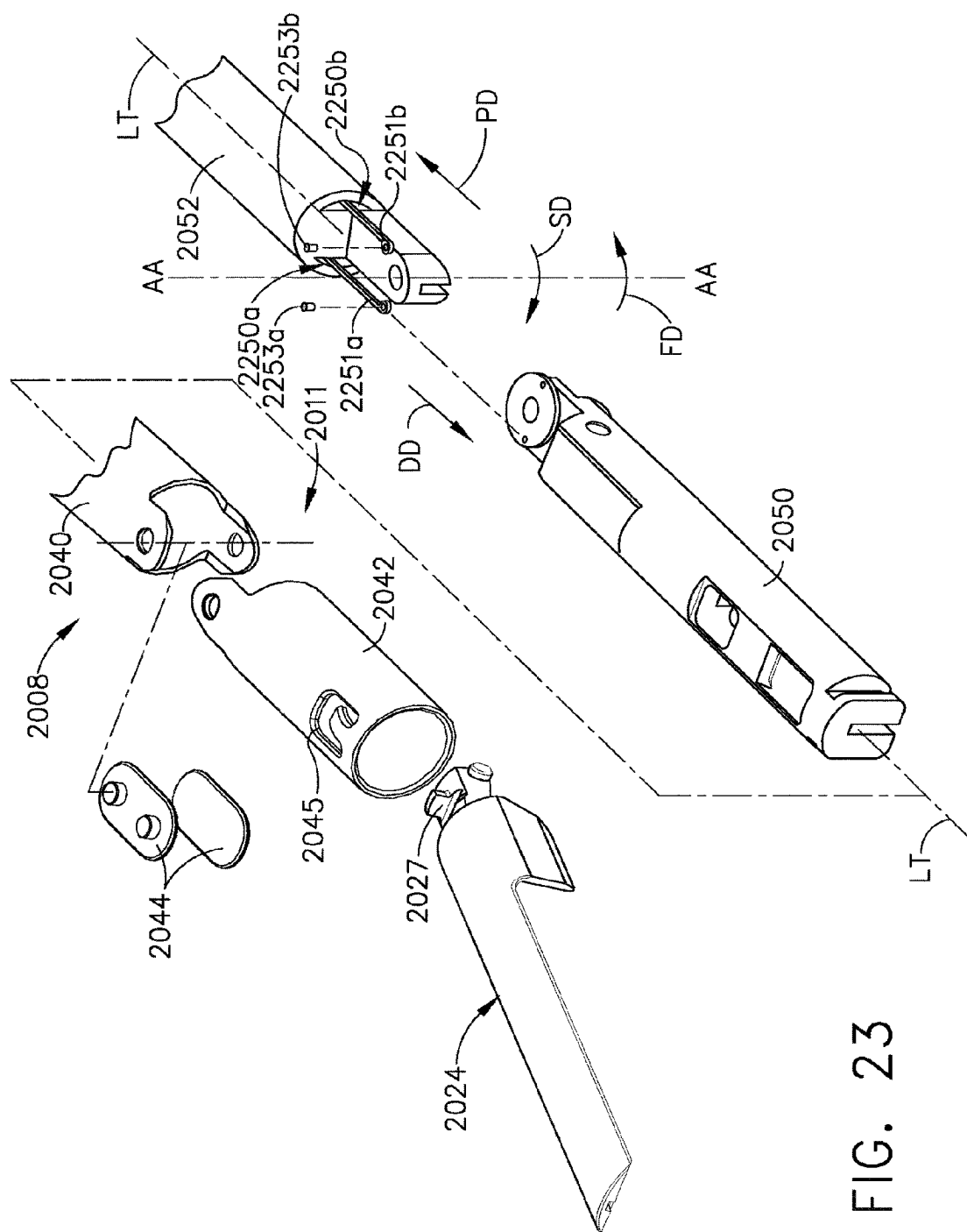


FIG. 22



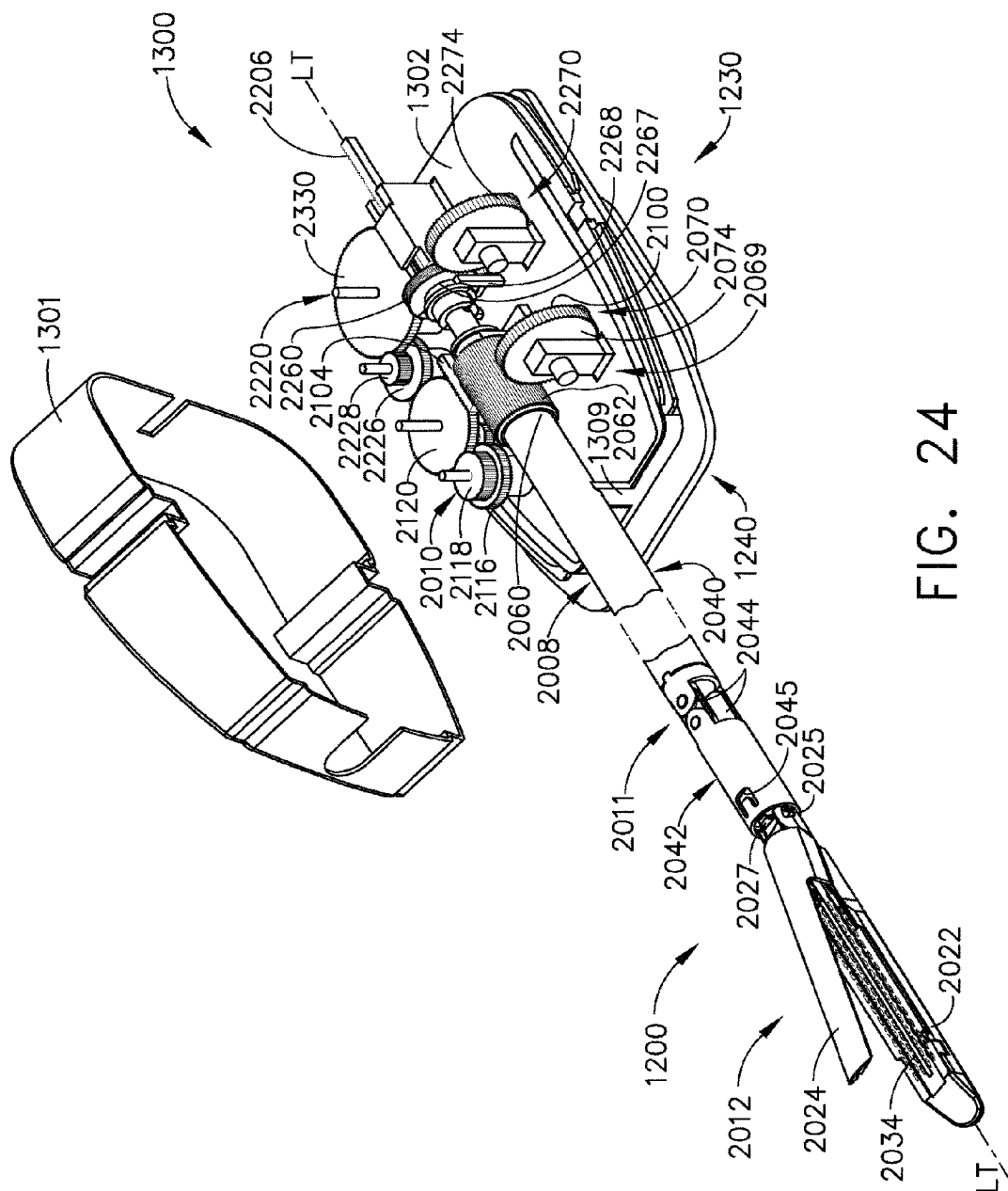


FIG. 24

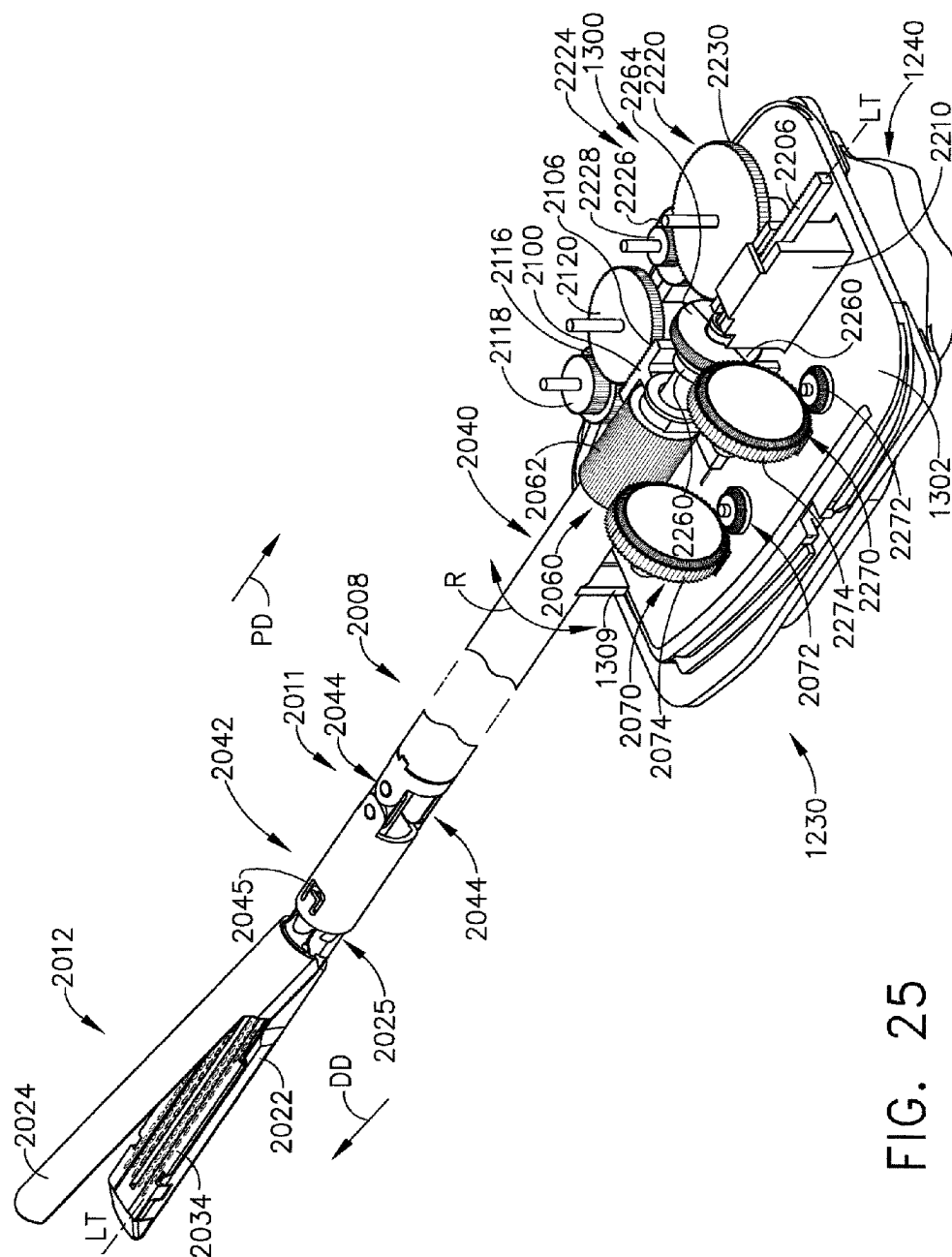


FIG. 25

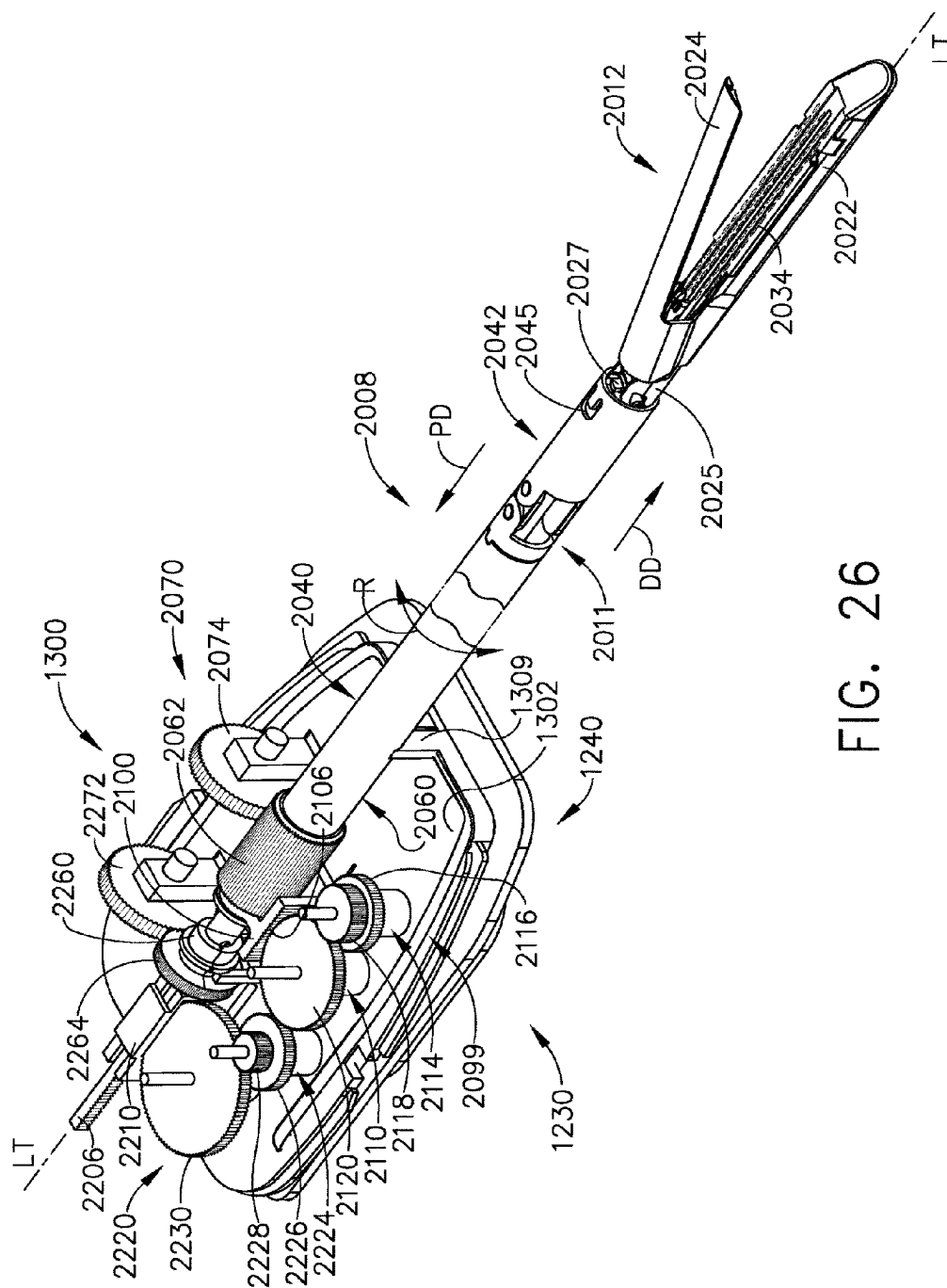
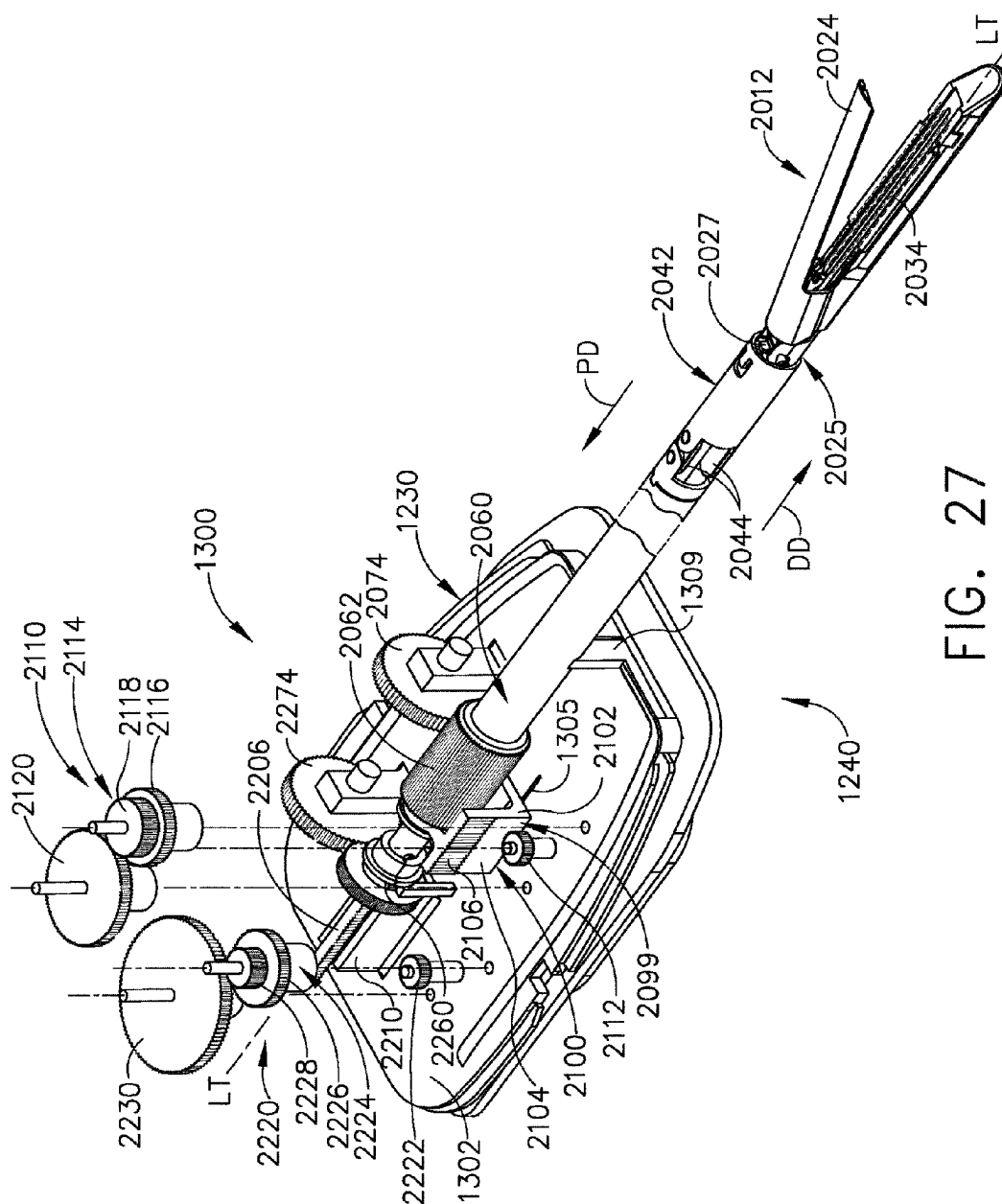


FIG. 26



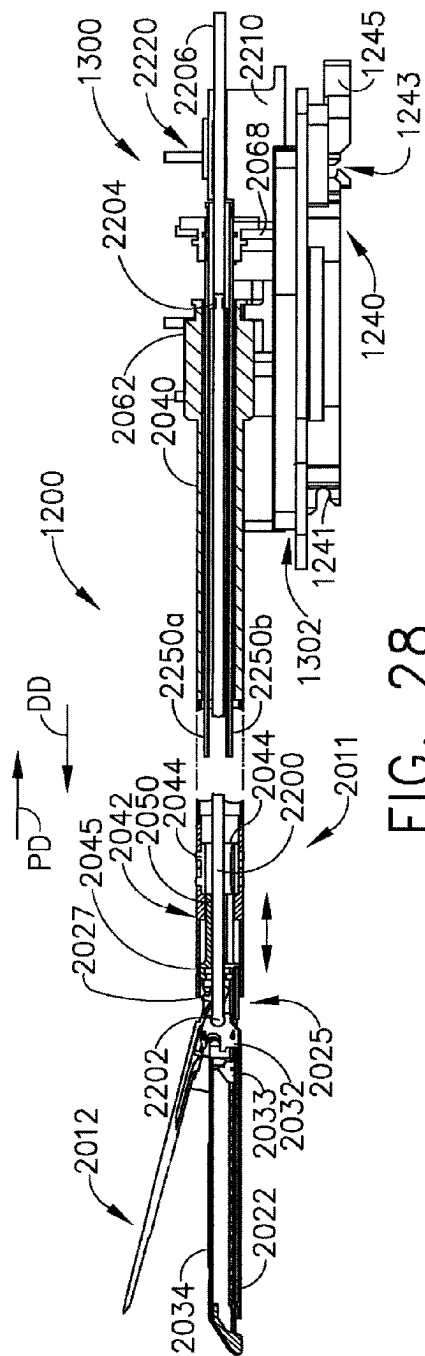


FIG. 28

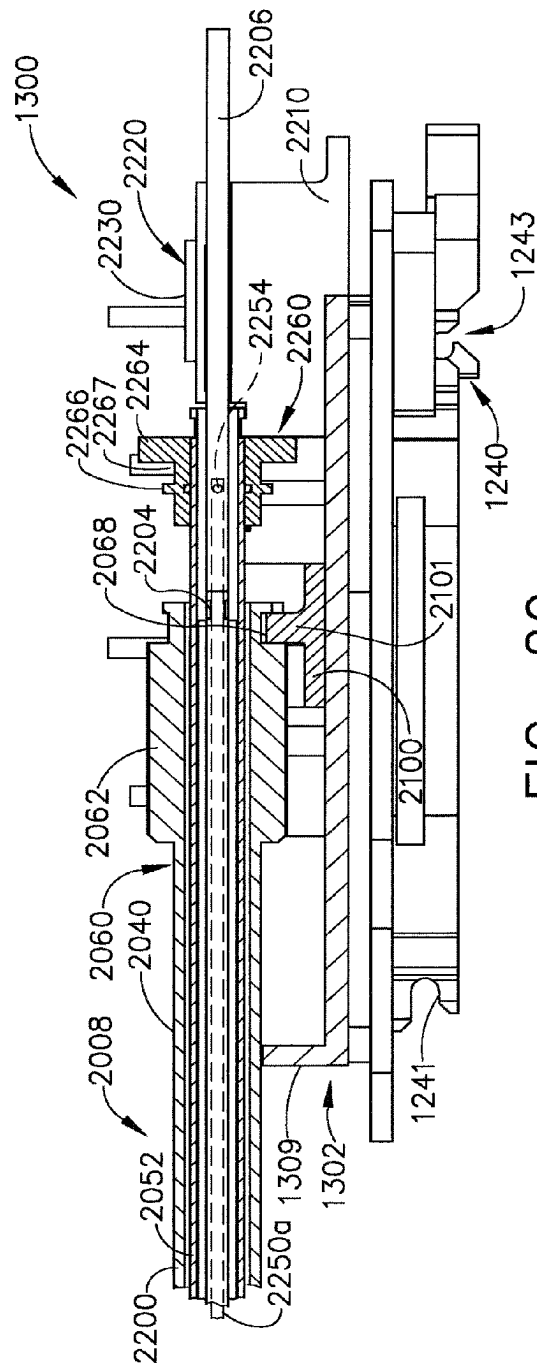
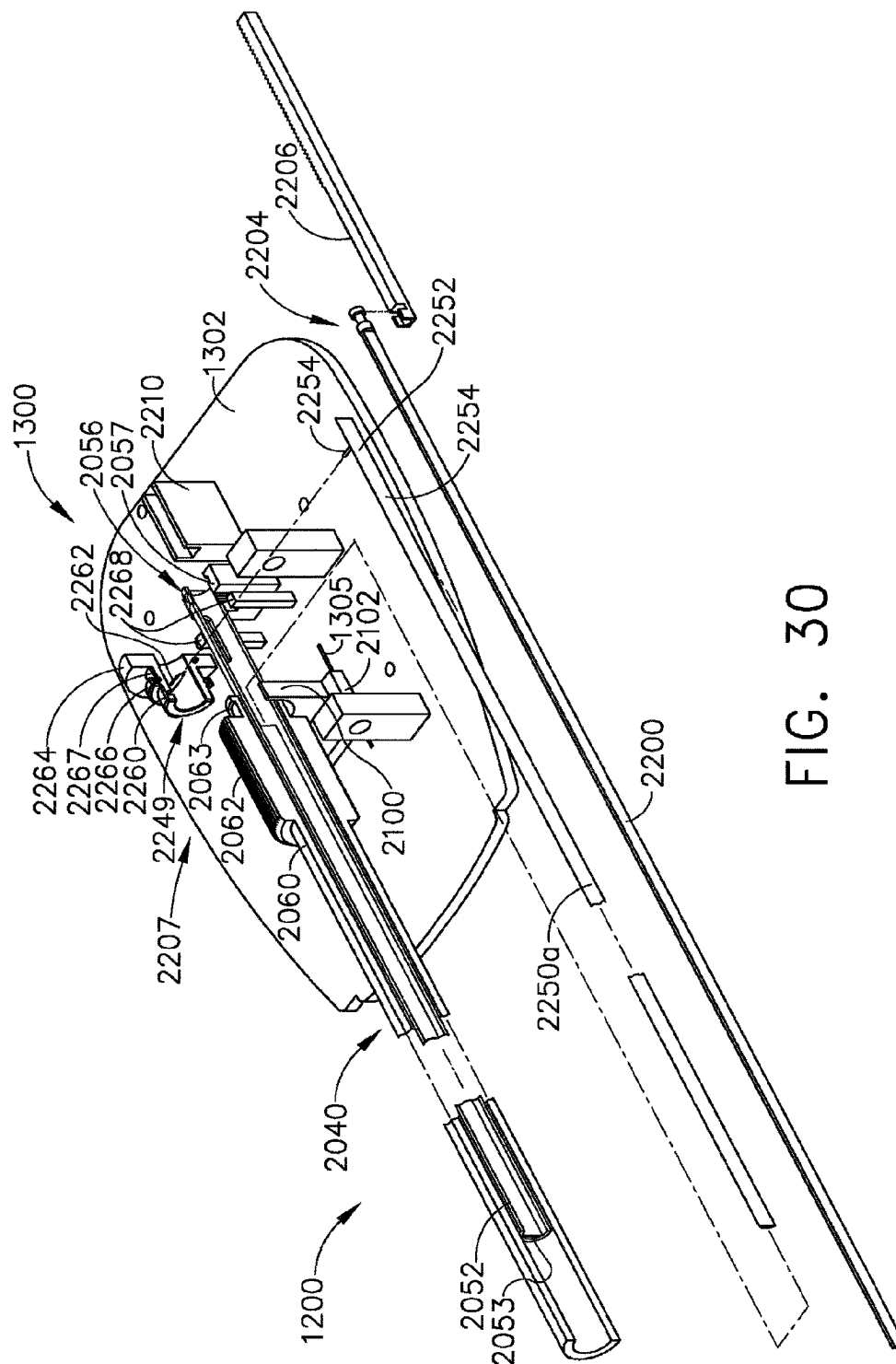


FIG. 29



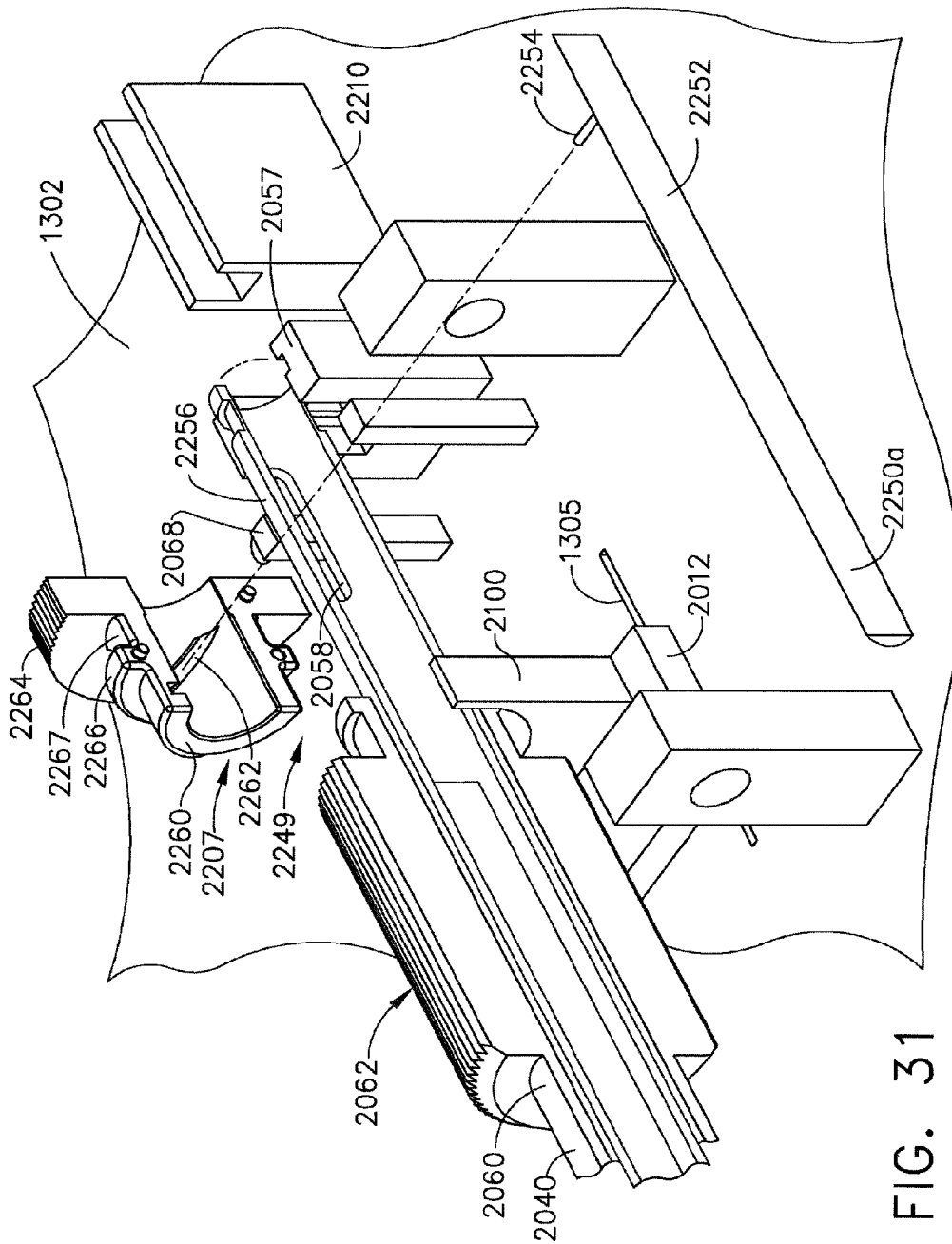


FIG. 31

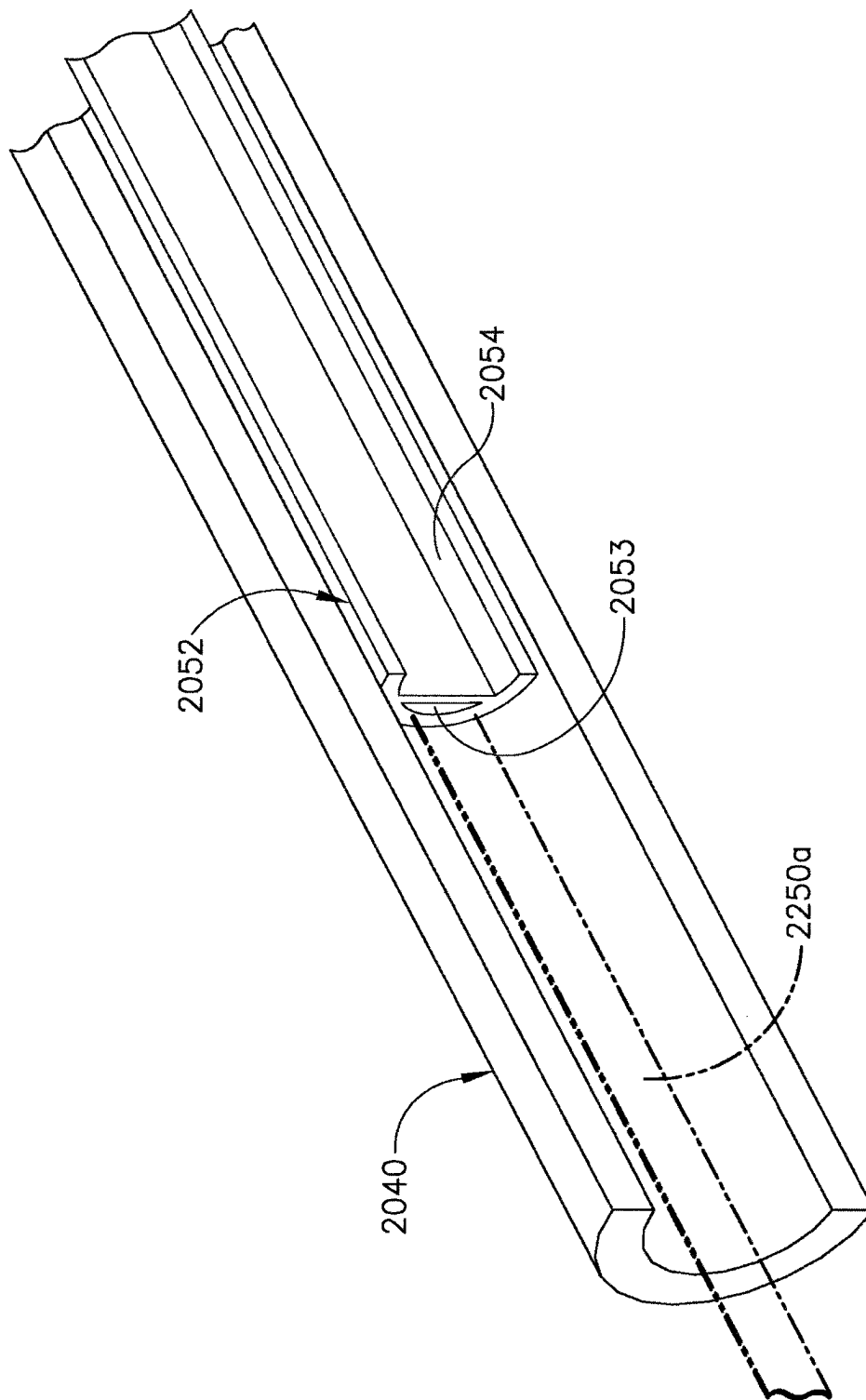


FIG. 32

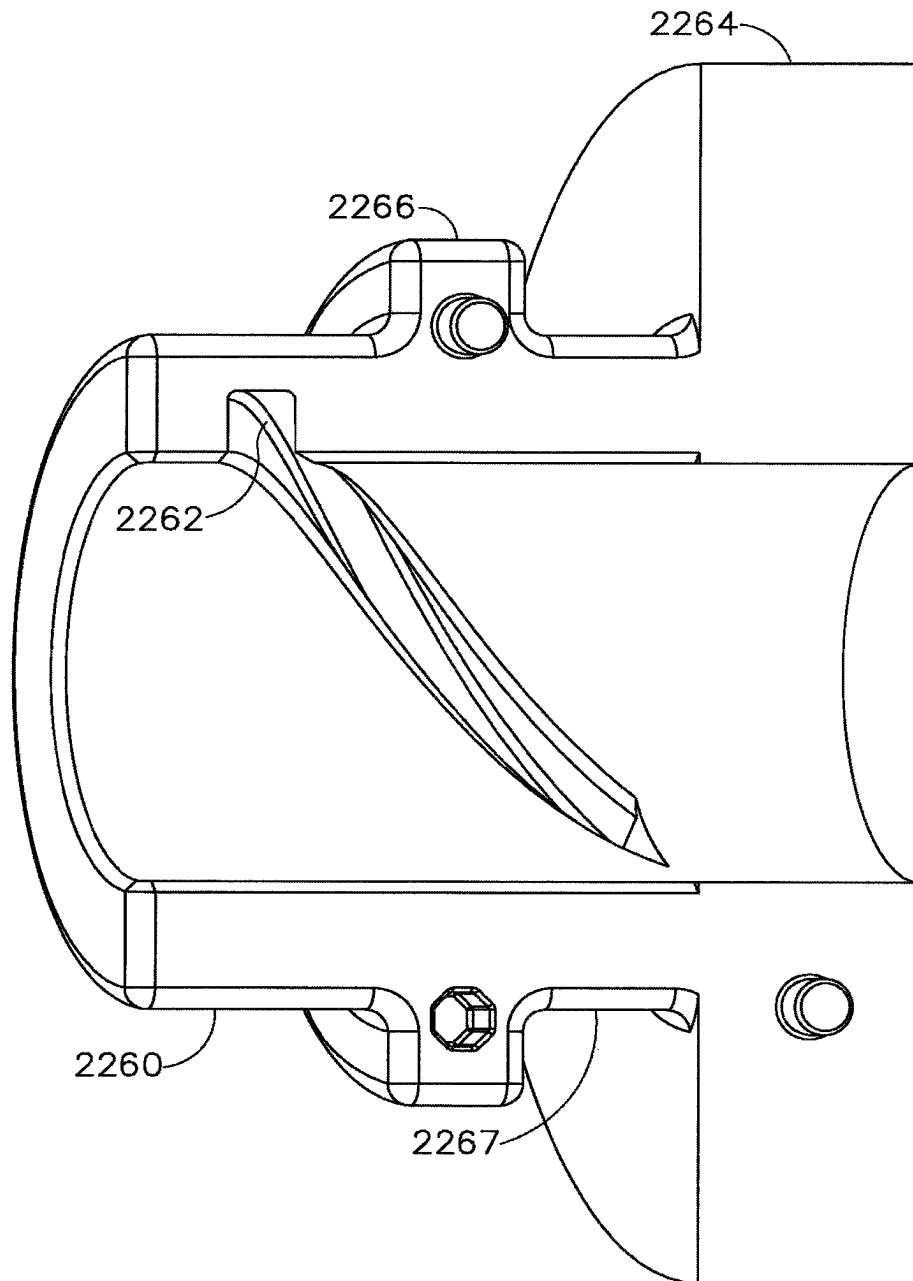
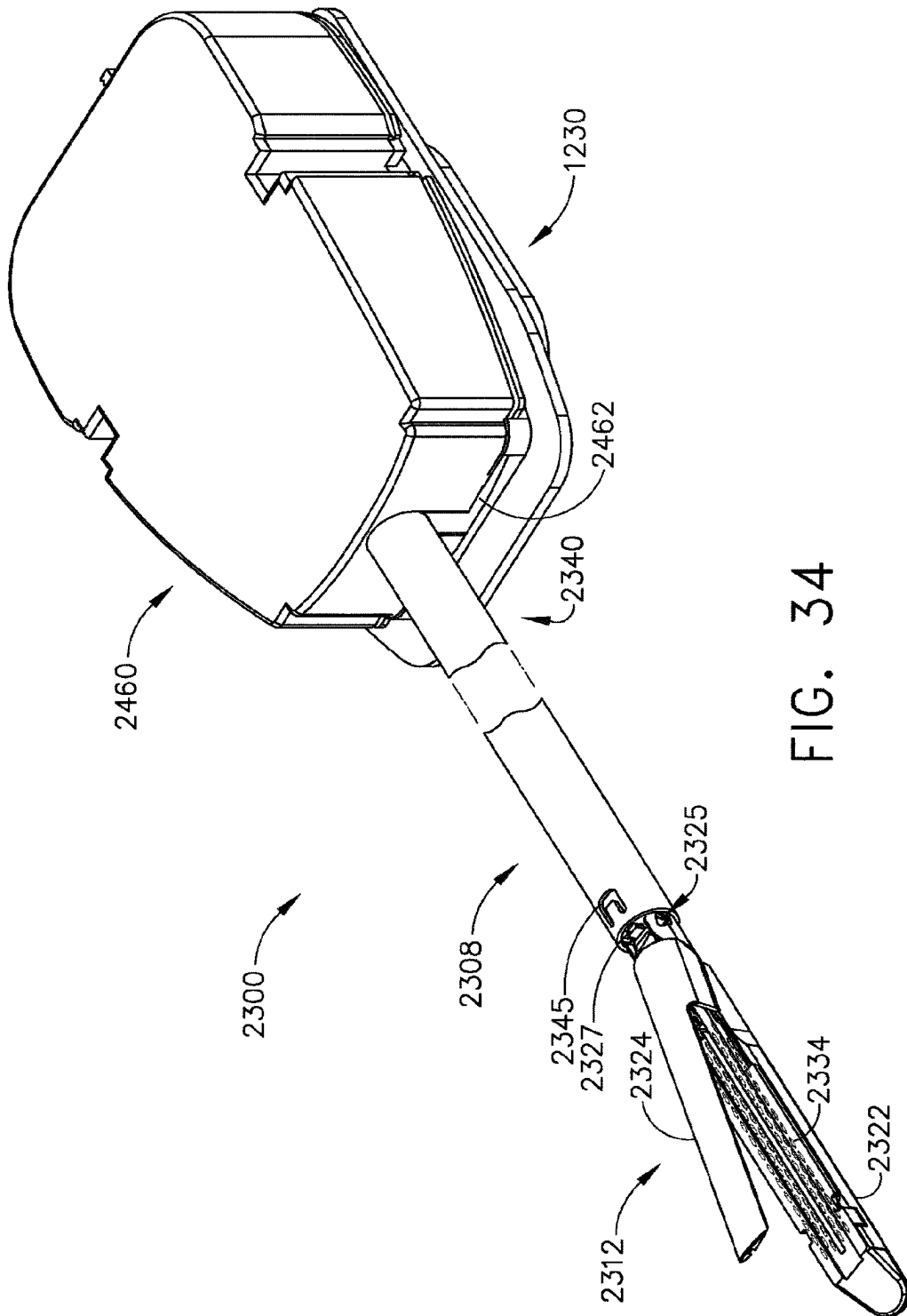
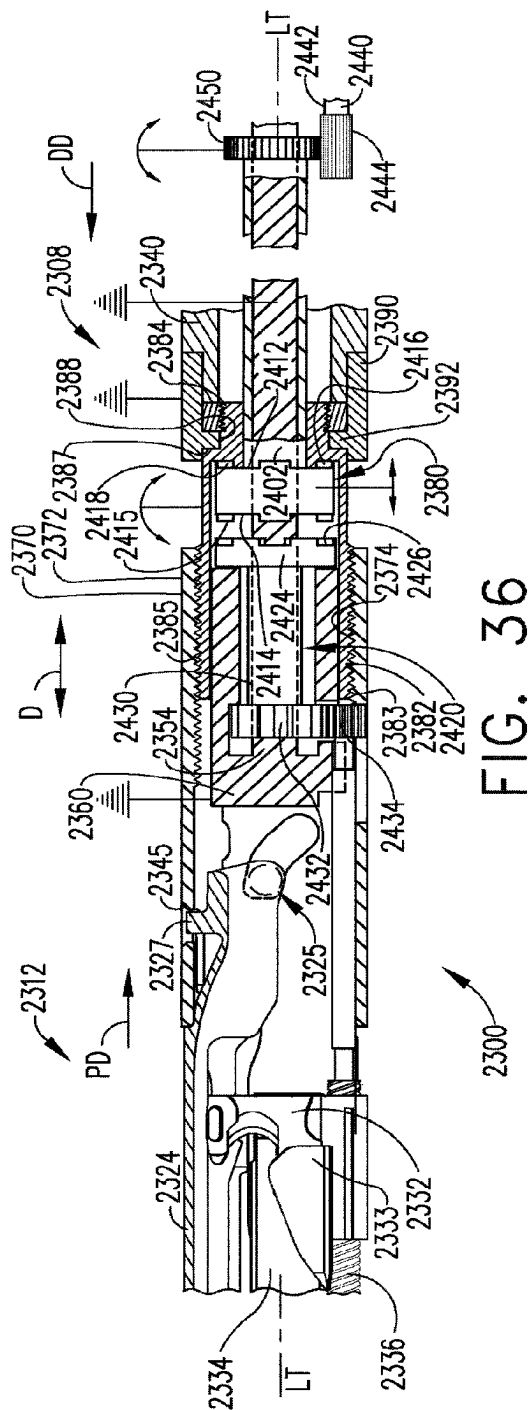
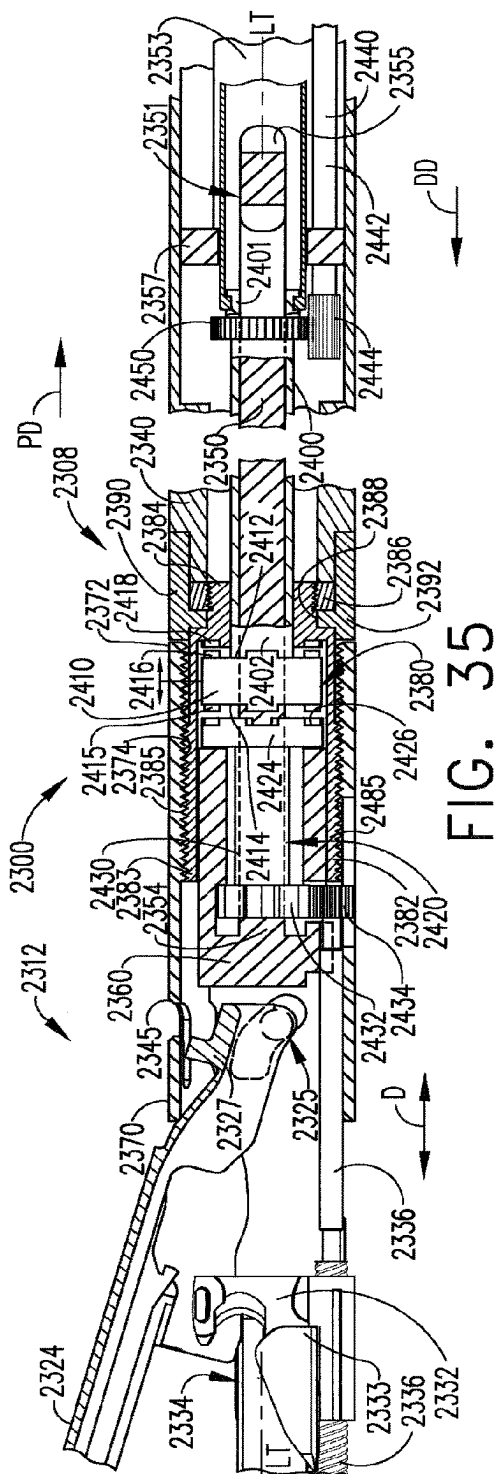


FIG. 33





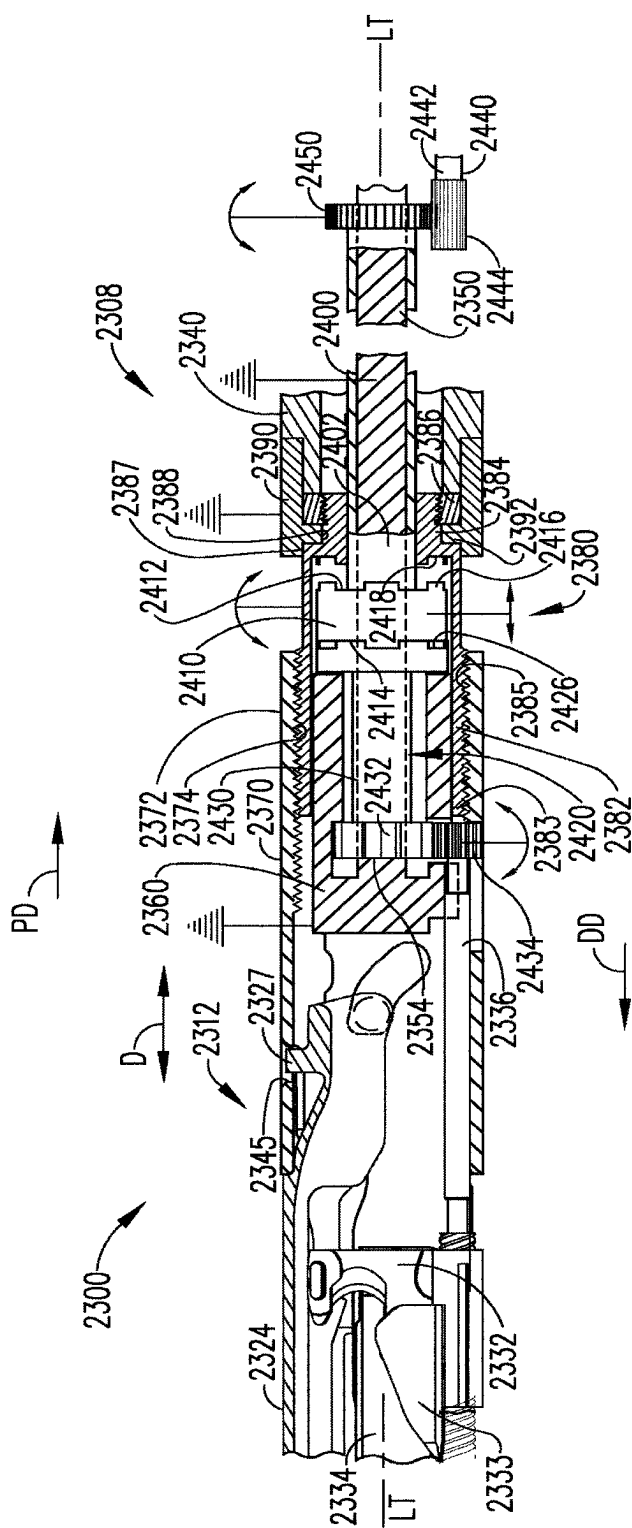


FIG. 37

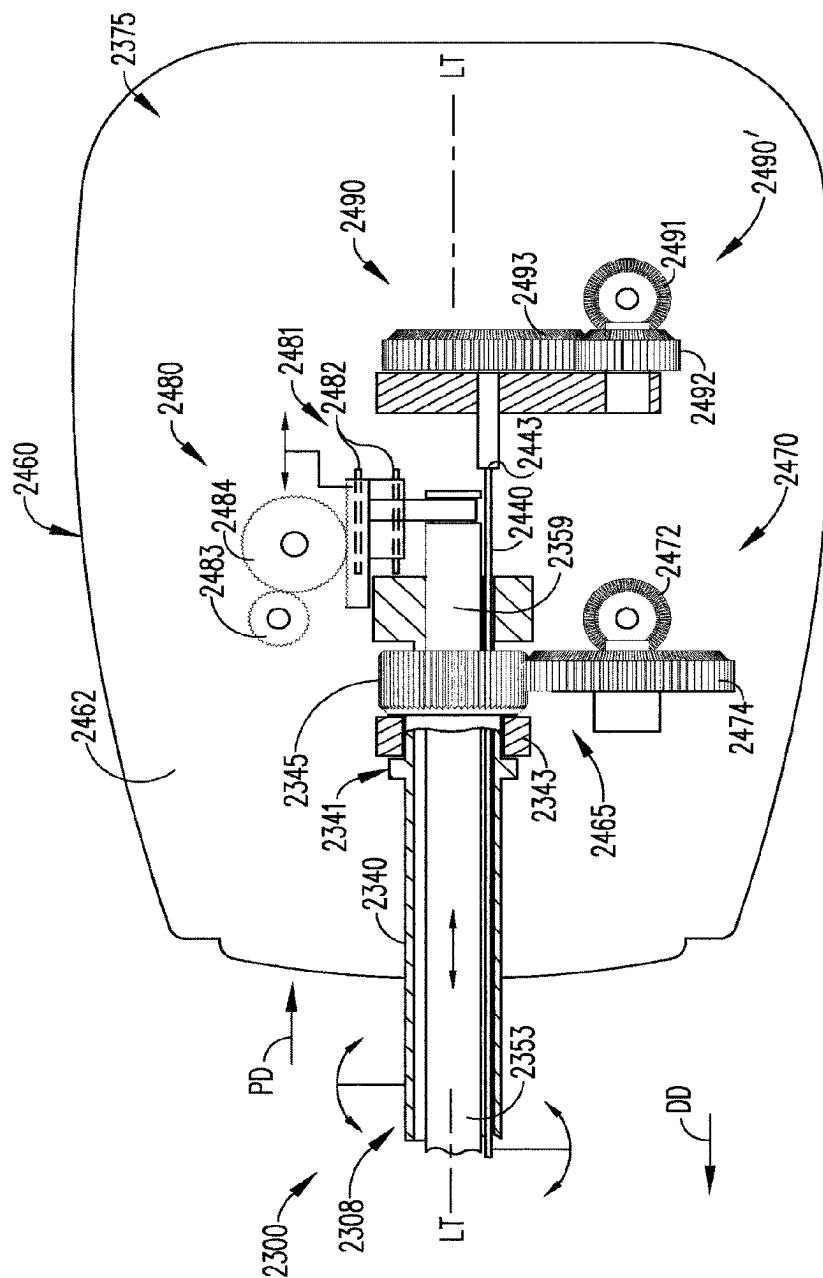


FIG. 38

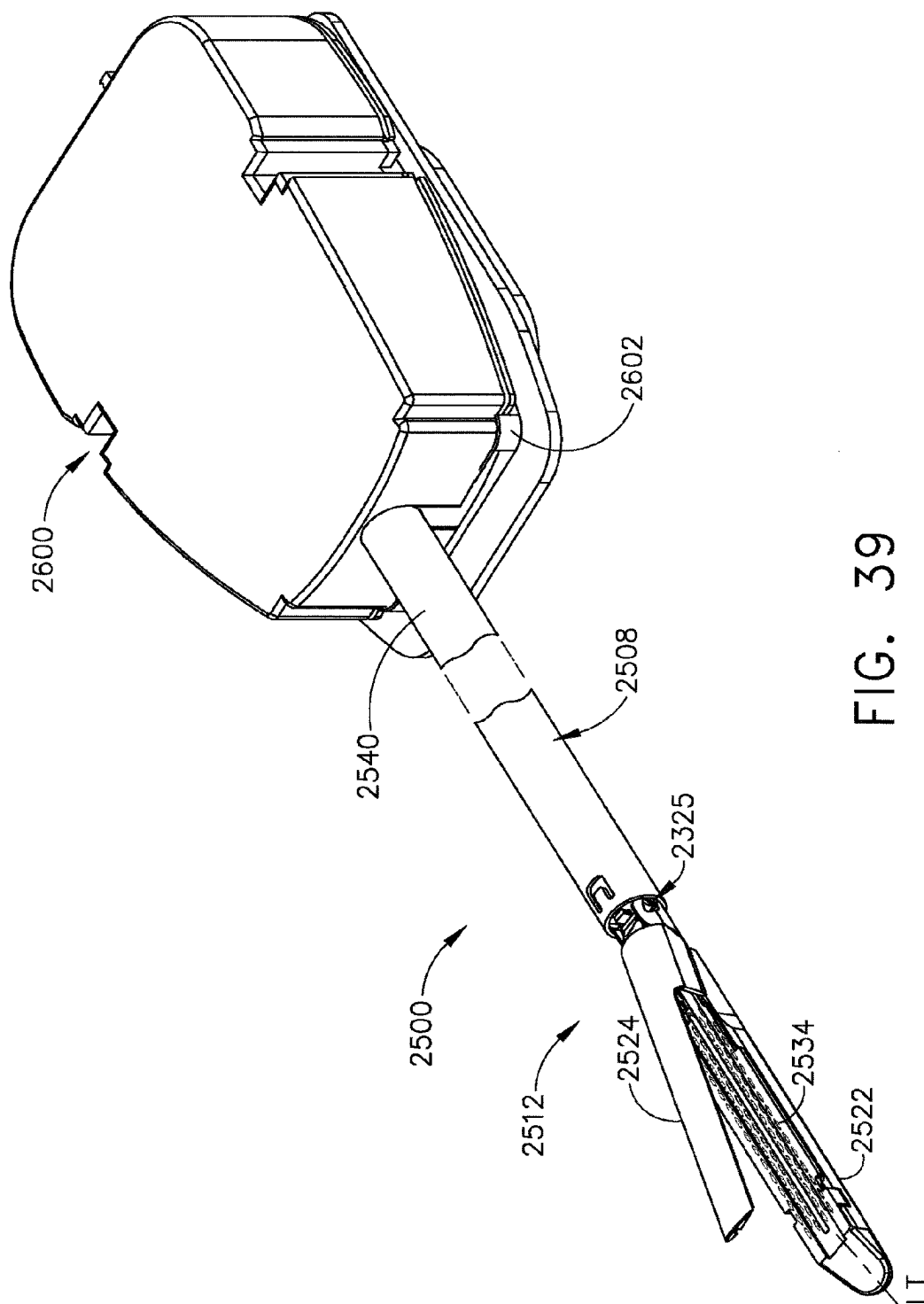


FIG. 39

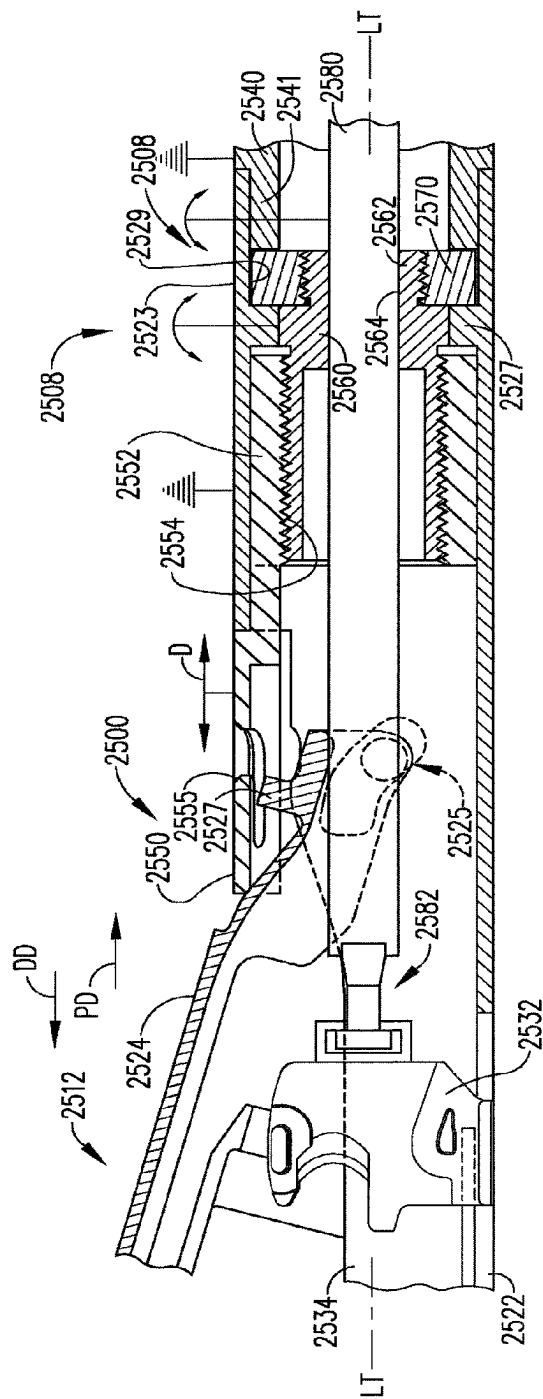


FIG. 40

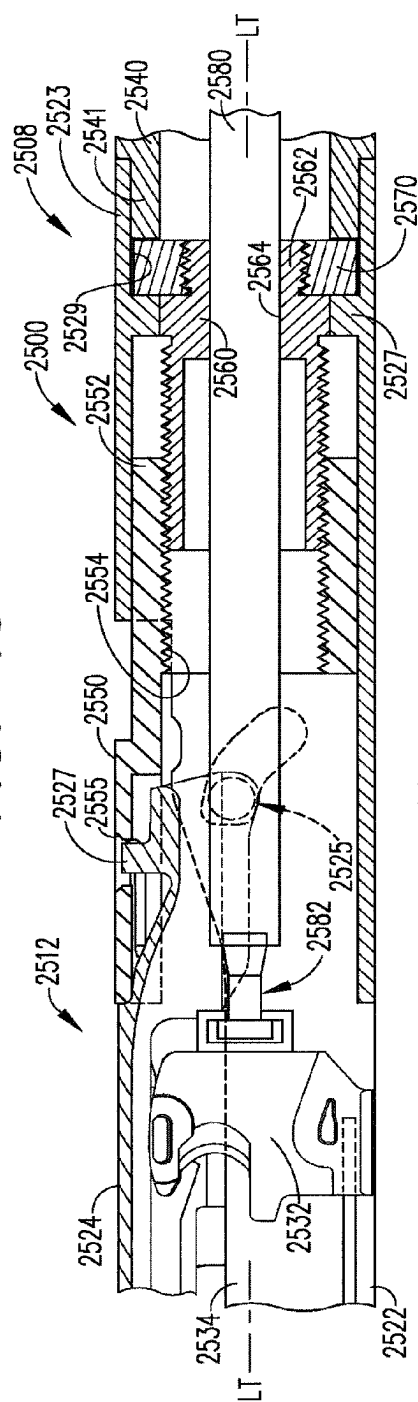


FIG. 41

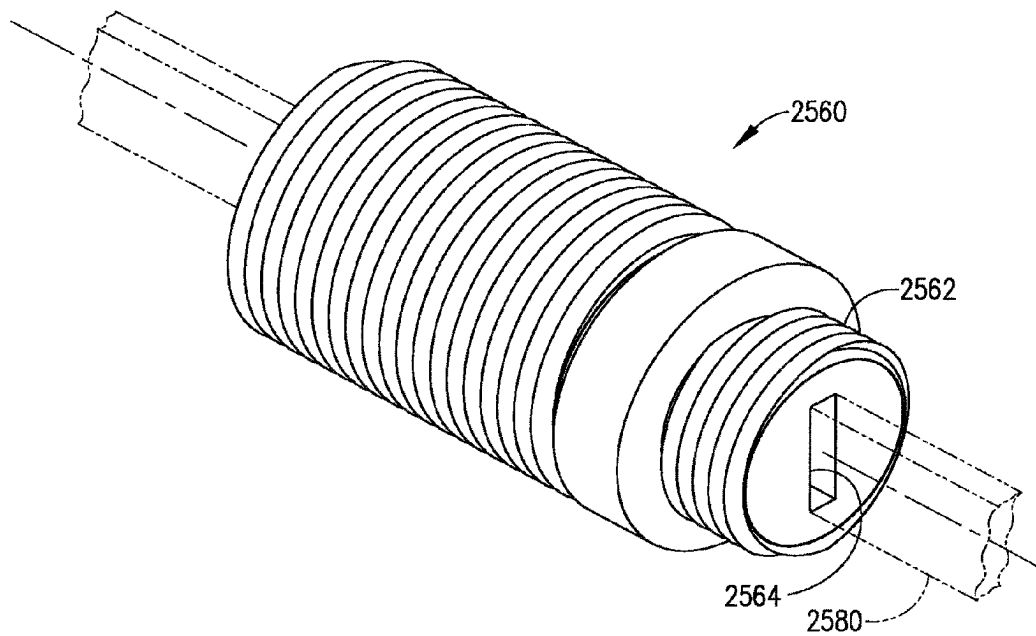


FIG. 42

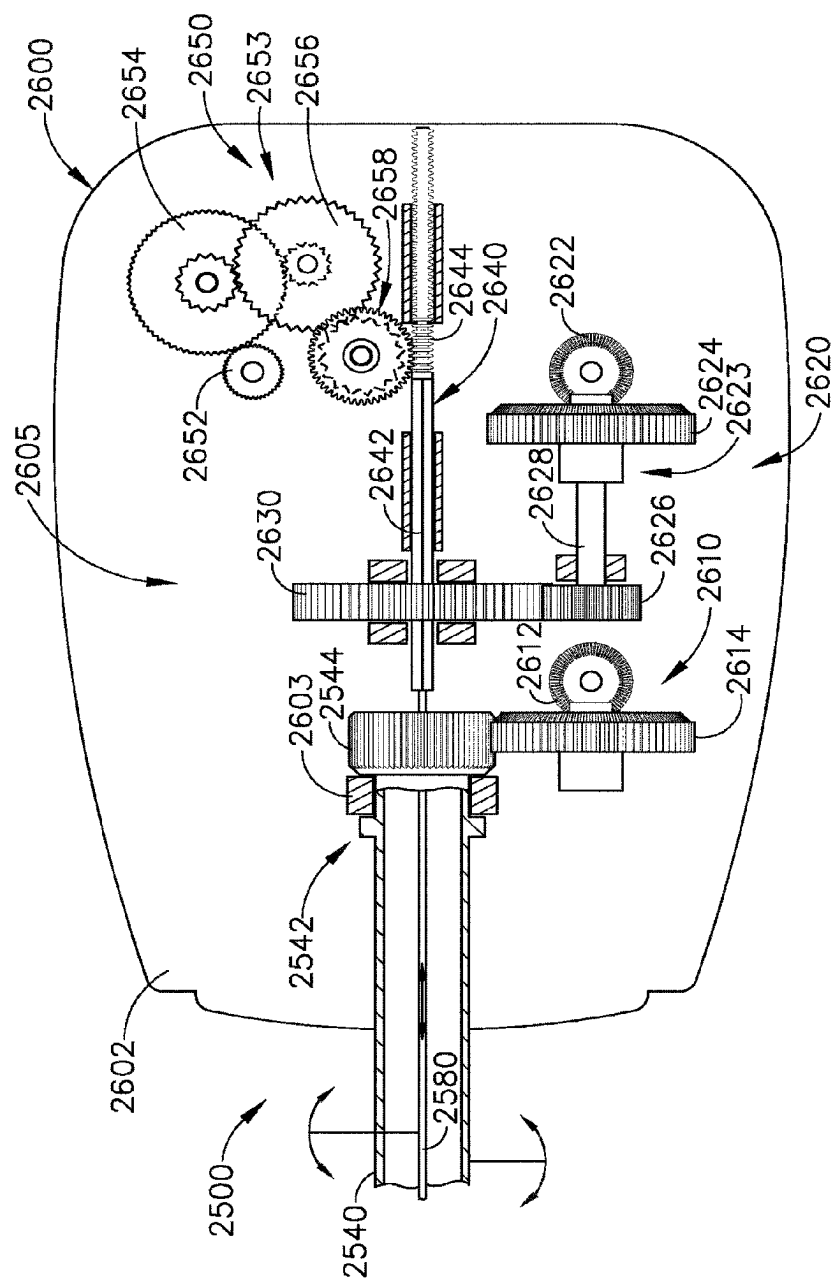


FIG. 43

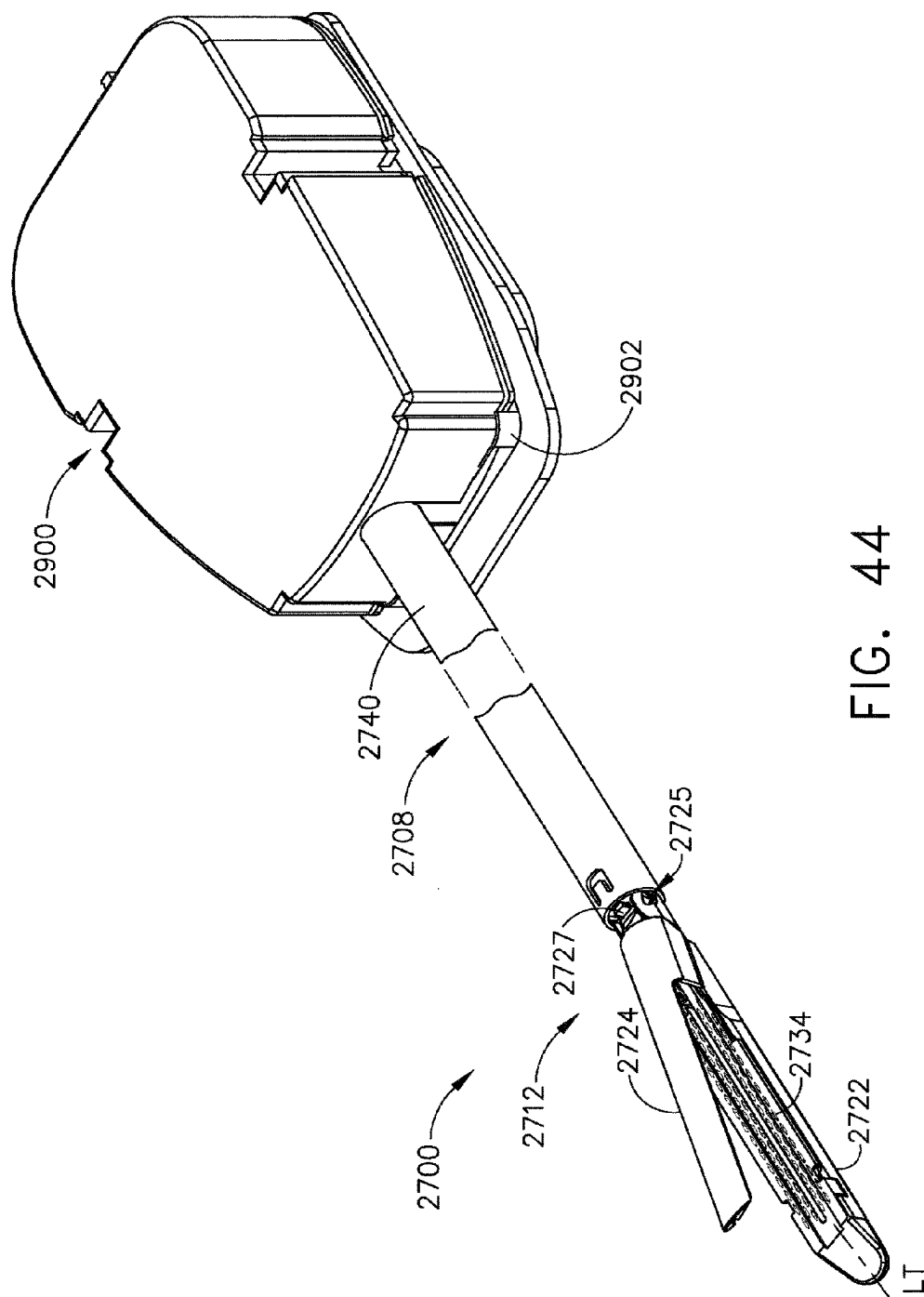


FIG. 44

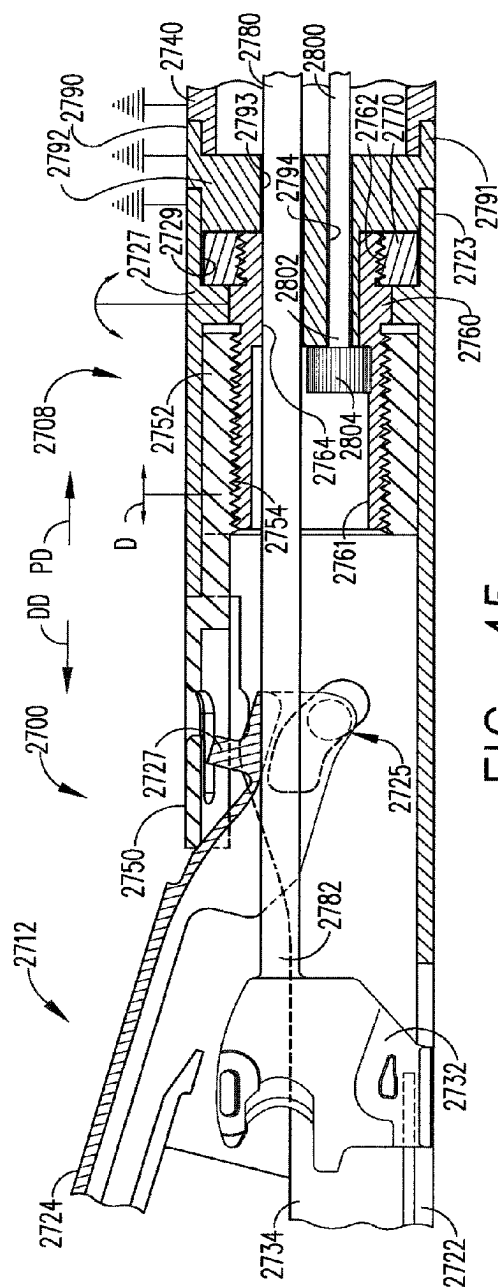


FIG. 45

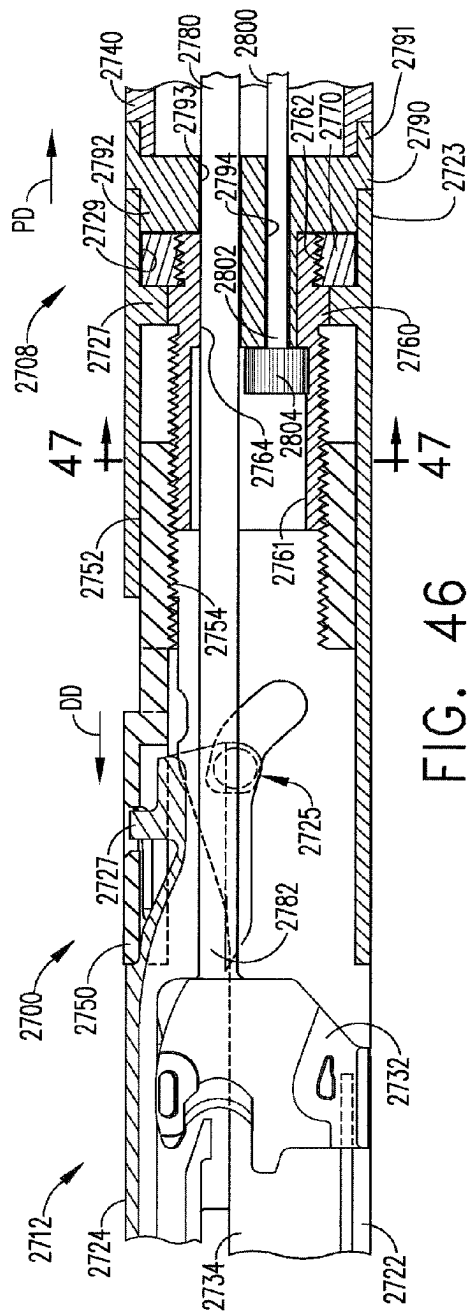


FIG. 46

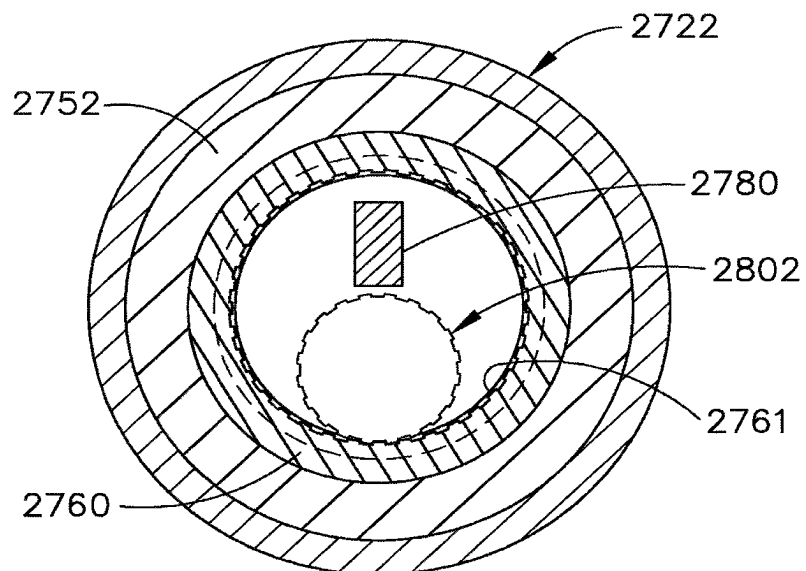


FIG. 47

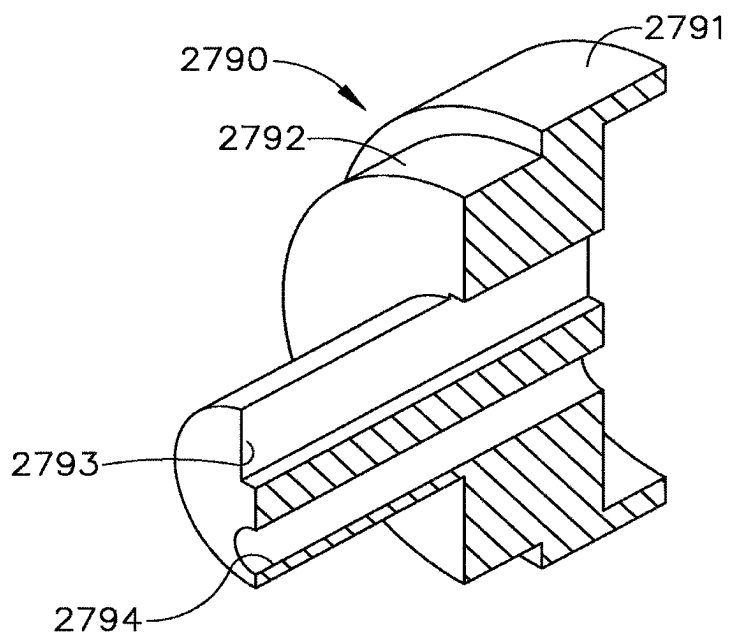


FIG. 48

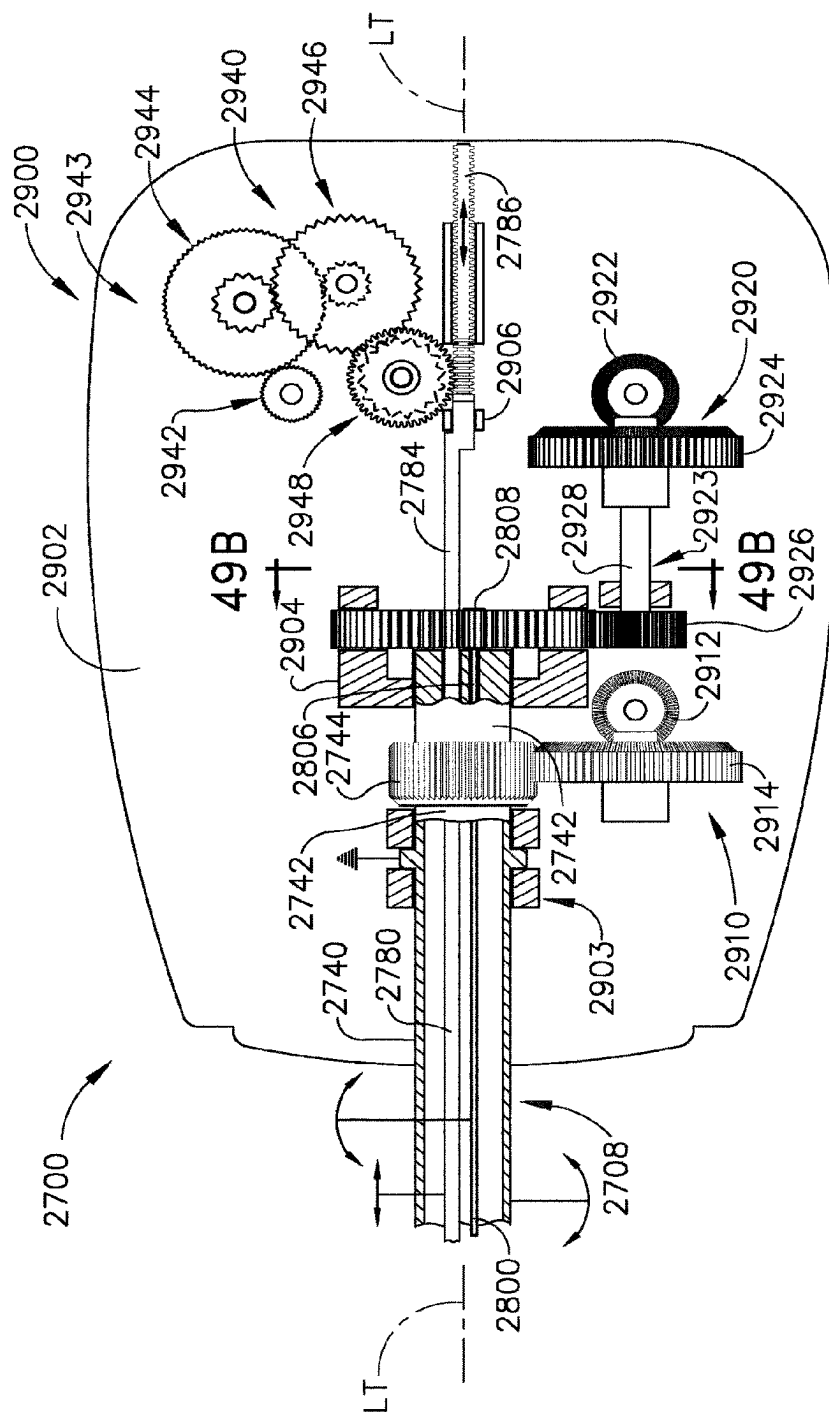


FIG. 49

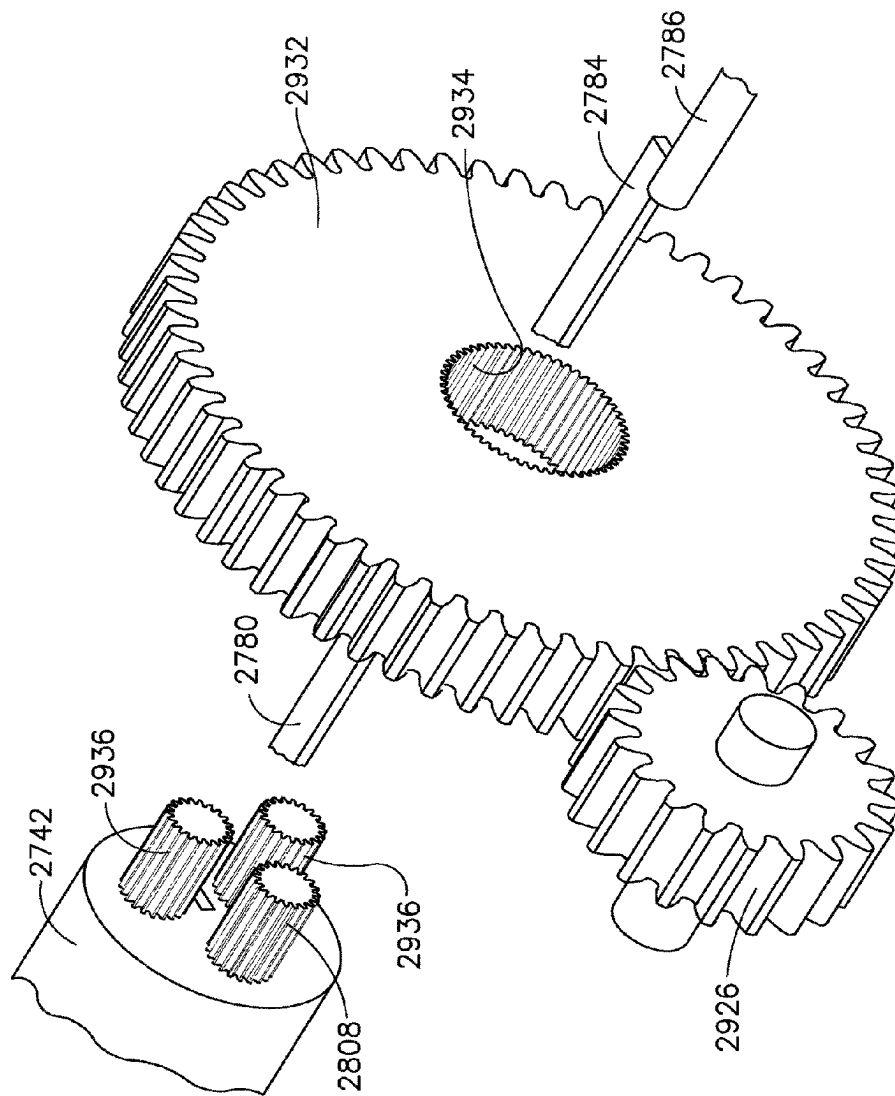


FIG. 49A

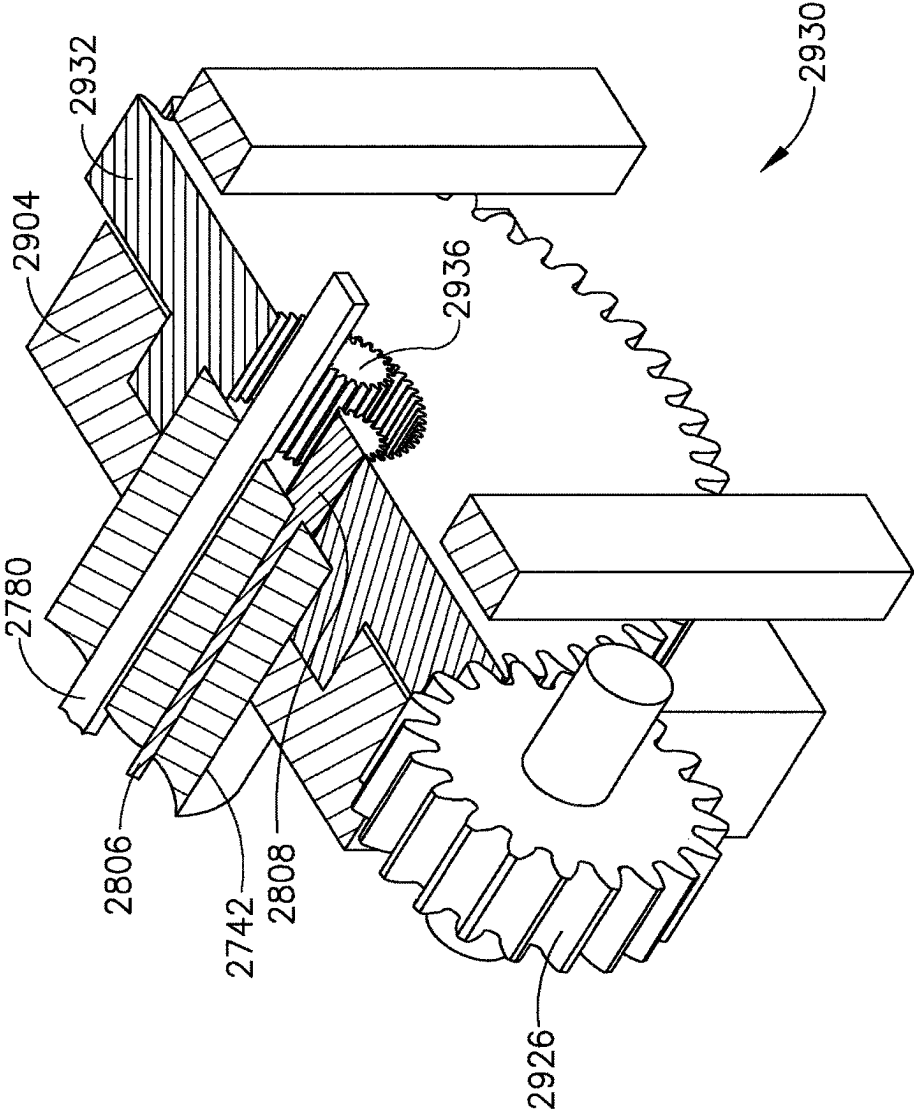


FIG. 49B

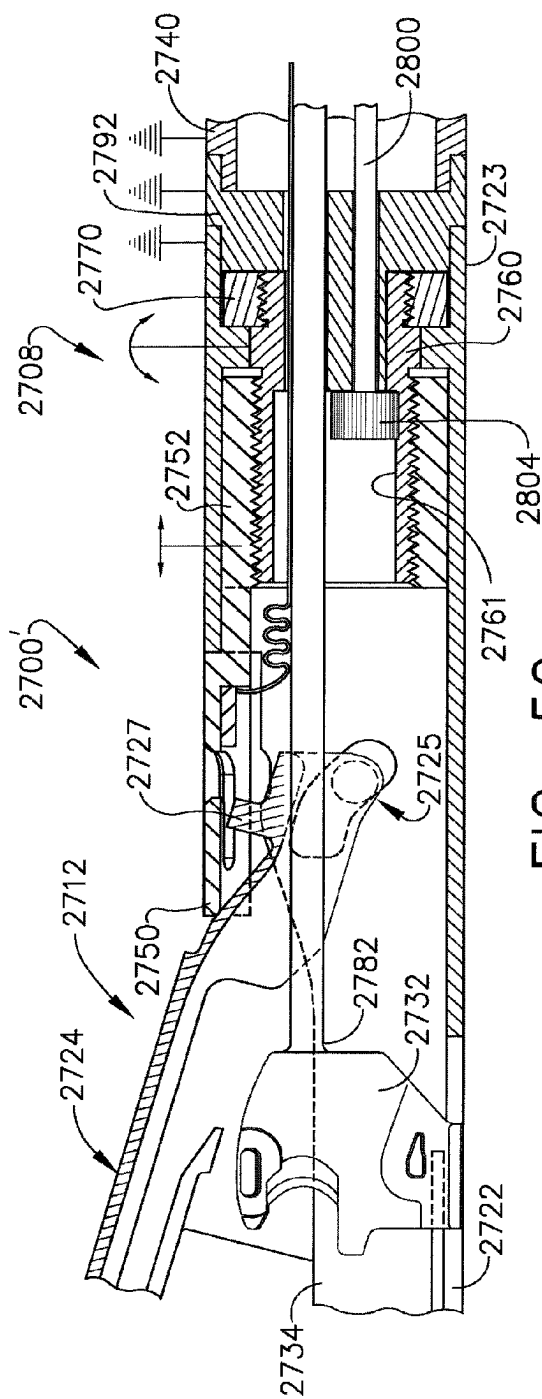


FIG. 50

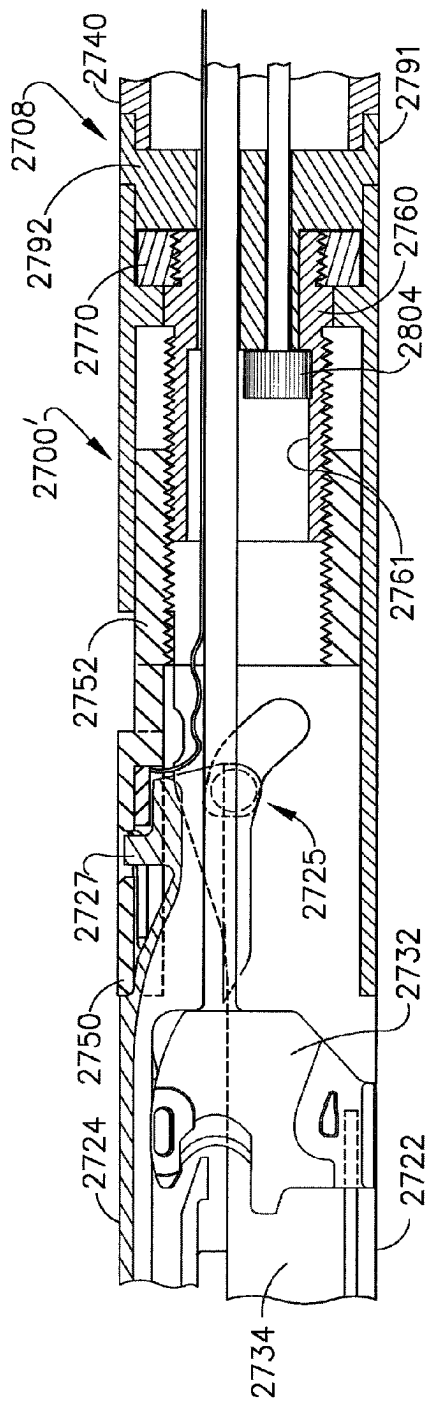


FIG. 51

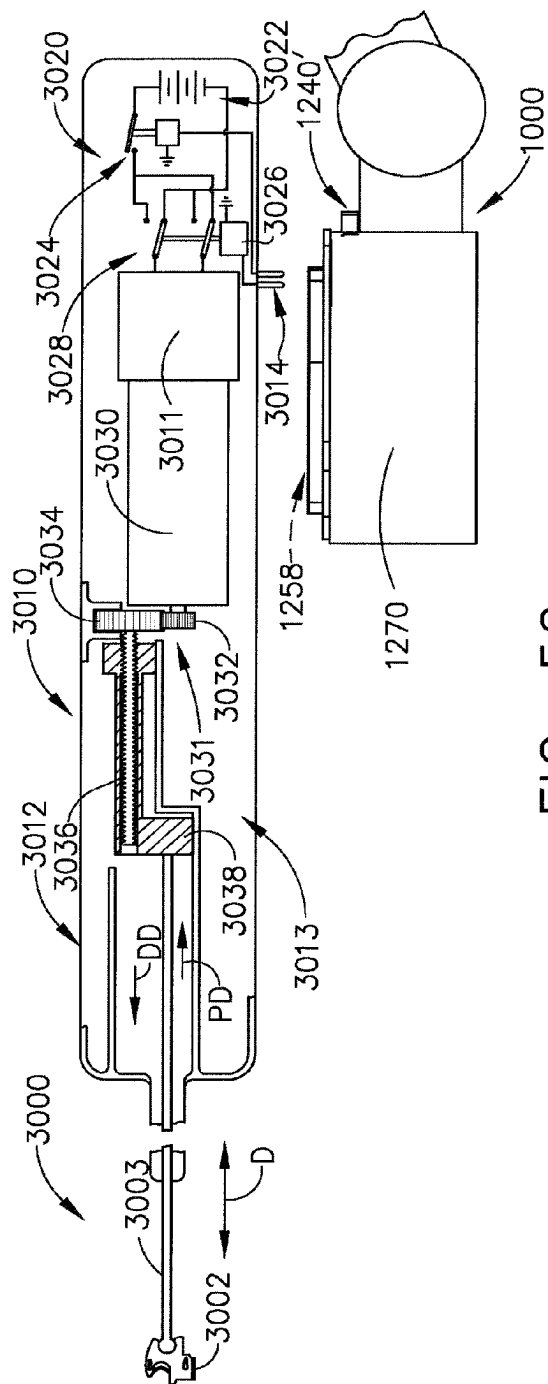


FIG. 52

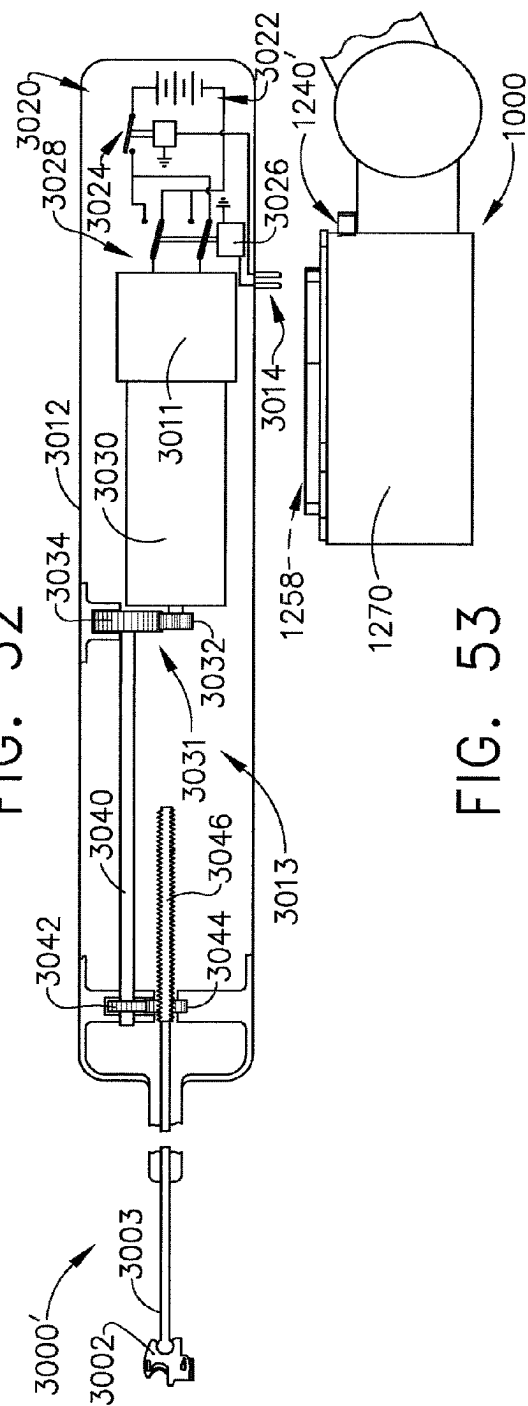


FIG. 53

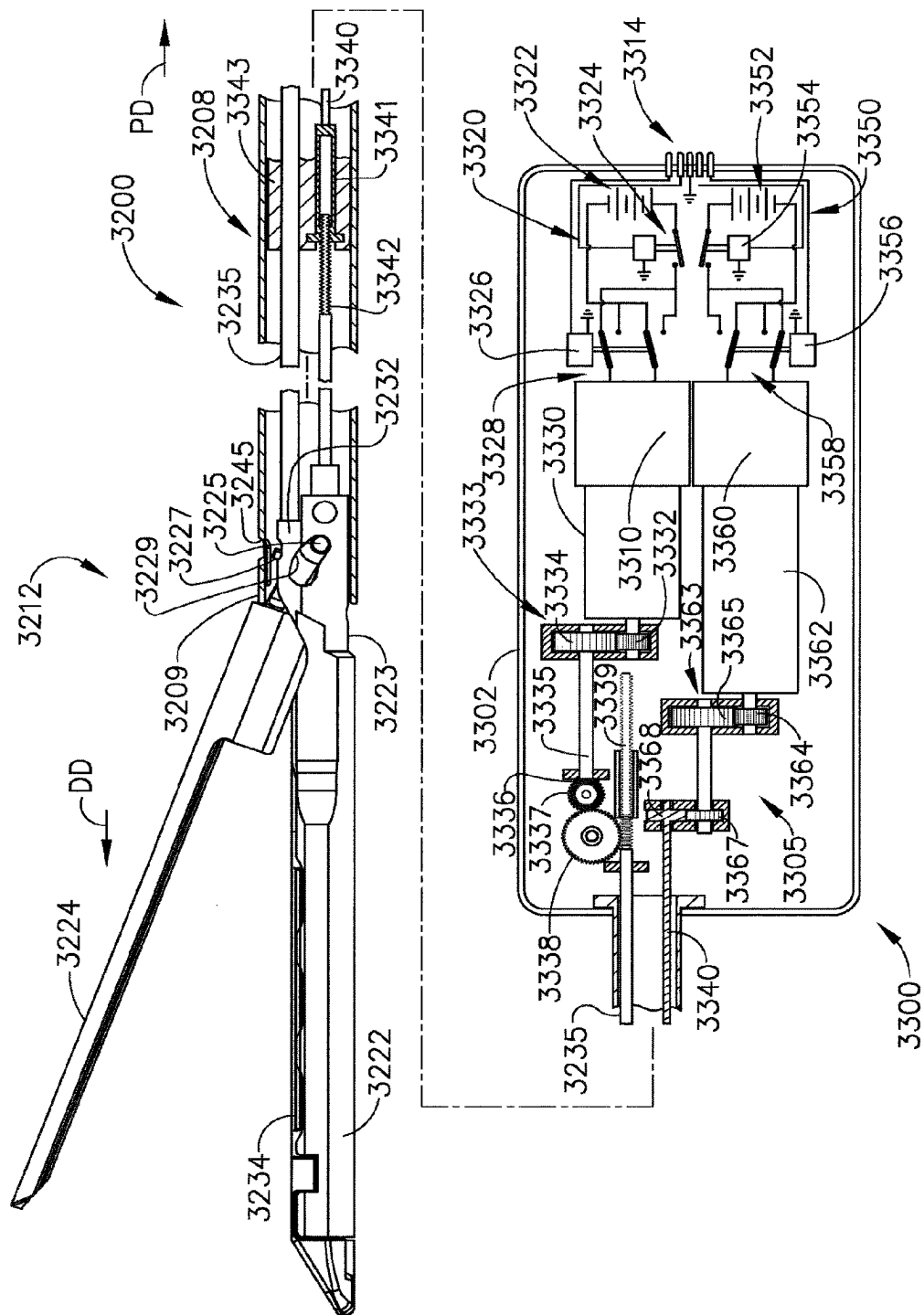


FIG. 54

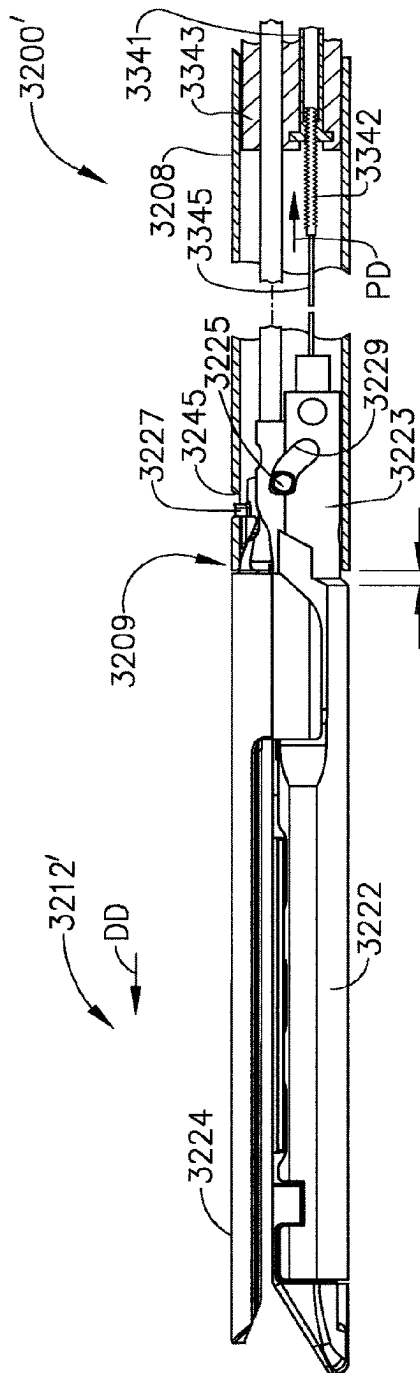


FIG. 55

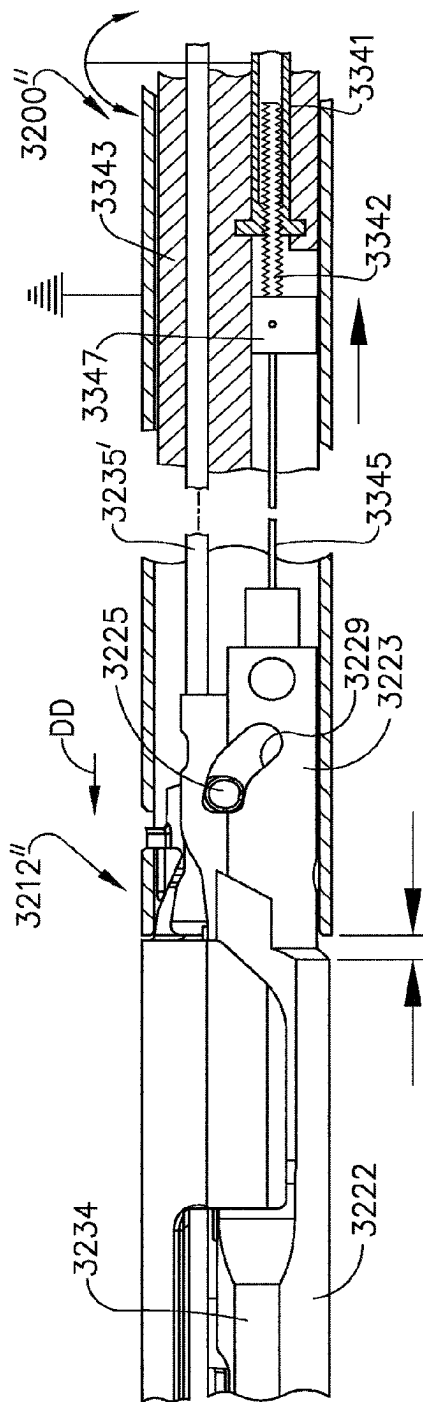


FIG. 56

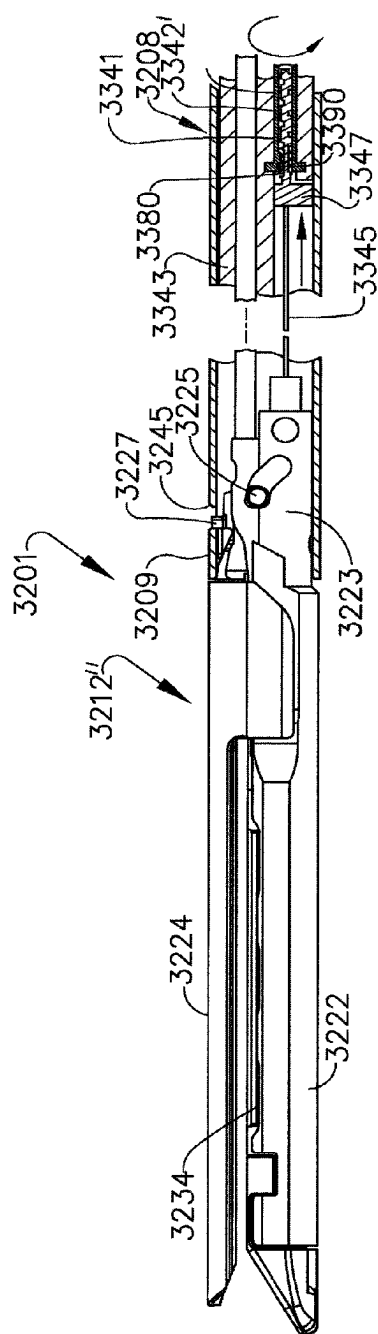


FIG. 57

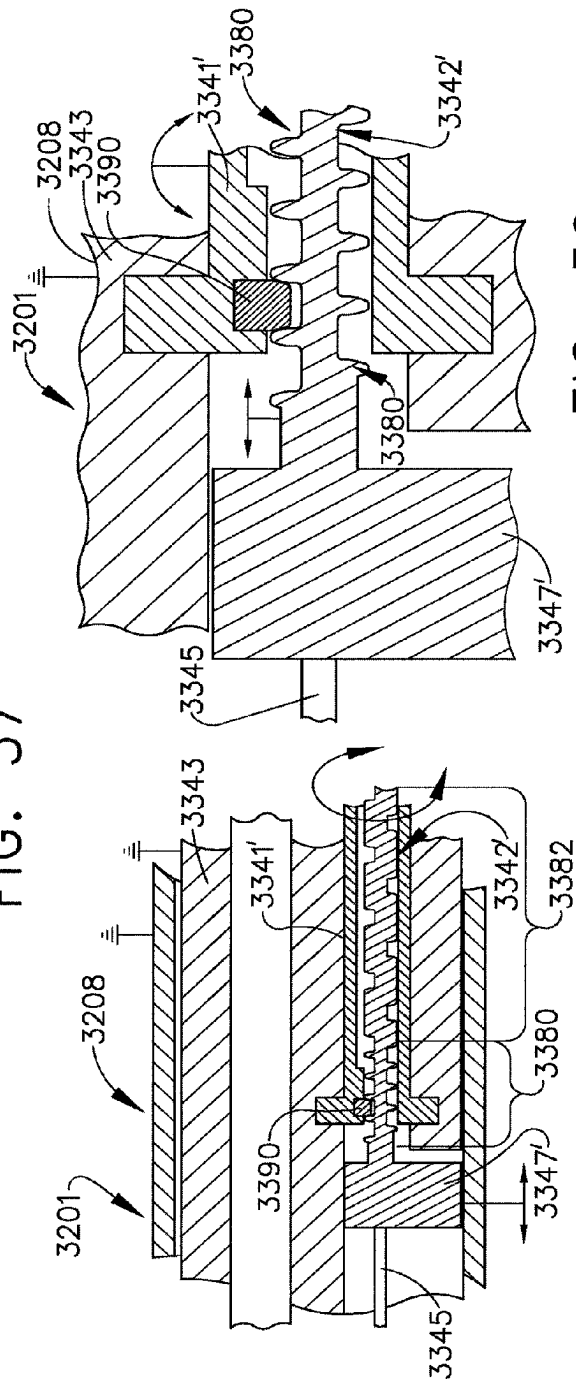


FIG. 59

FIG. 58

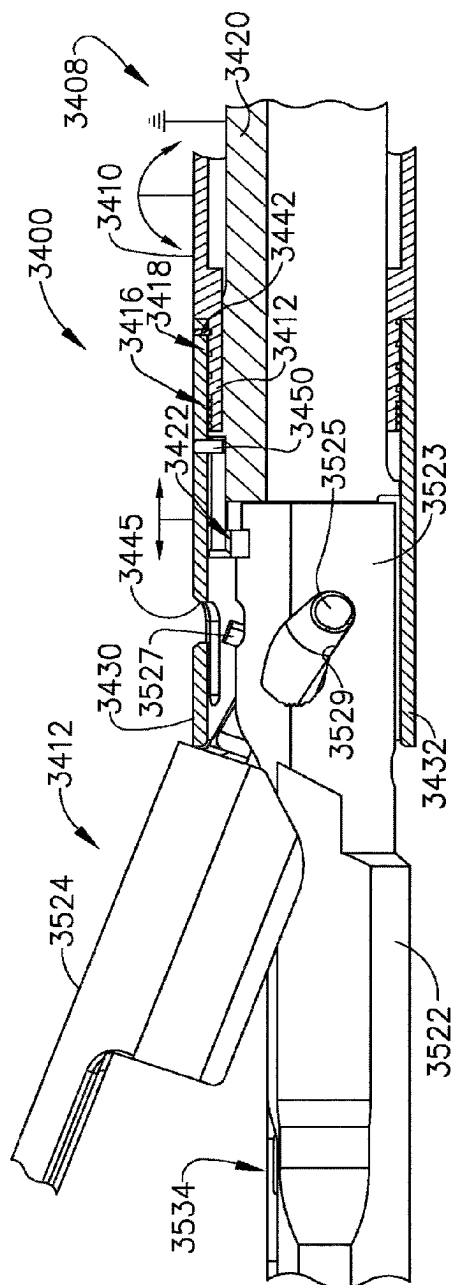


FIG. 60

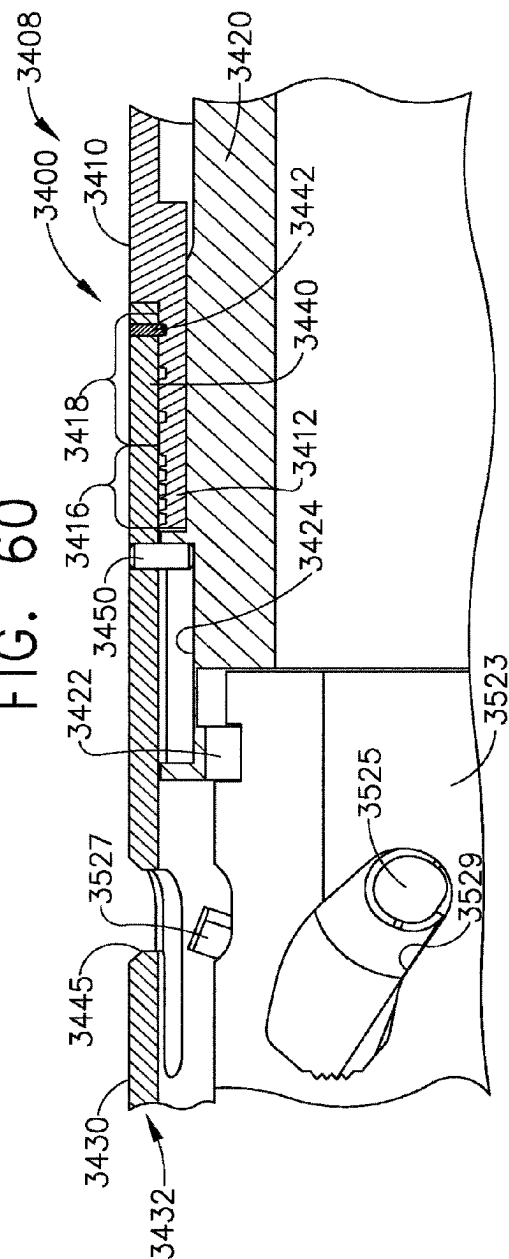


FIG. 61

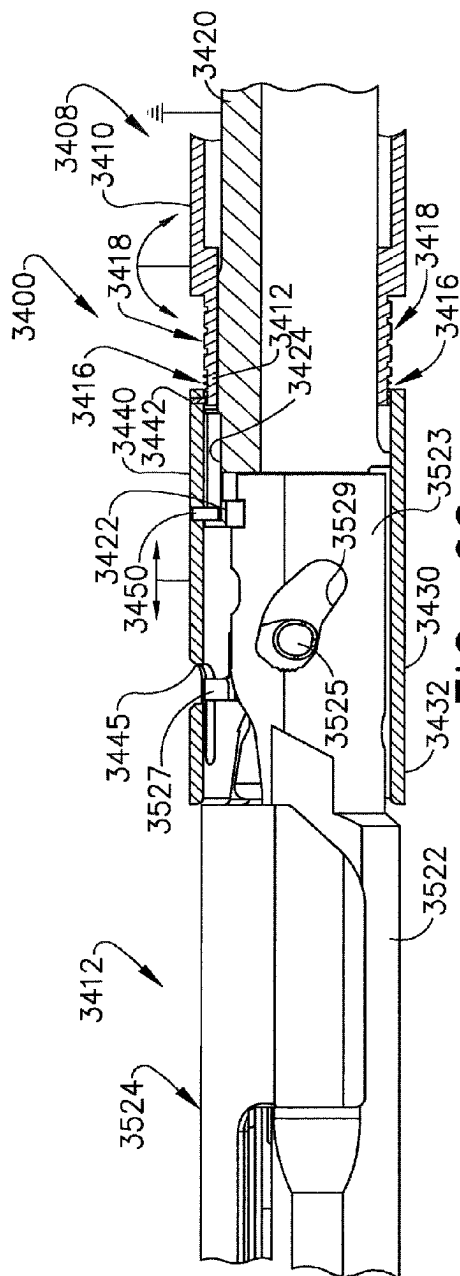


FIG. 62

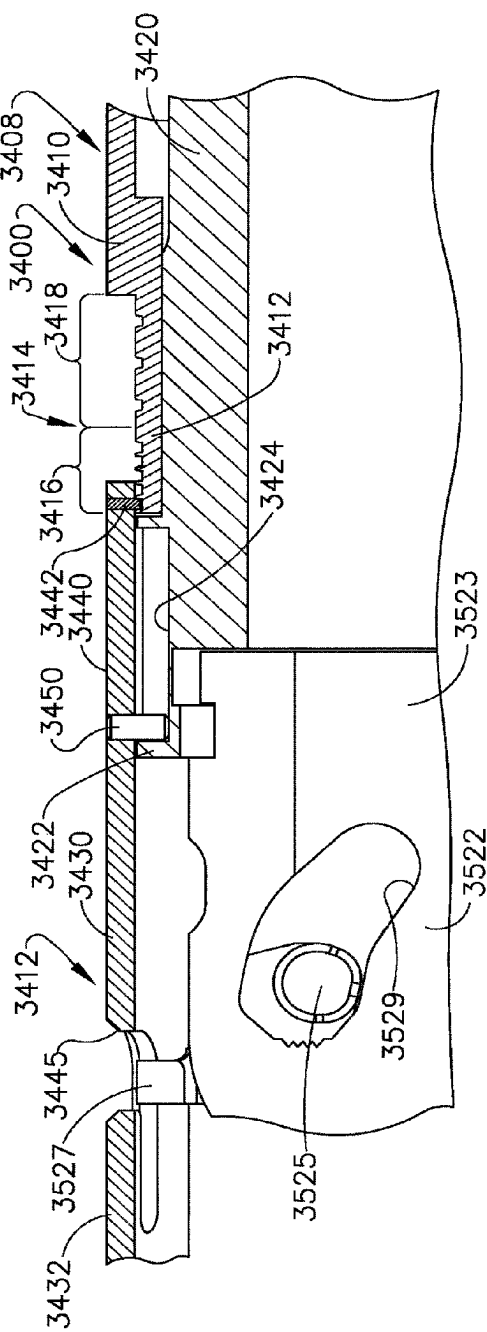


FIG. 63

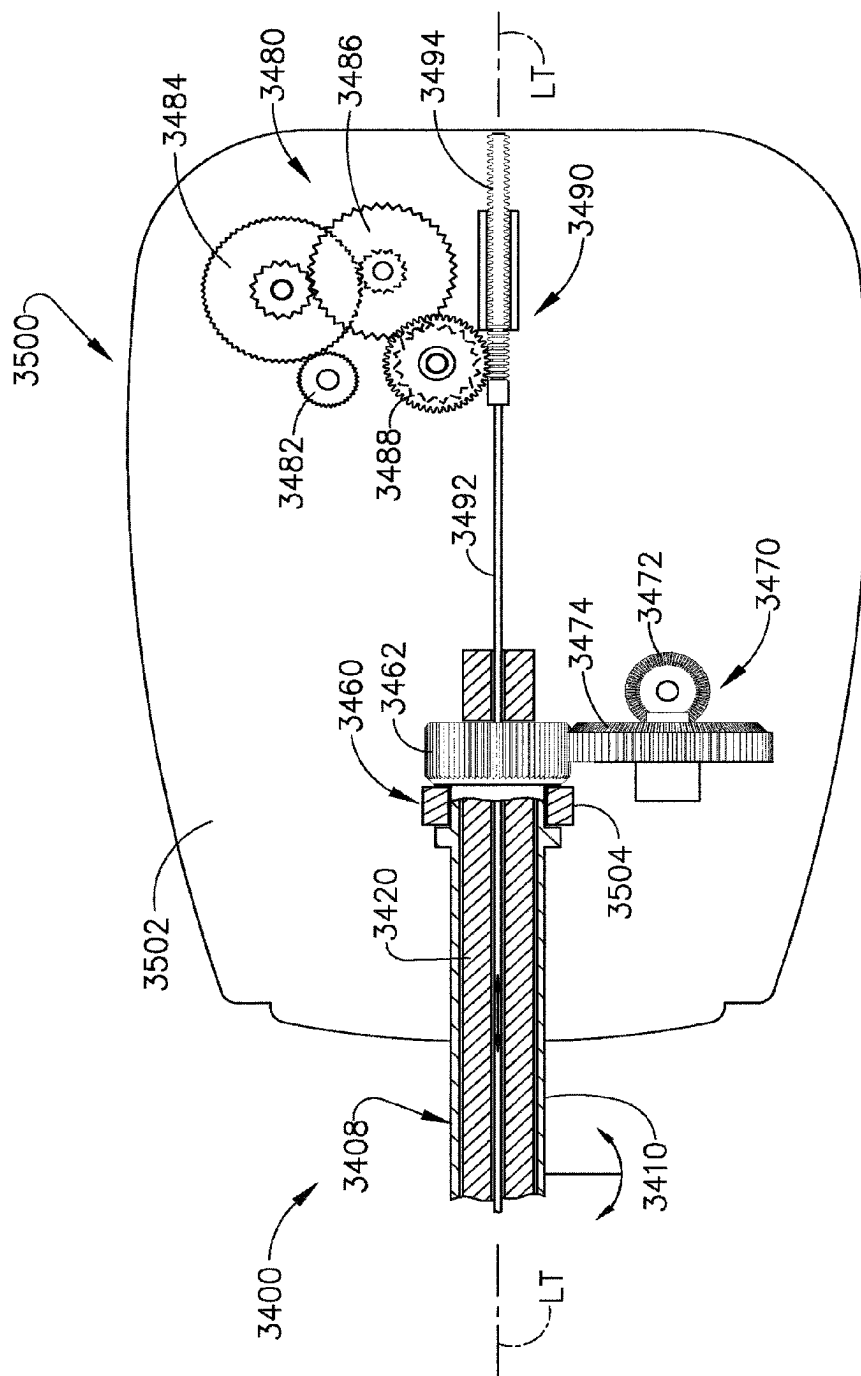


FIG. 64

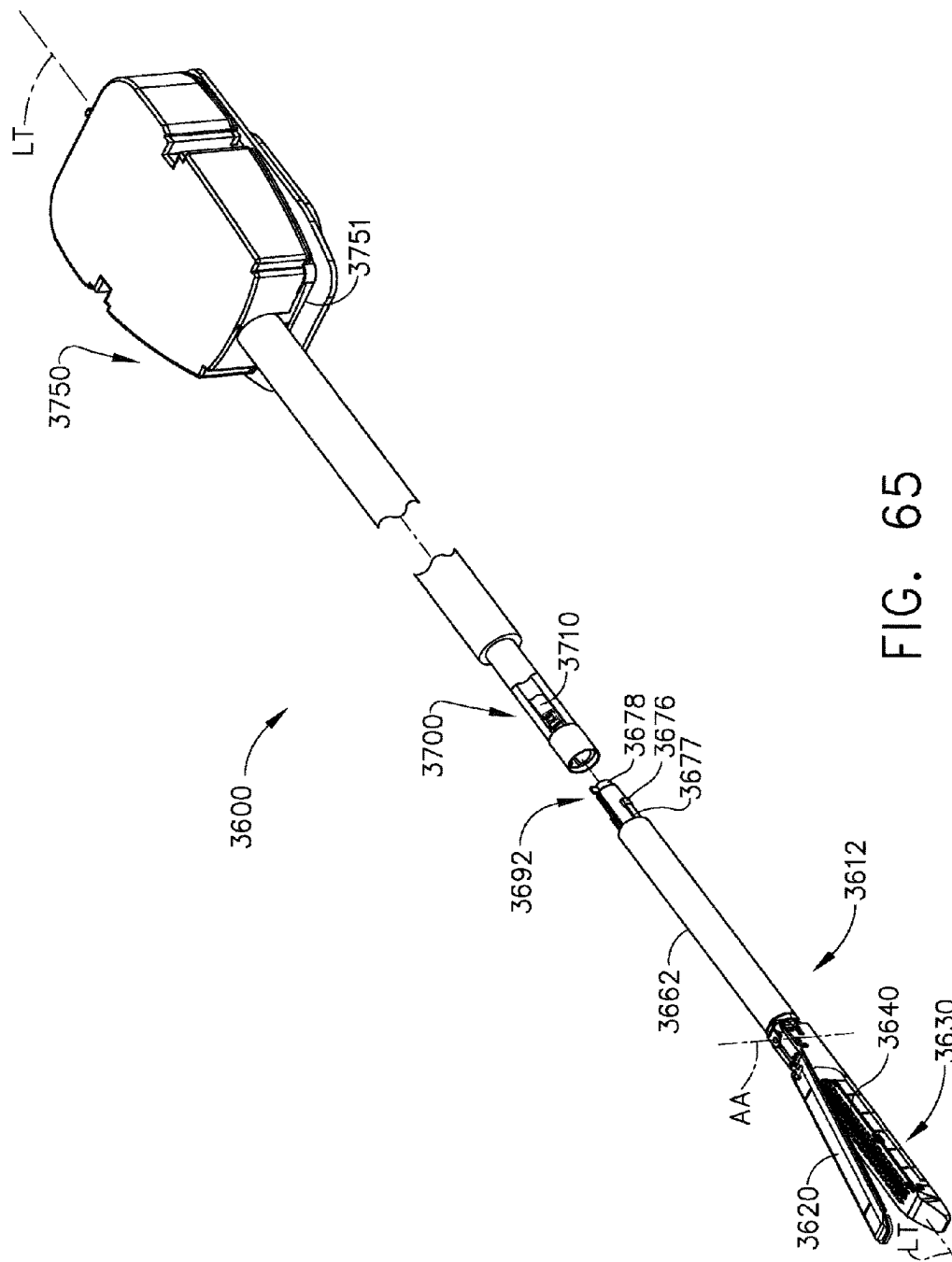


FIG. 65

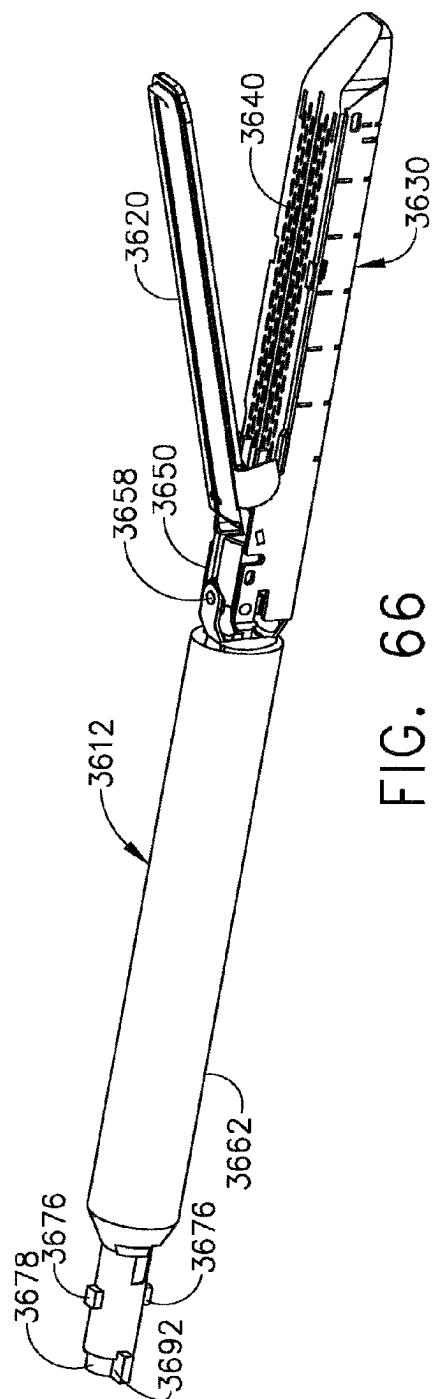


FIG. 66

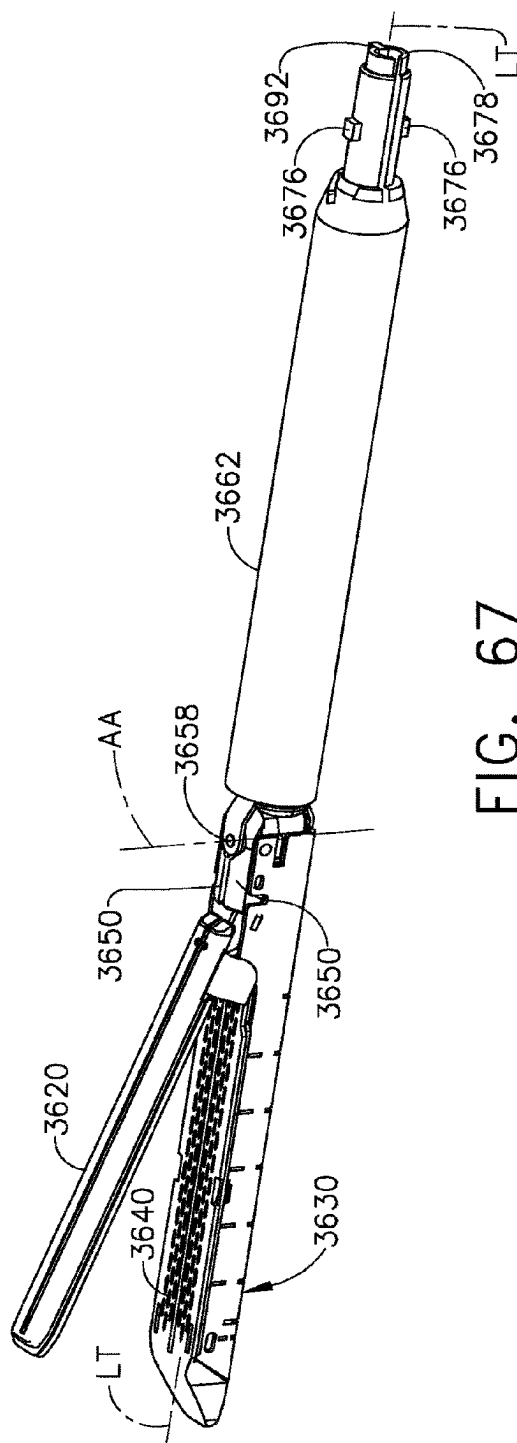


FIG. 67

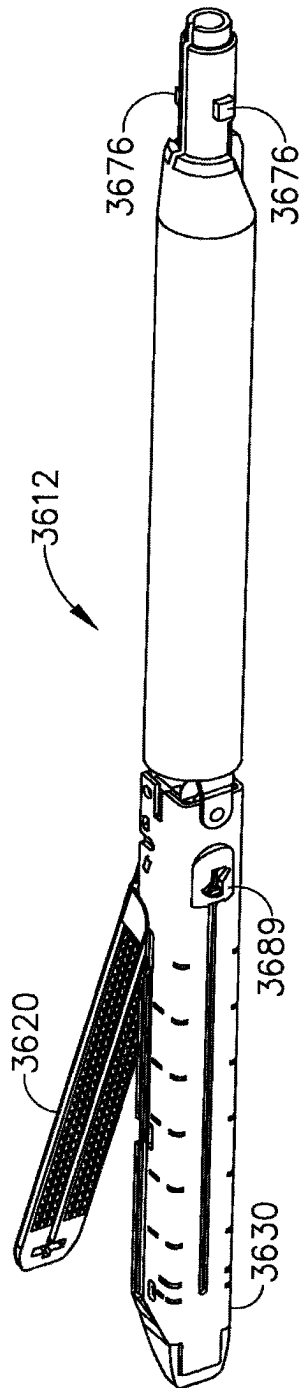


FIG. 68

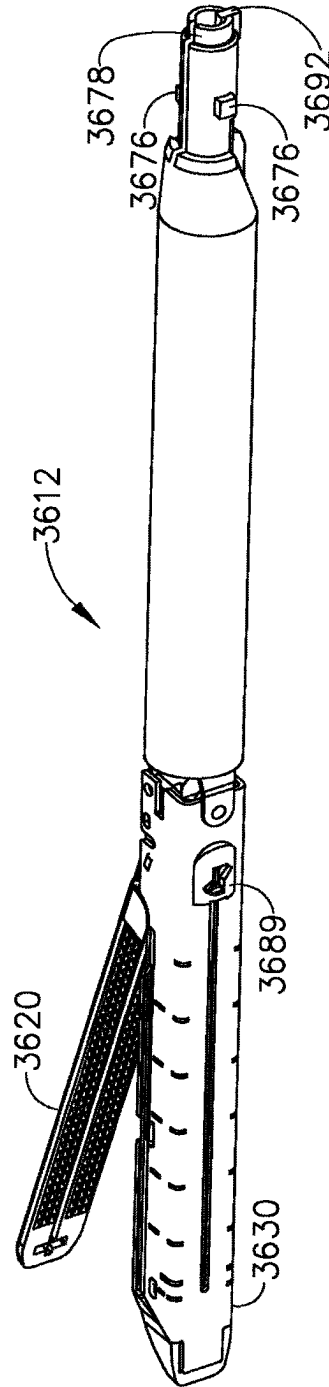


FIG. 69

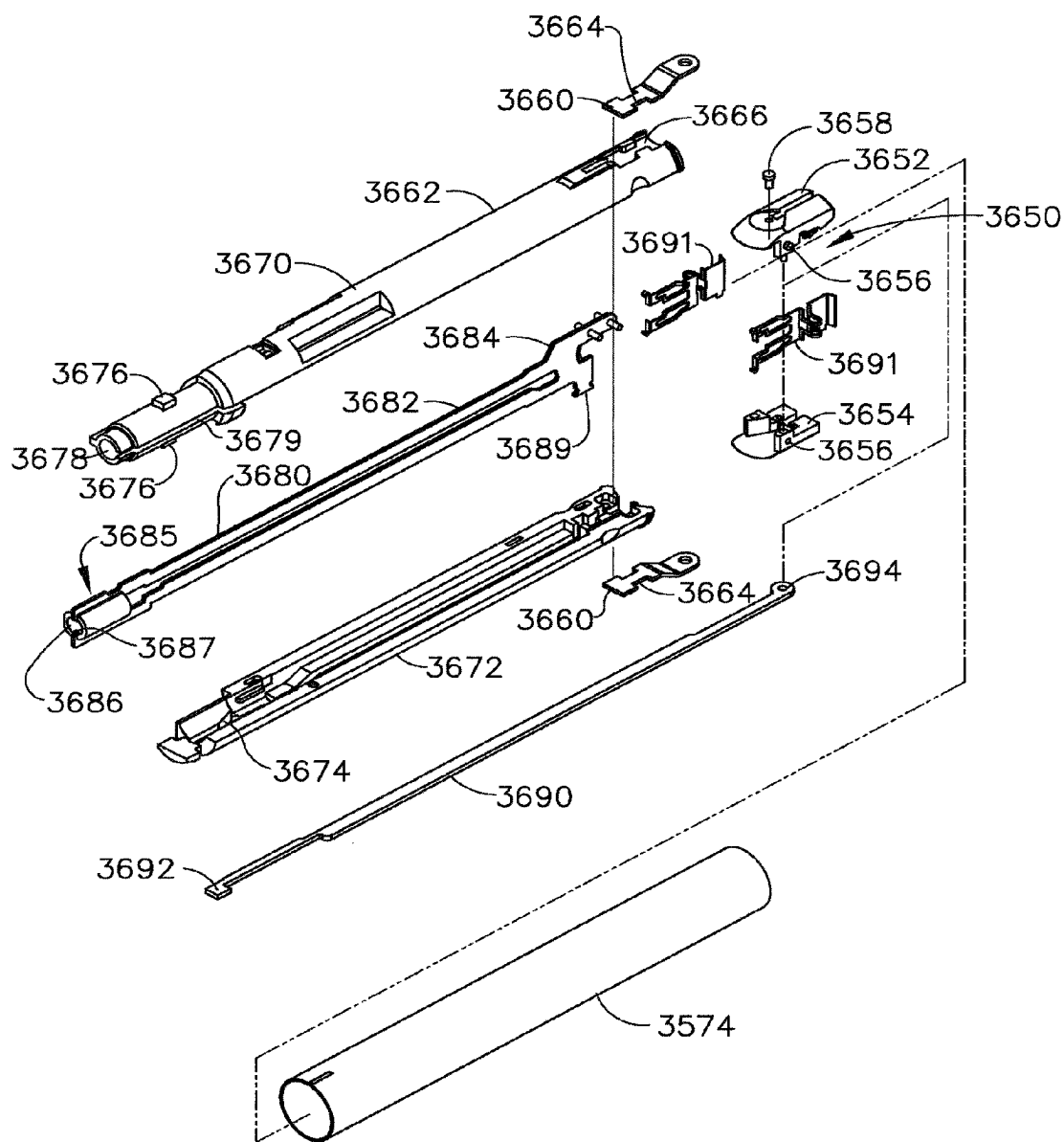
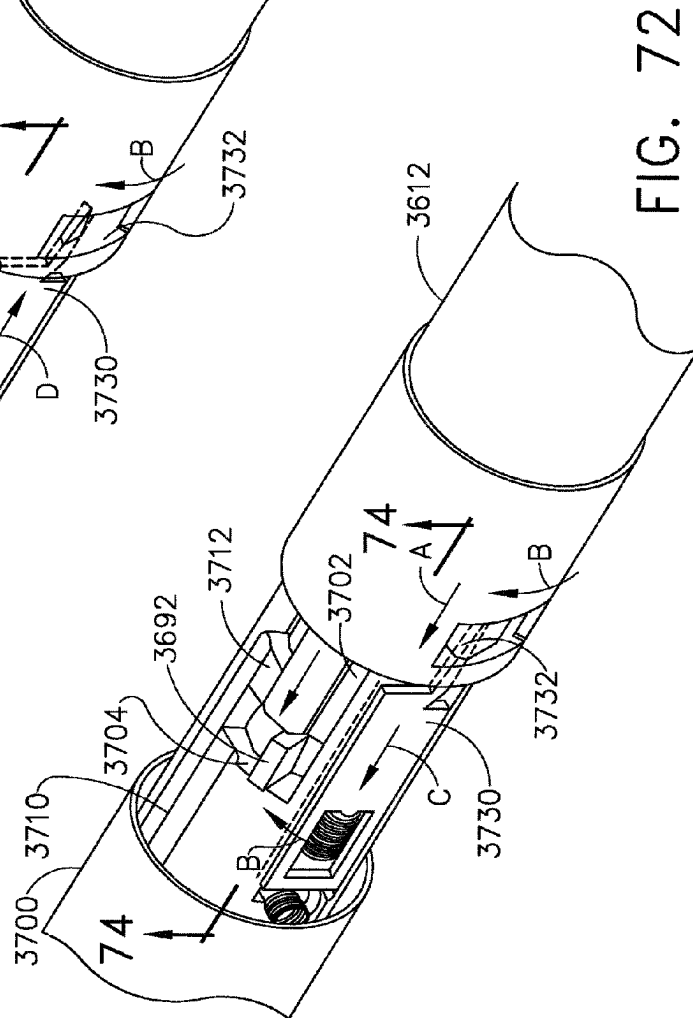
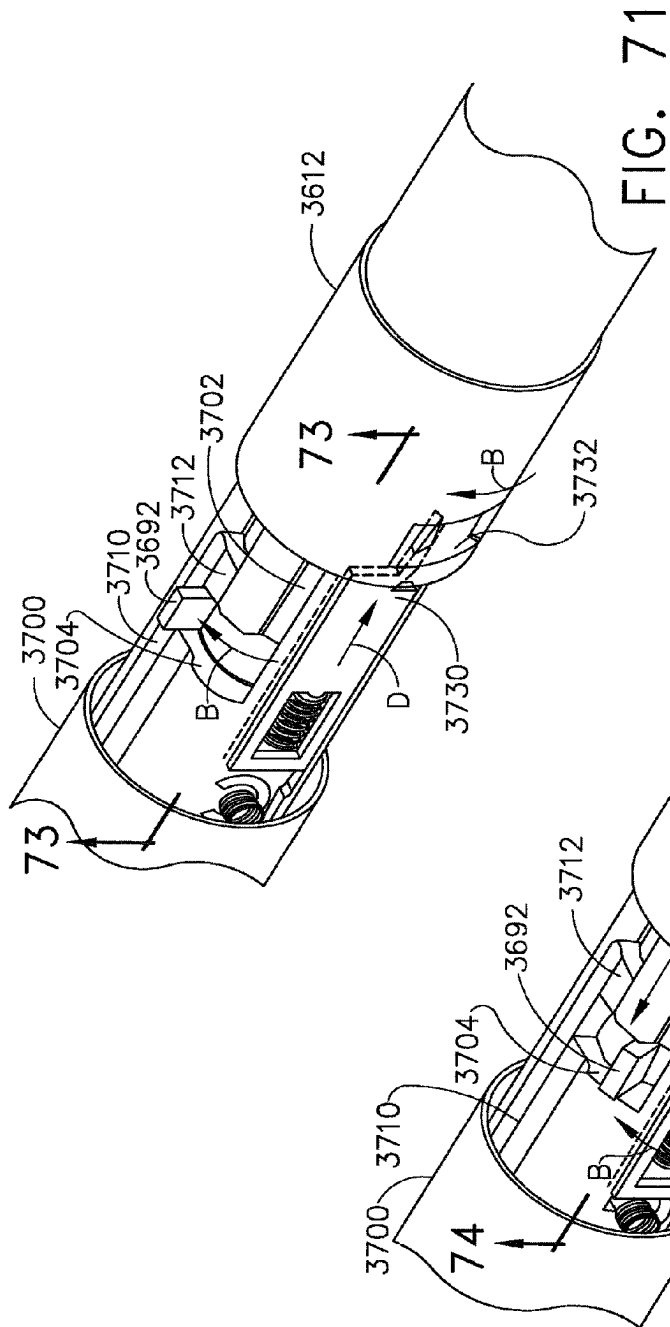


FIG. 70



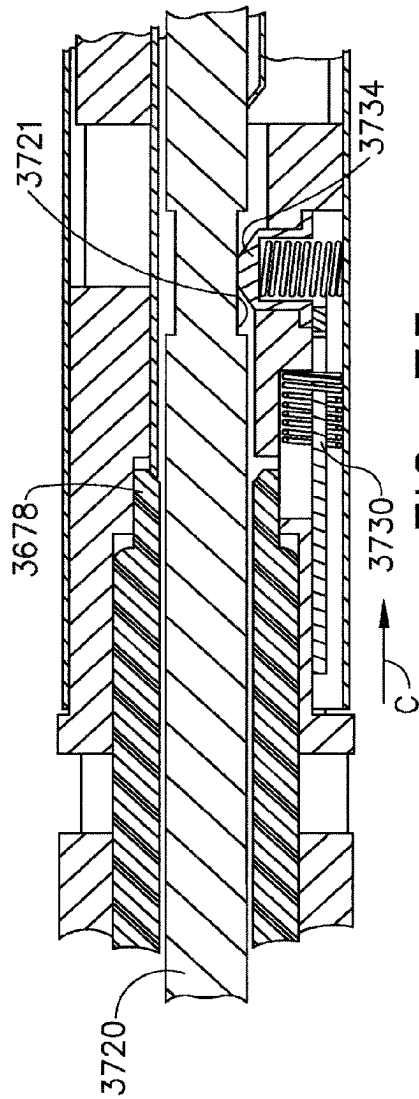


FIG. 73

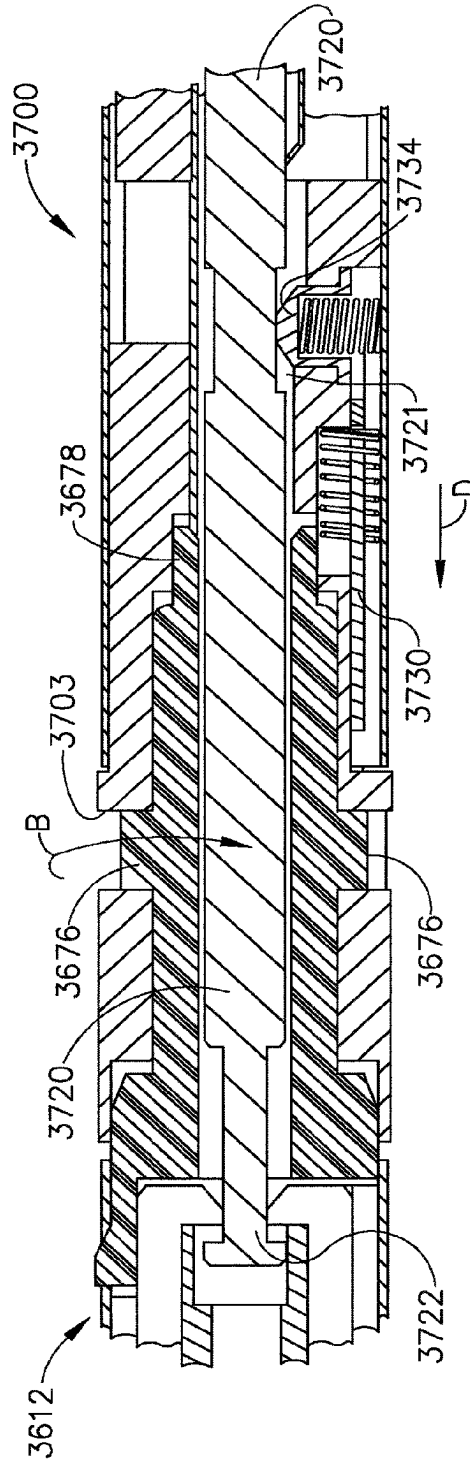
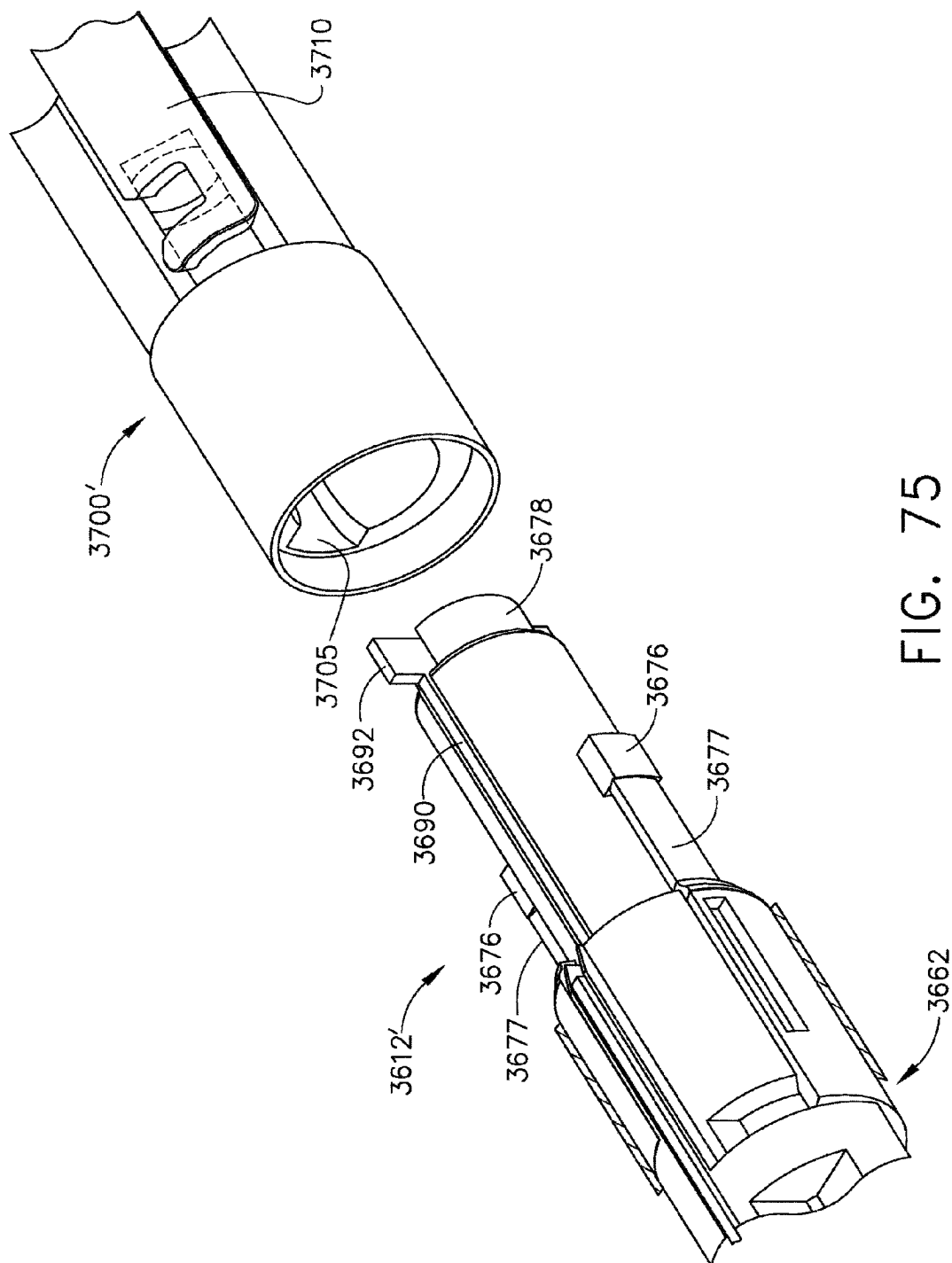


FIG. 74



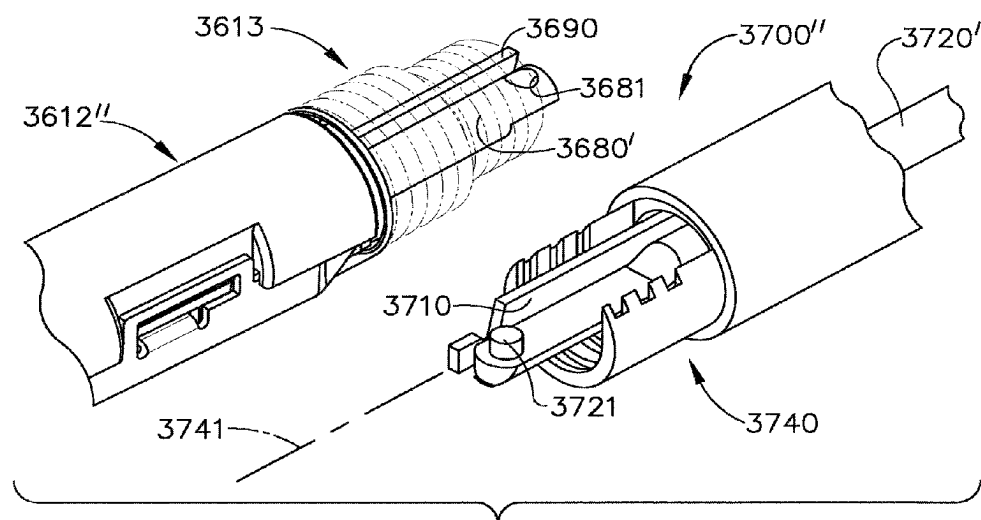


FIG. 76

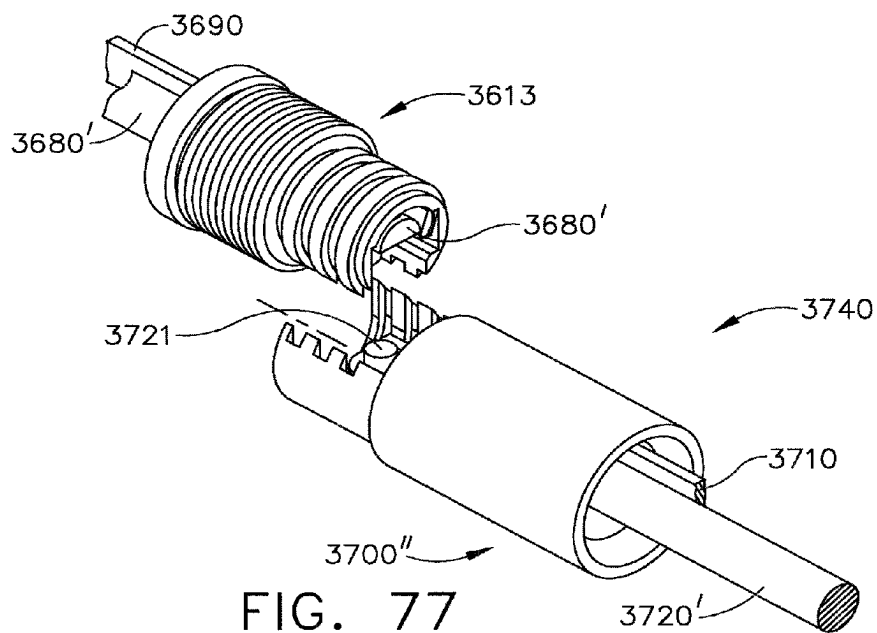


FIG. 77

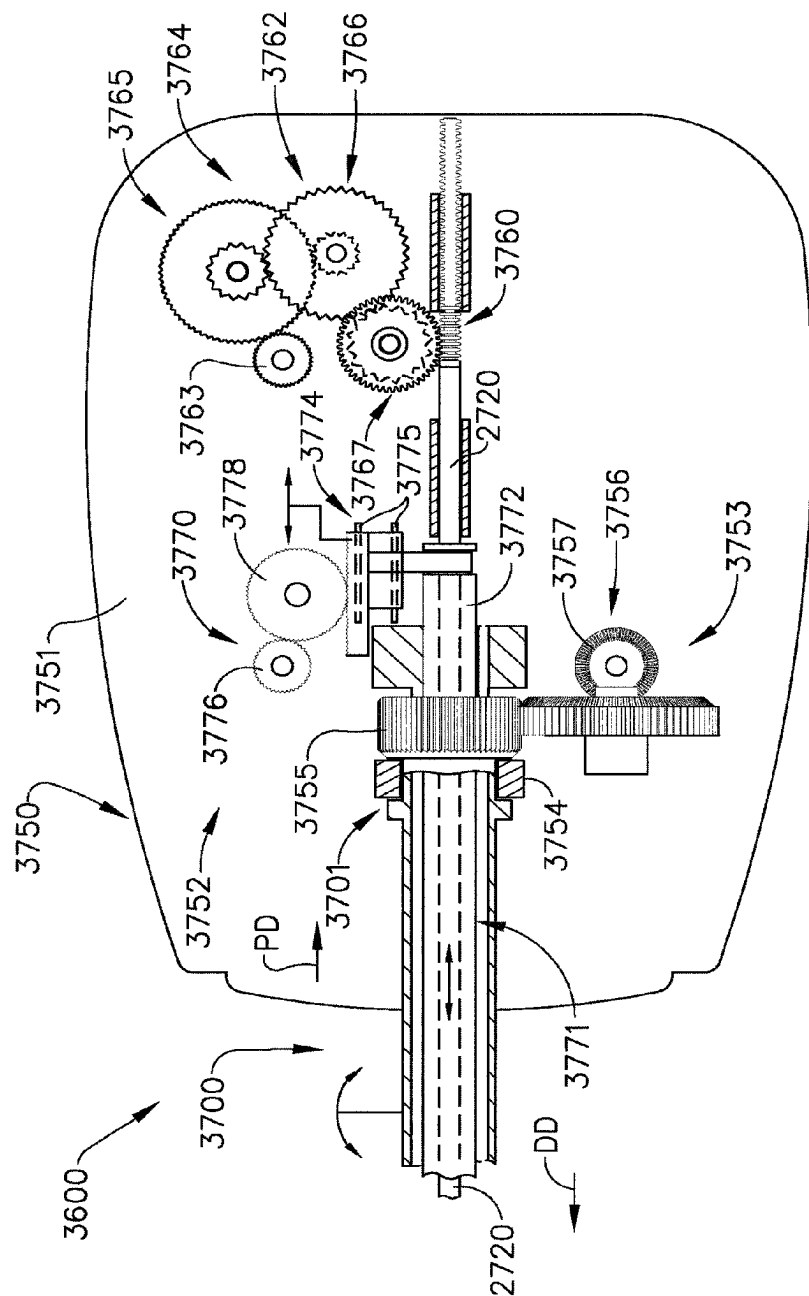


FIG. 78

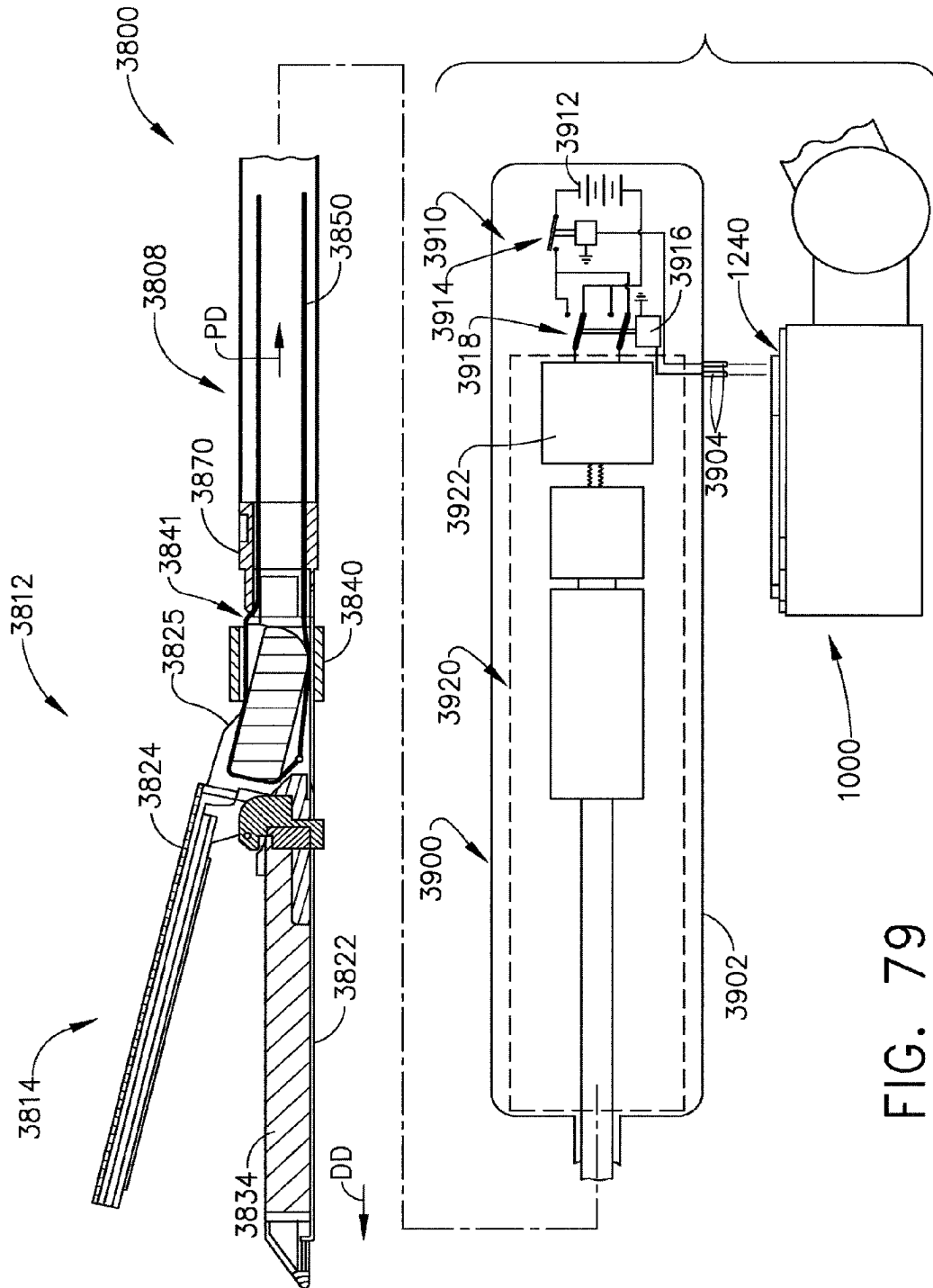
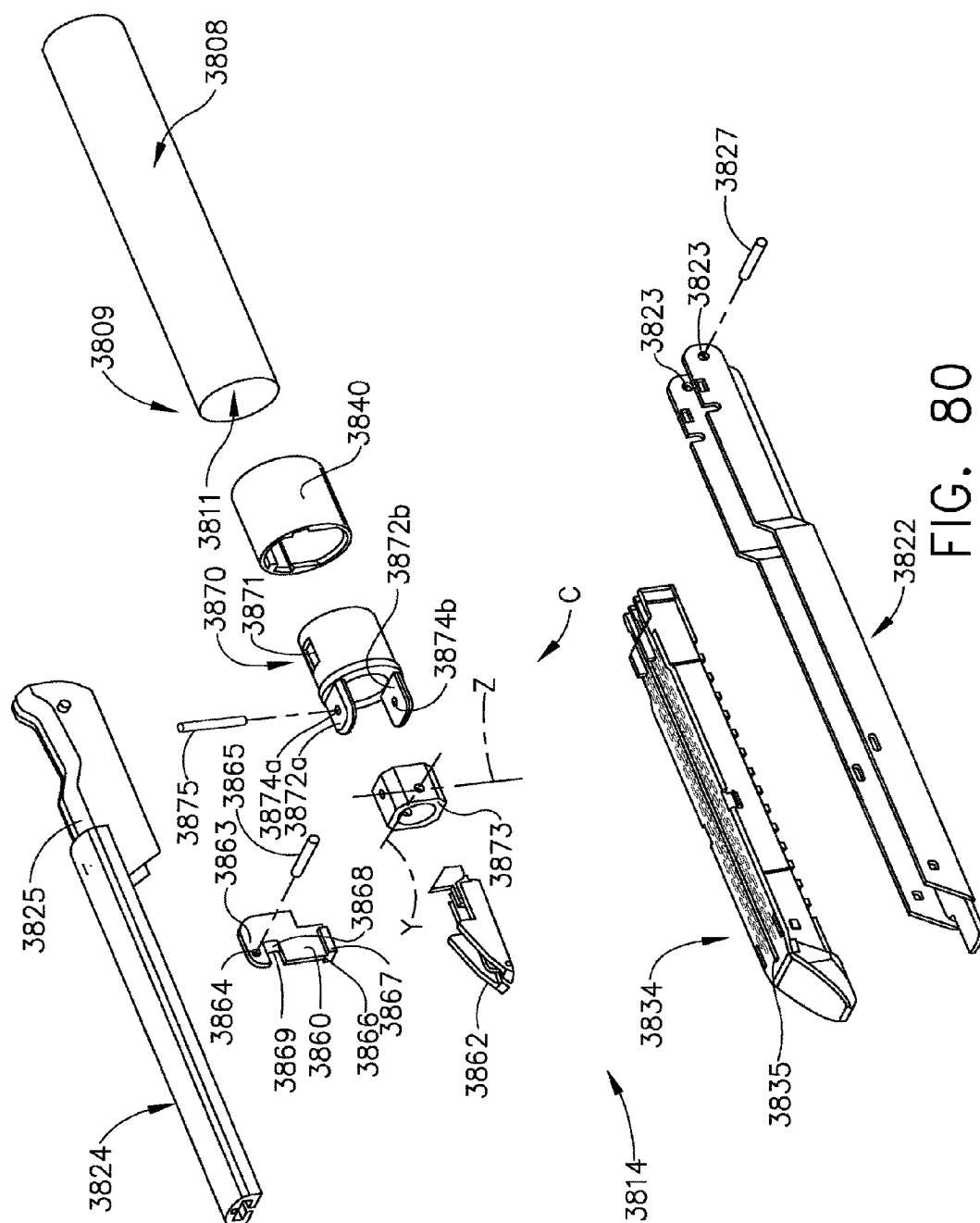
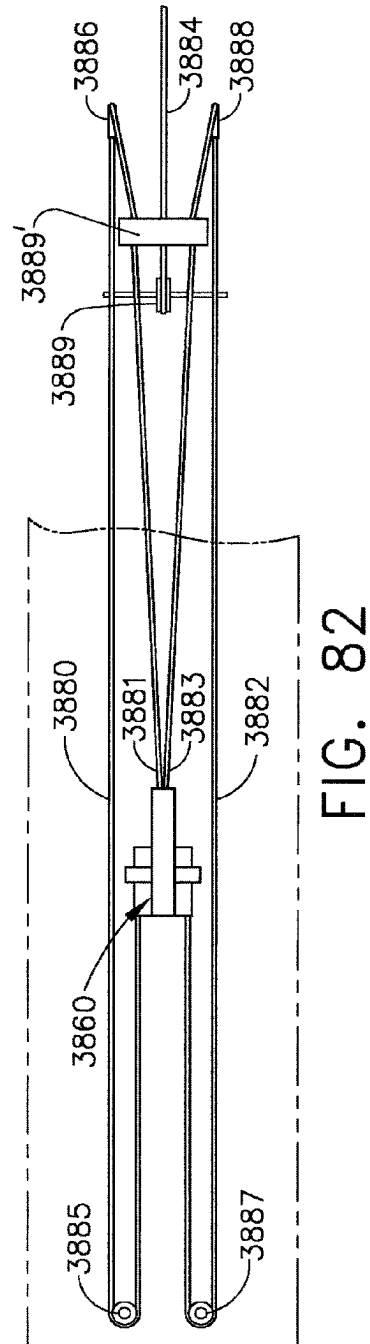
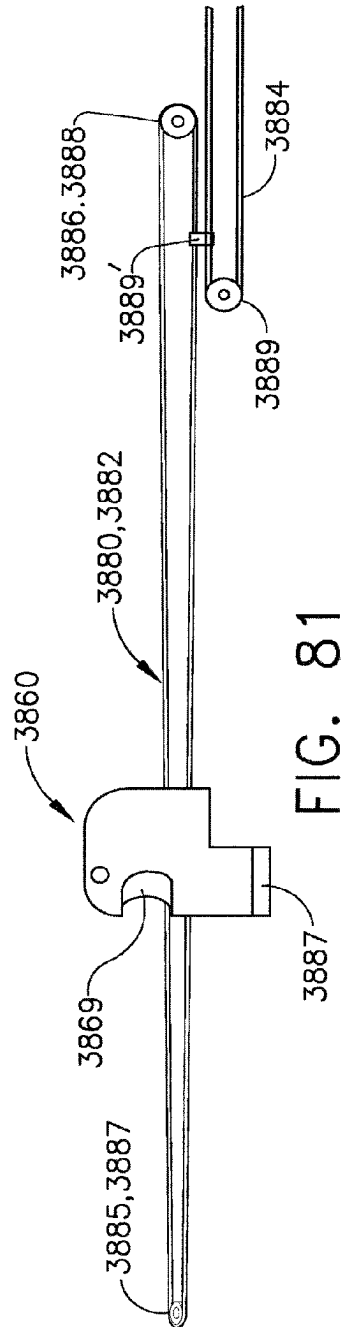


FIG. 79





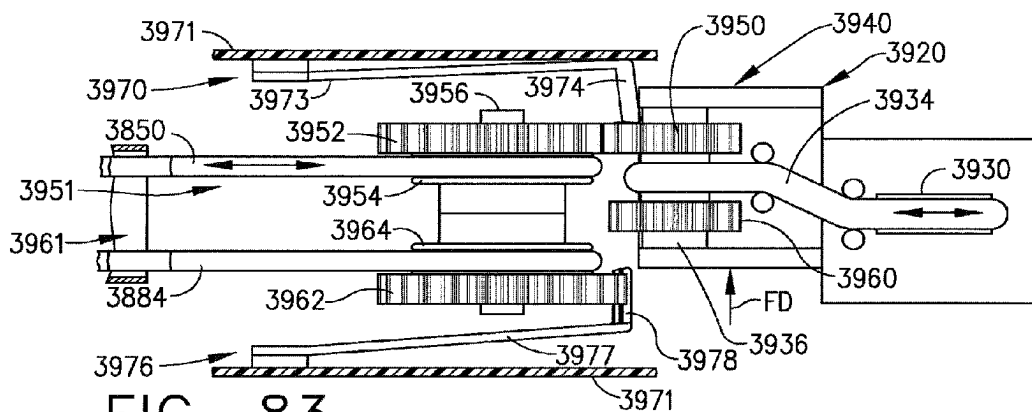


FIG. 83

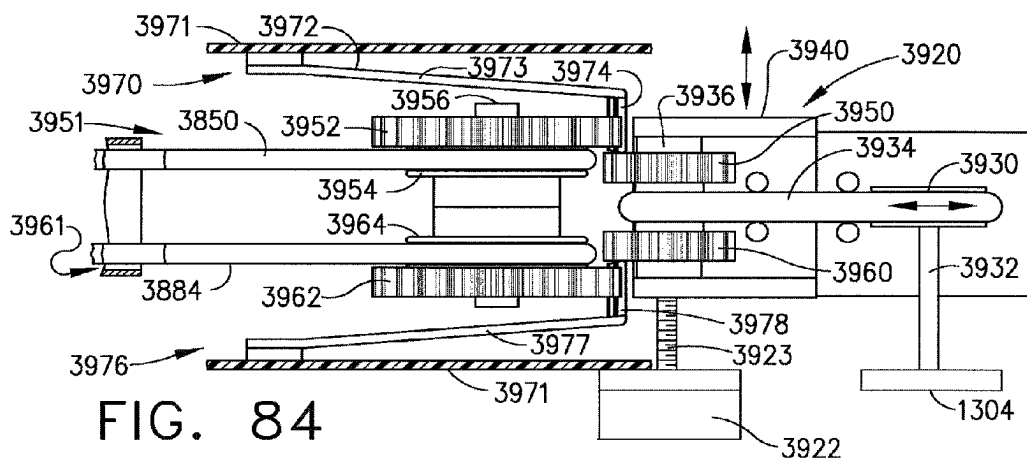


FIG. 84

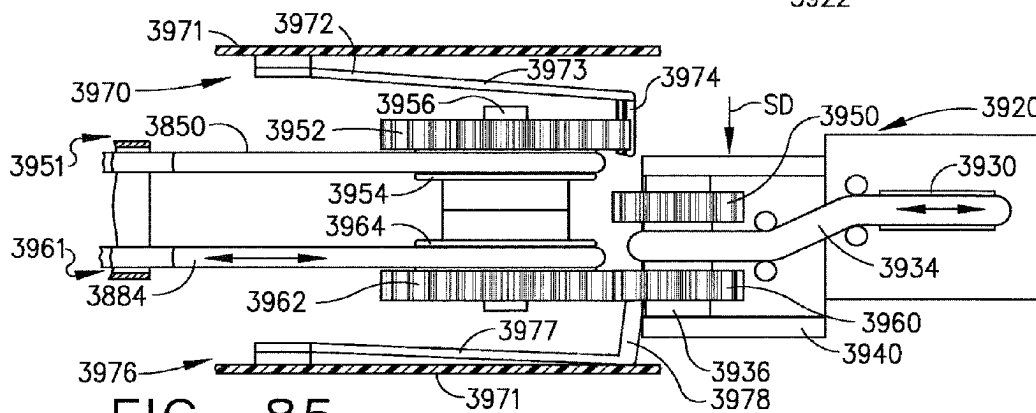


FIG. 85

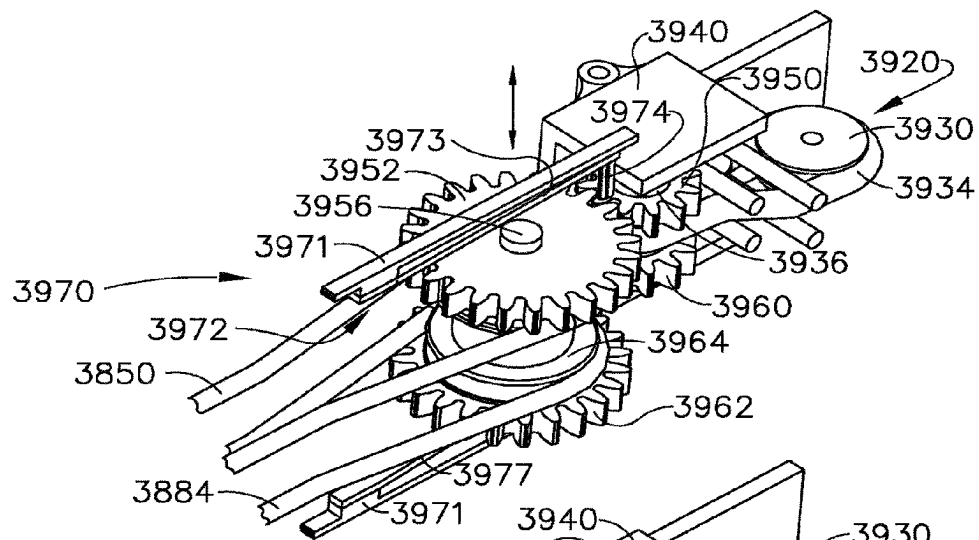


FIG. 86

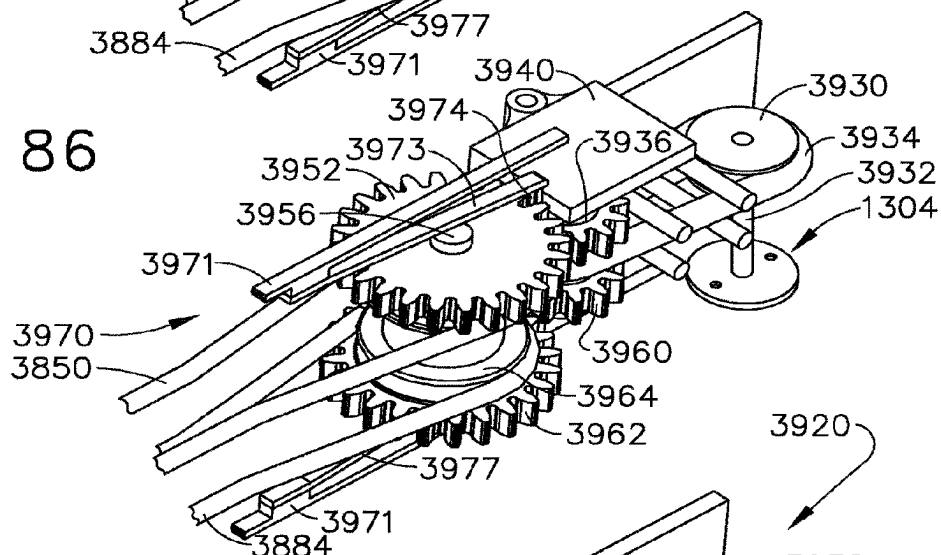


FIG. 87

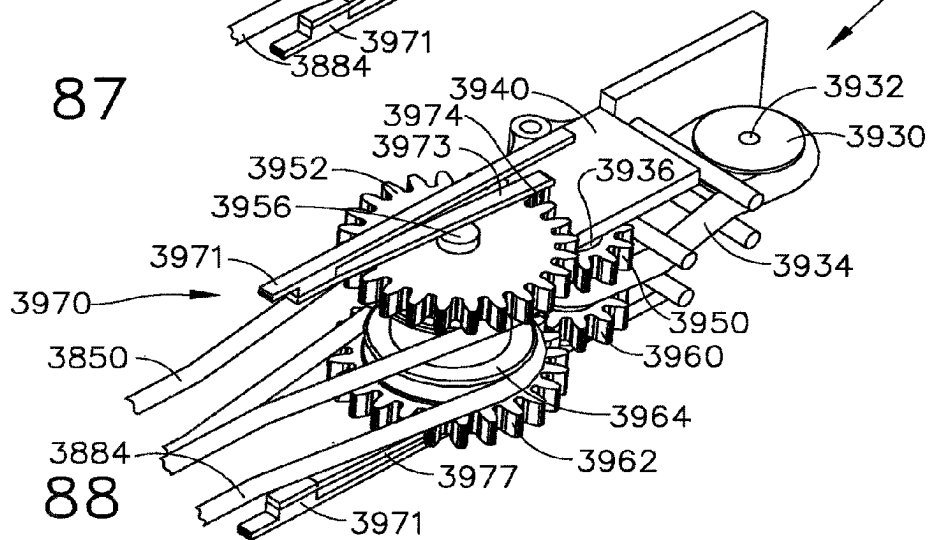
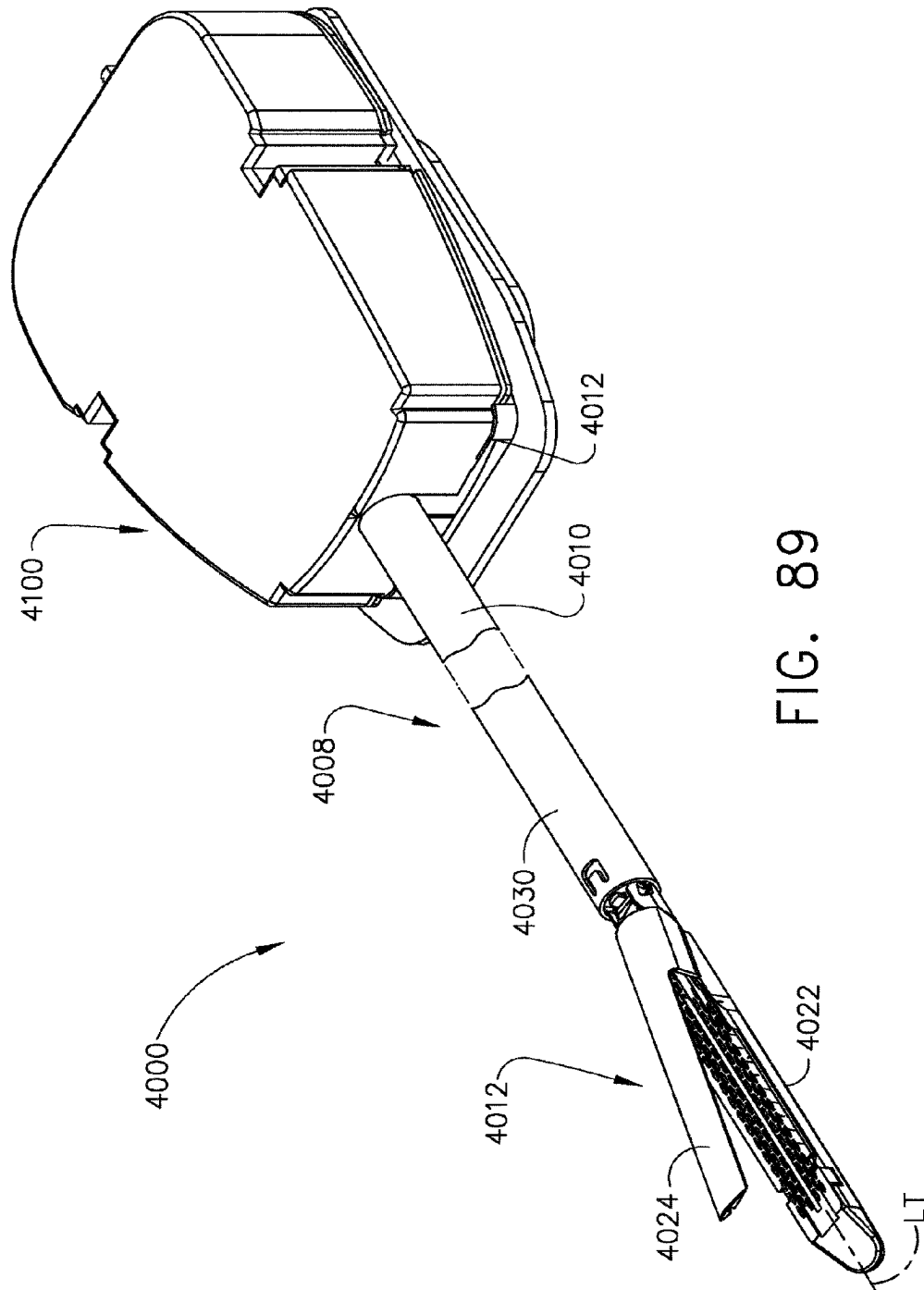


FIG. 88



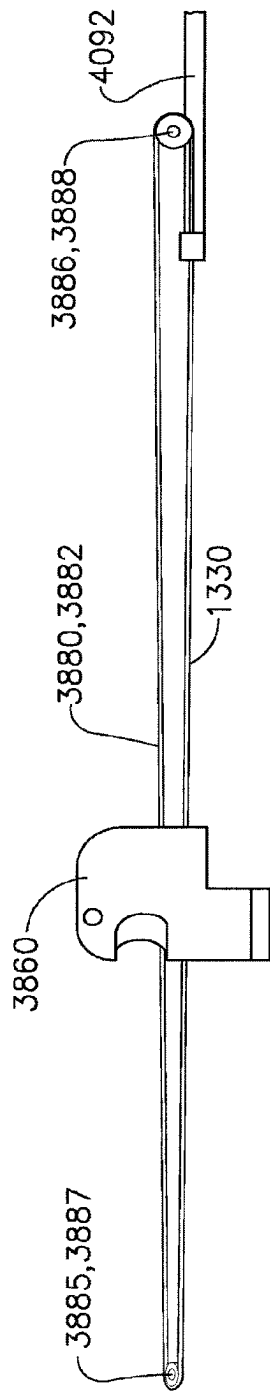


FIG. 90

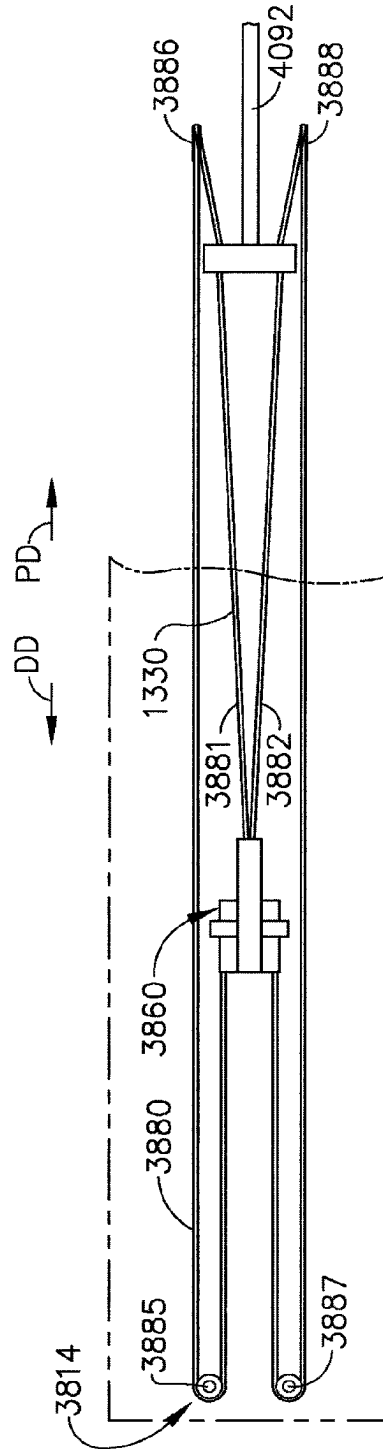


FIG. 91

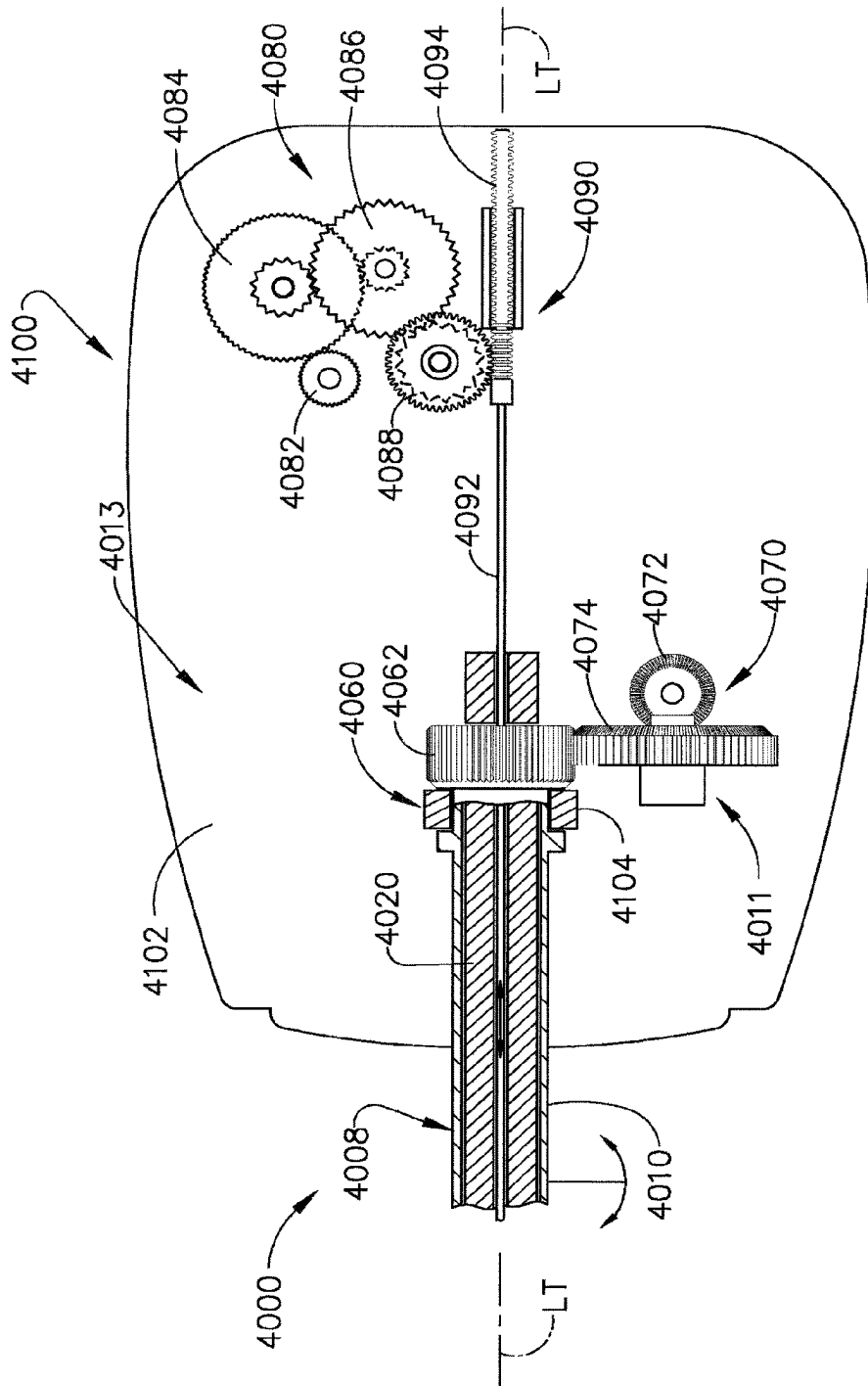


FIG. 92

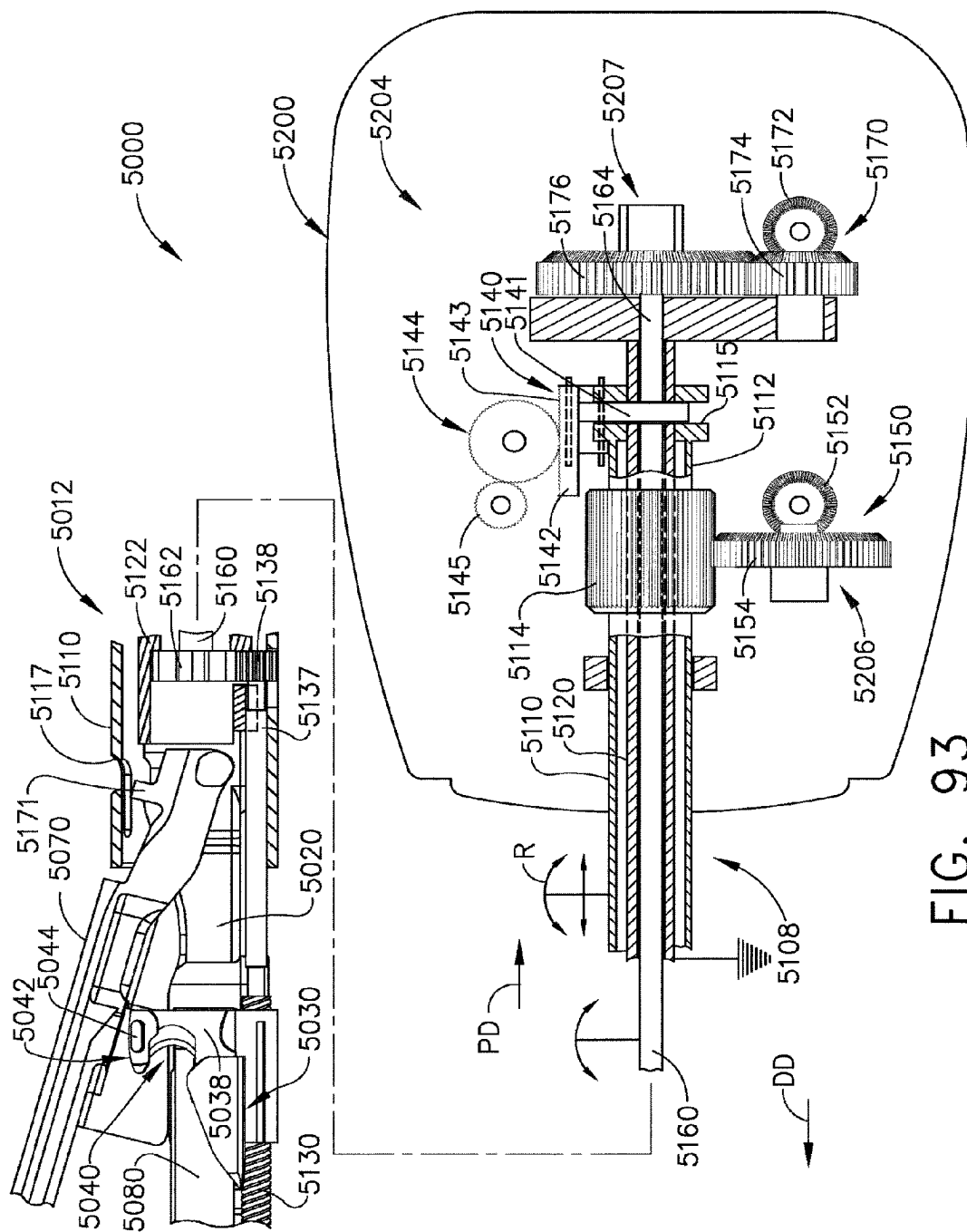
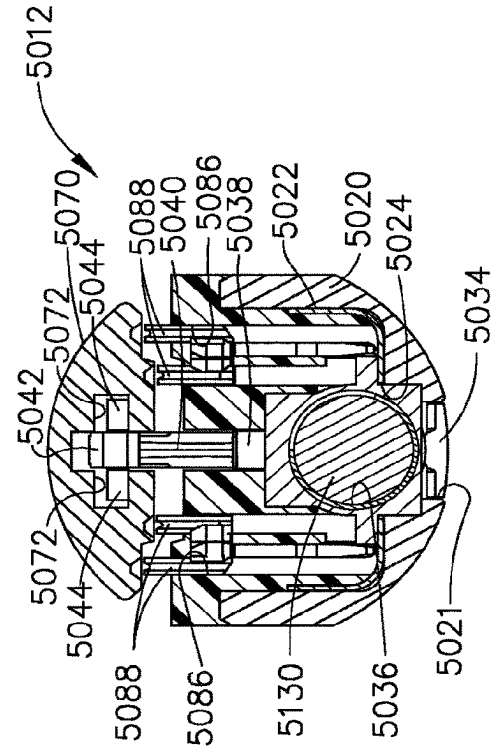
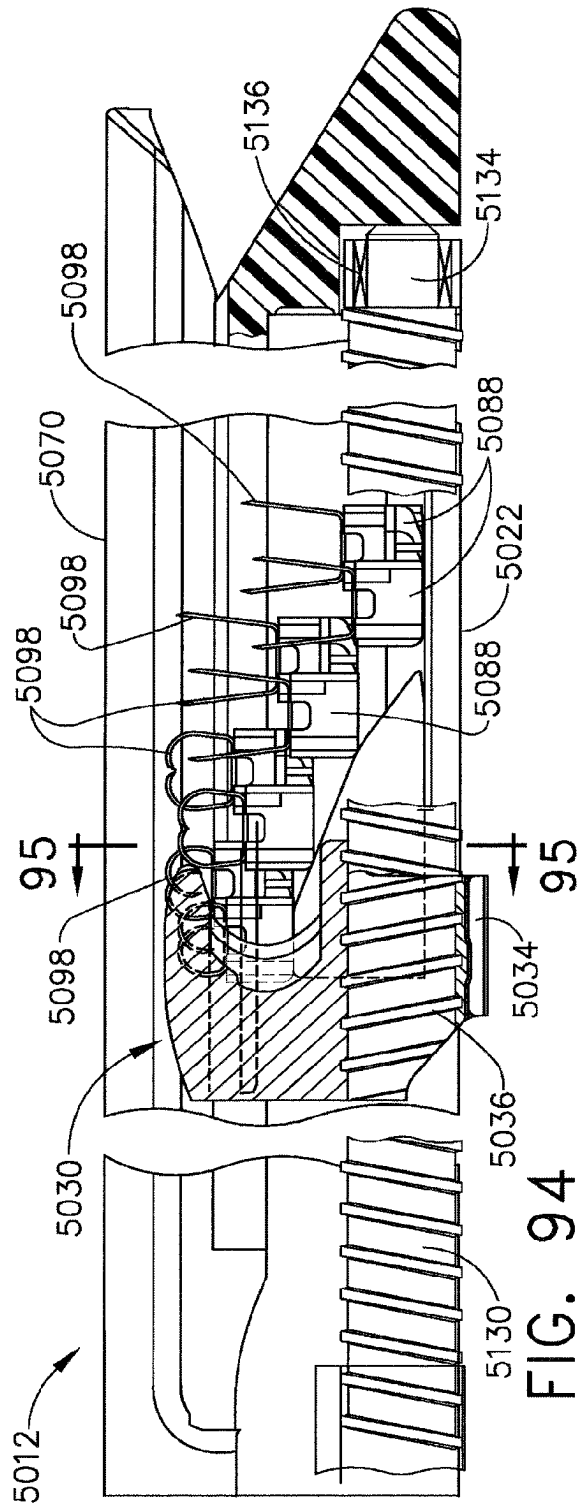


FIG. 93



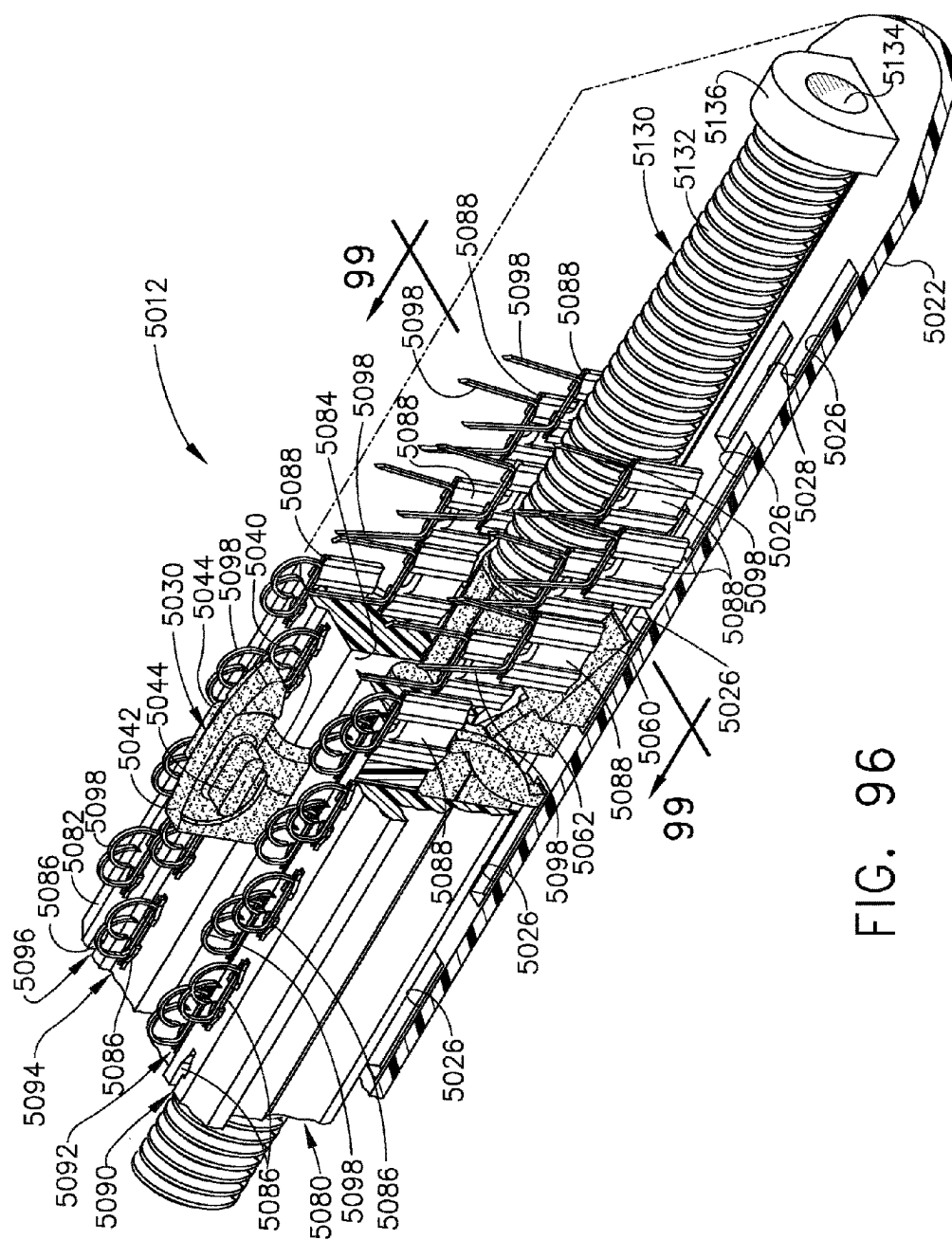


FIG. 96

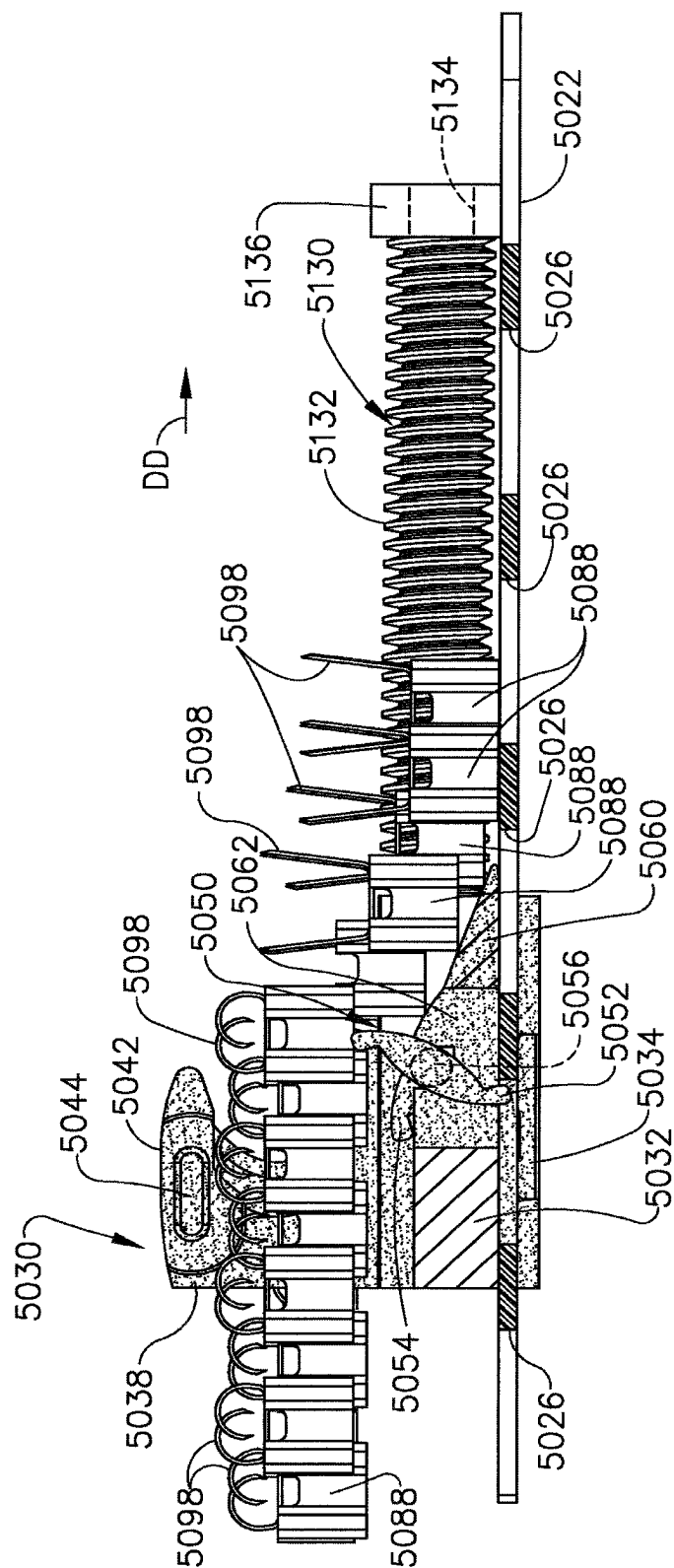


FIG. 97

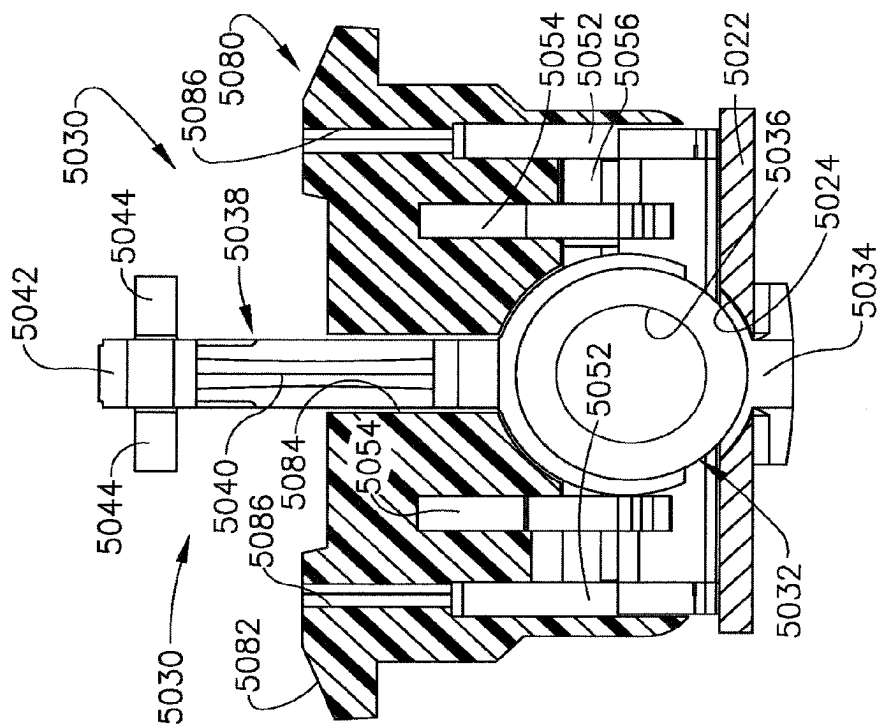


FIG. 98

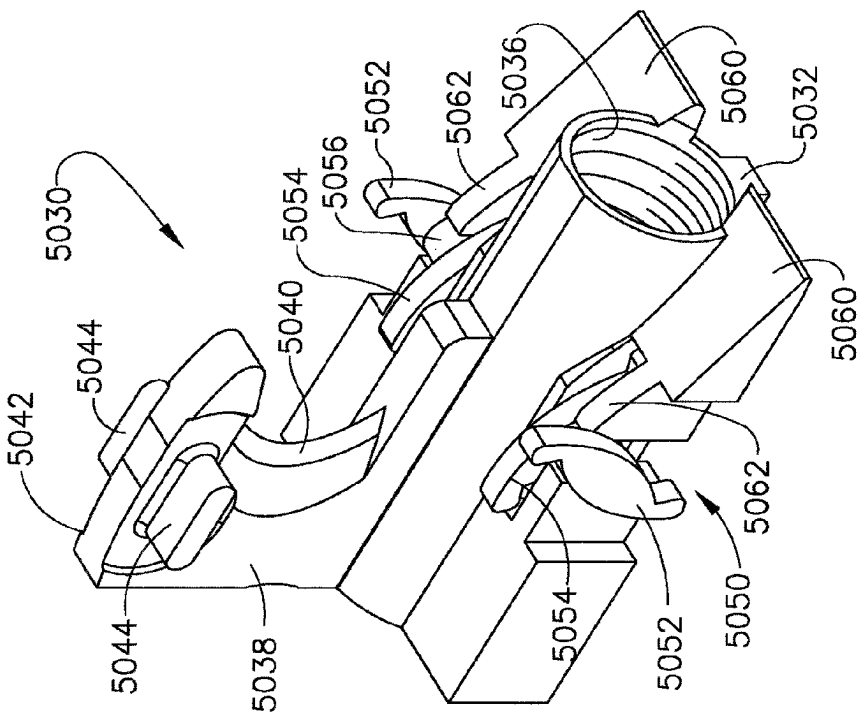


FIG. 99

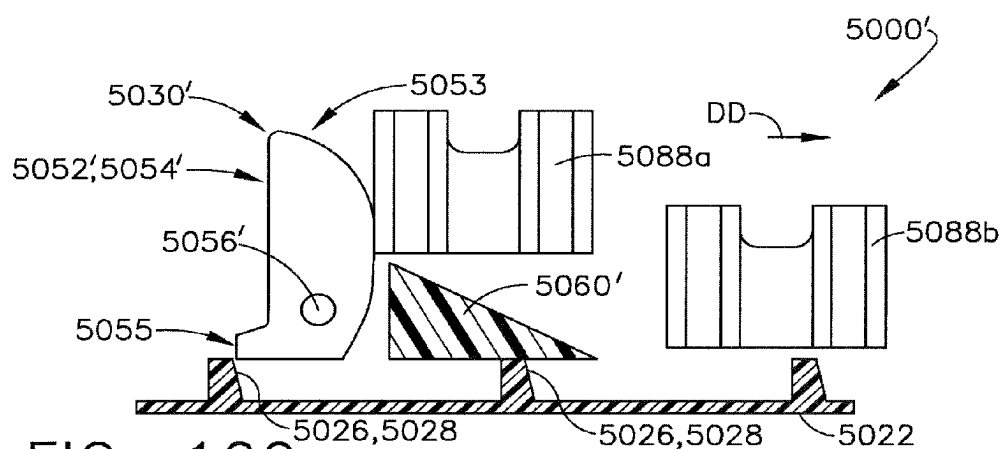


FIG. 100

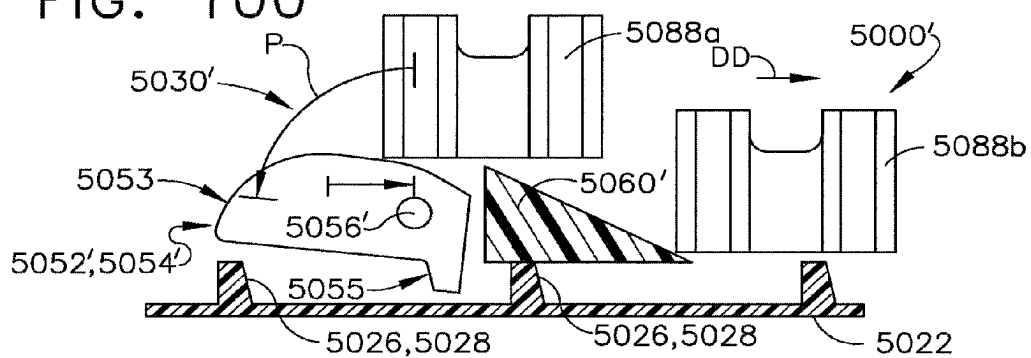


FIG. 101

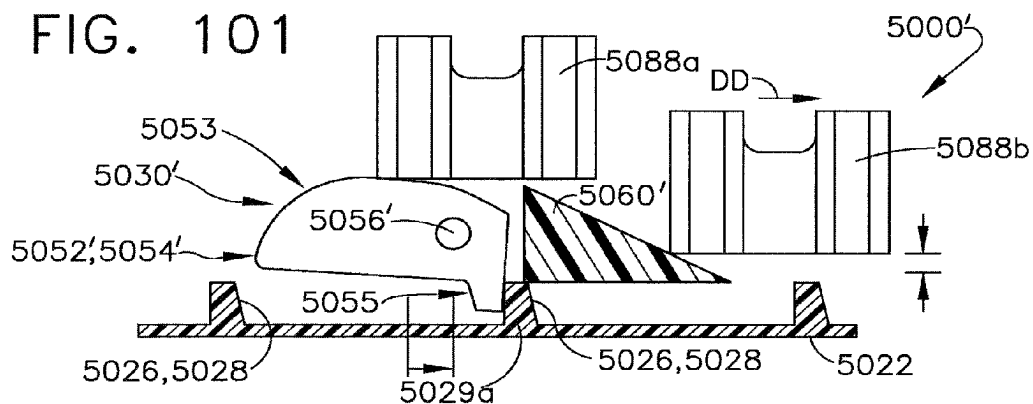


FIG. 102

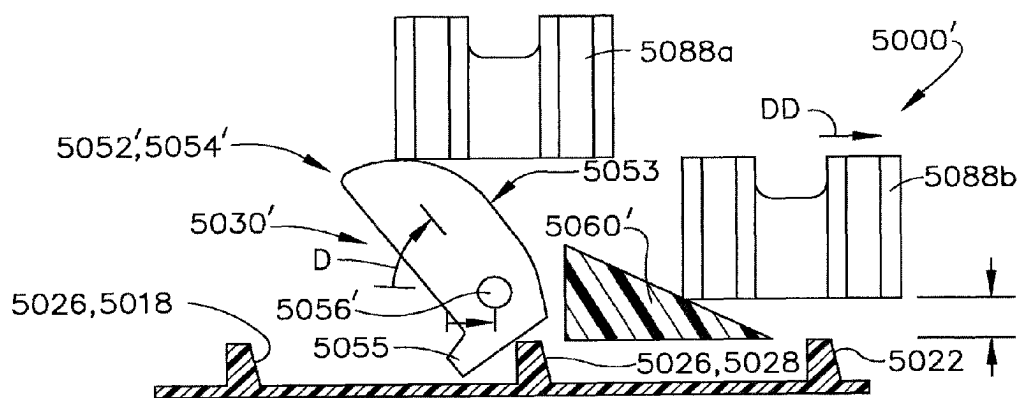


FIG. 103

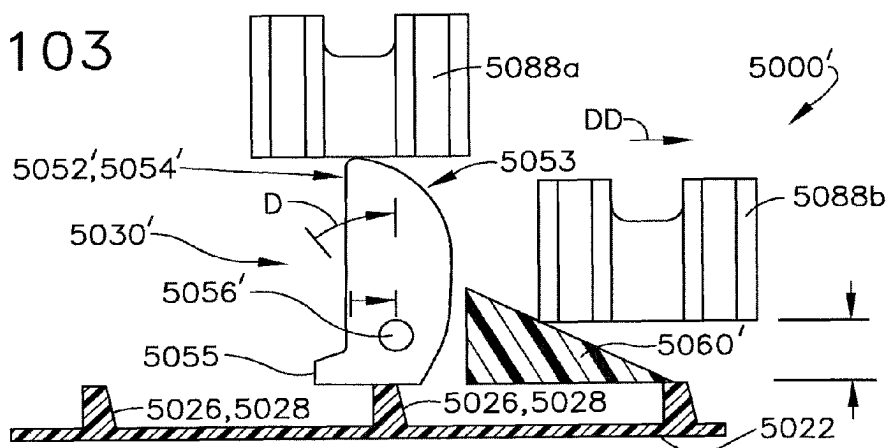


FIG. 104

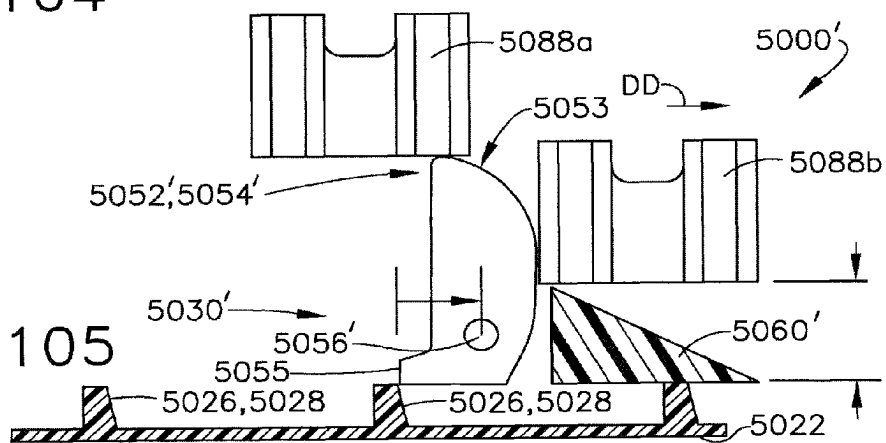


FIG. 105

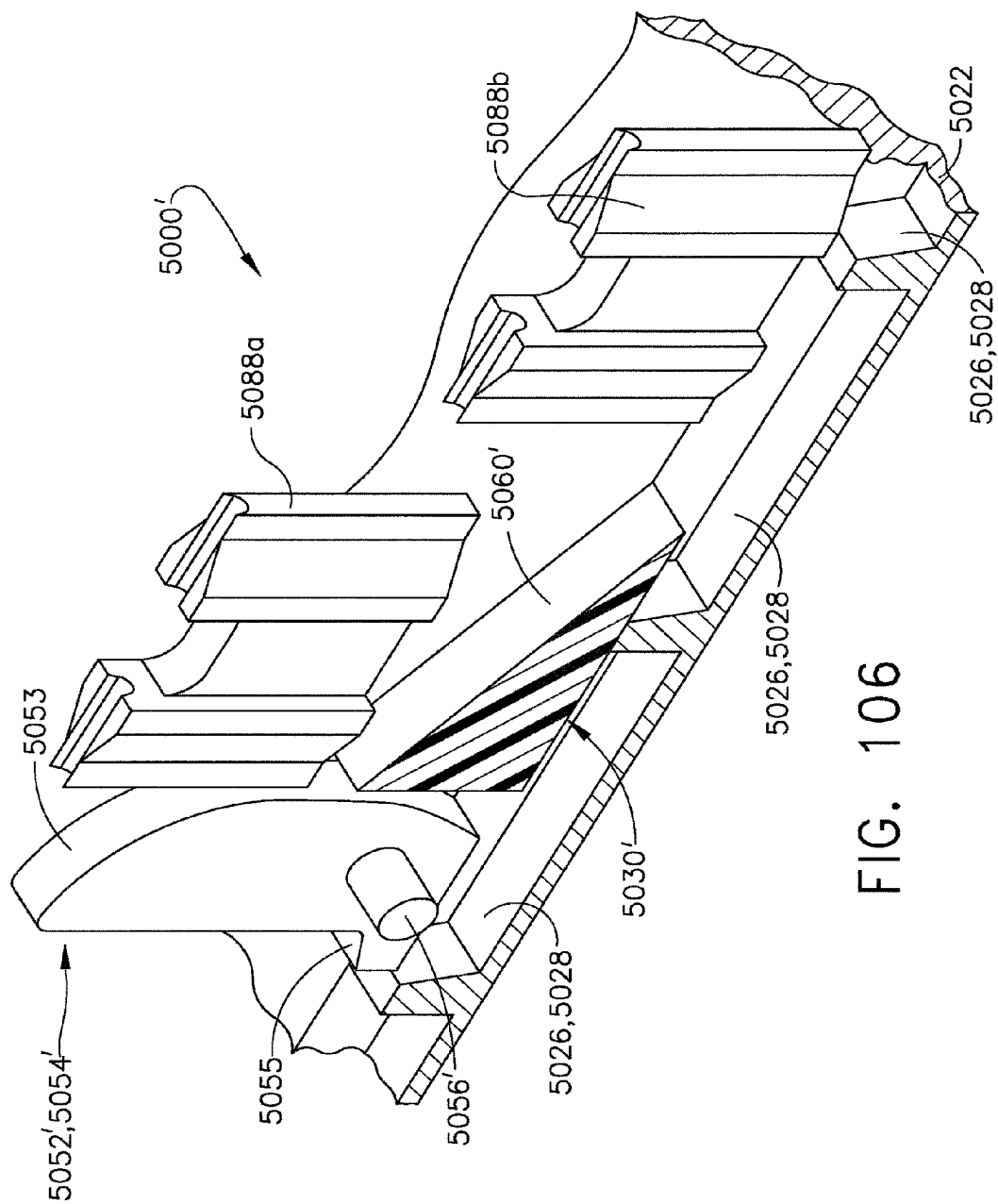


FIG. 106

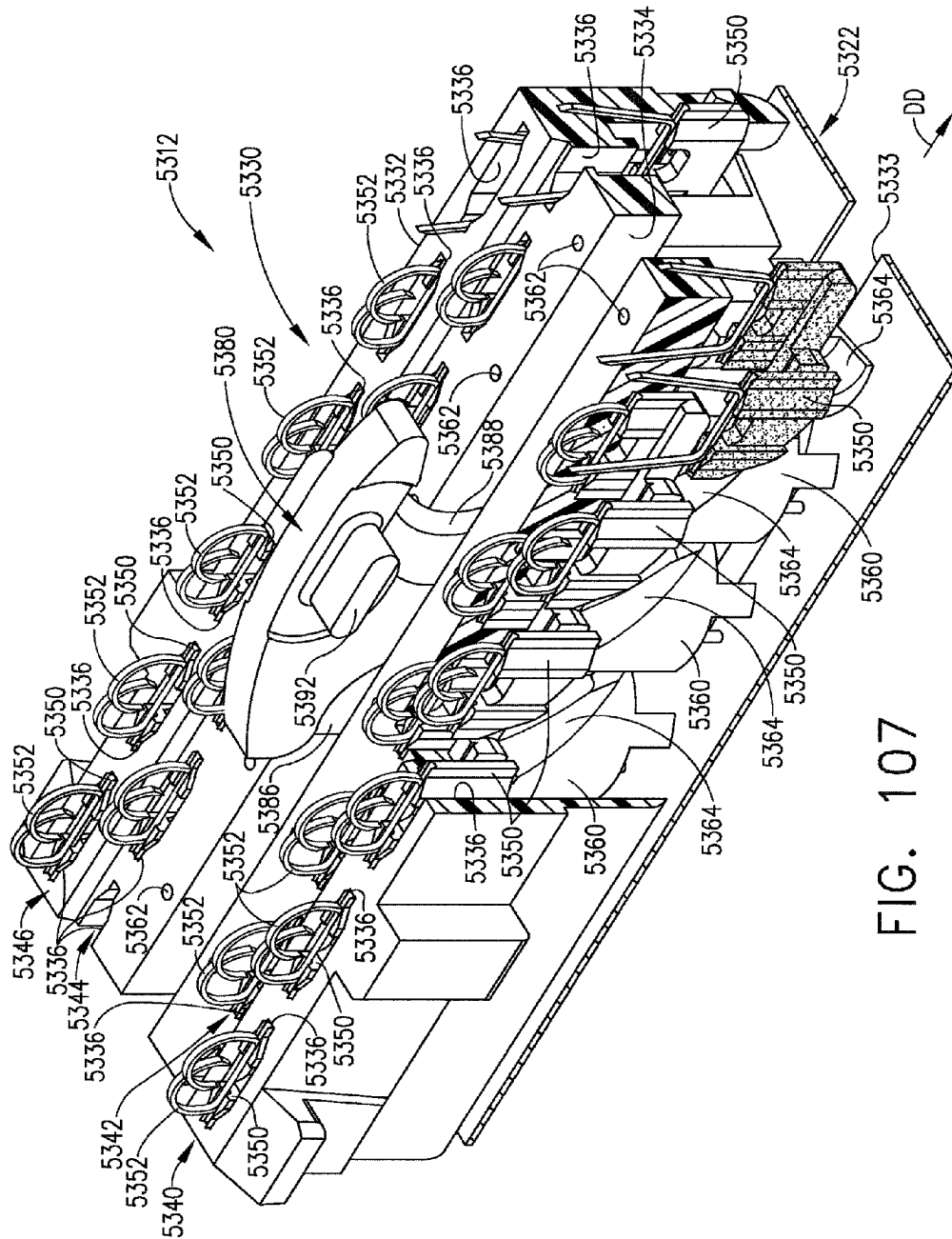


FIG. 107

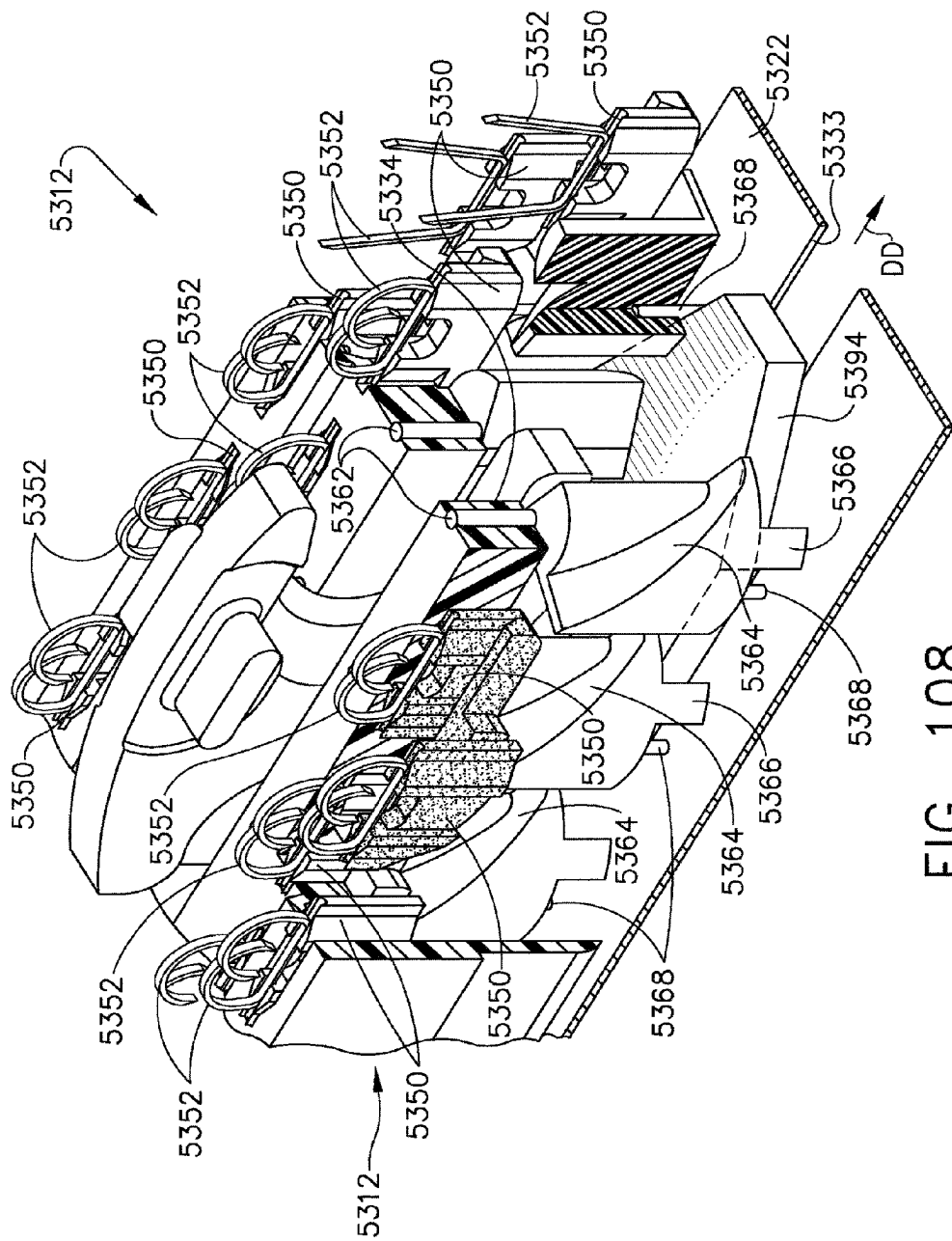


FIG. 108

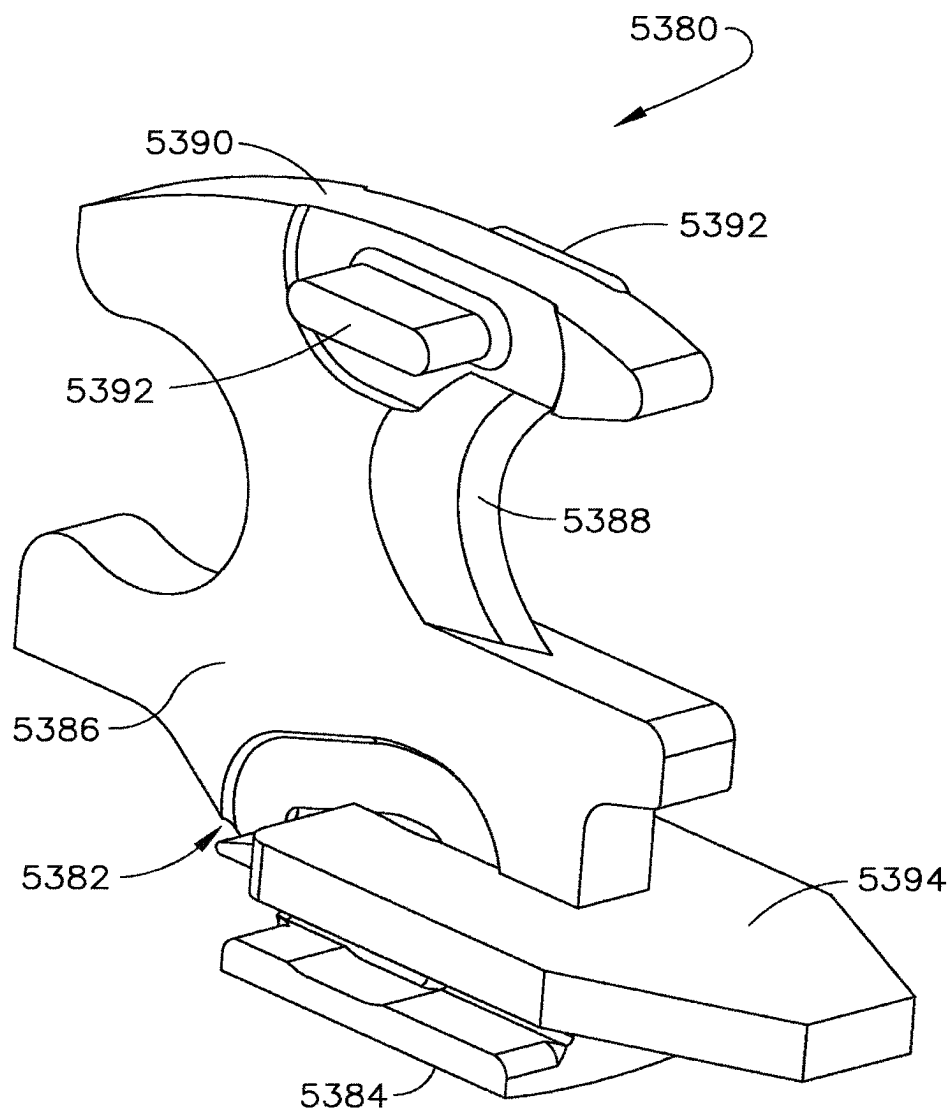


FIG. 109

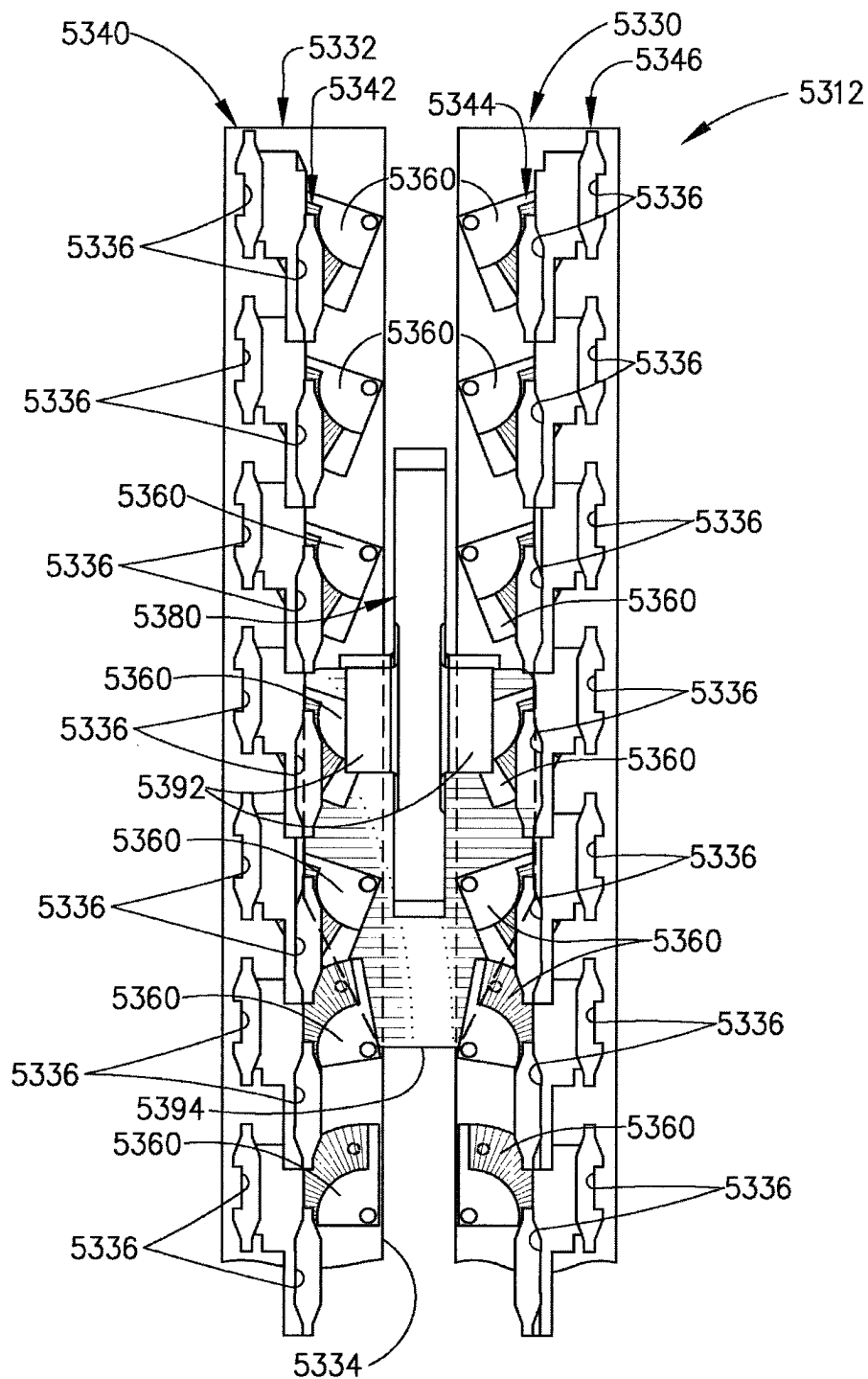


FIG. 110

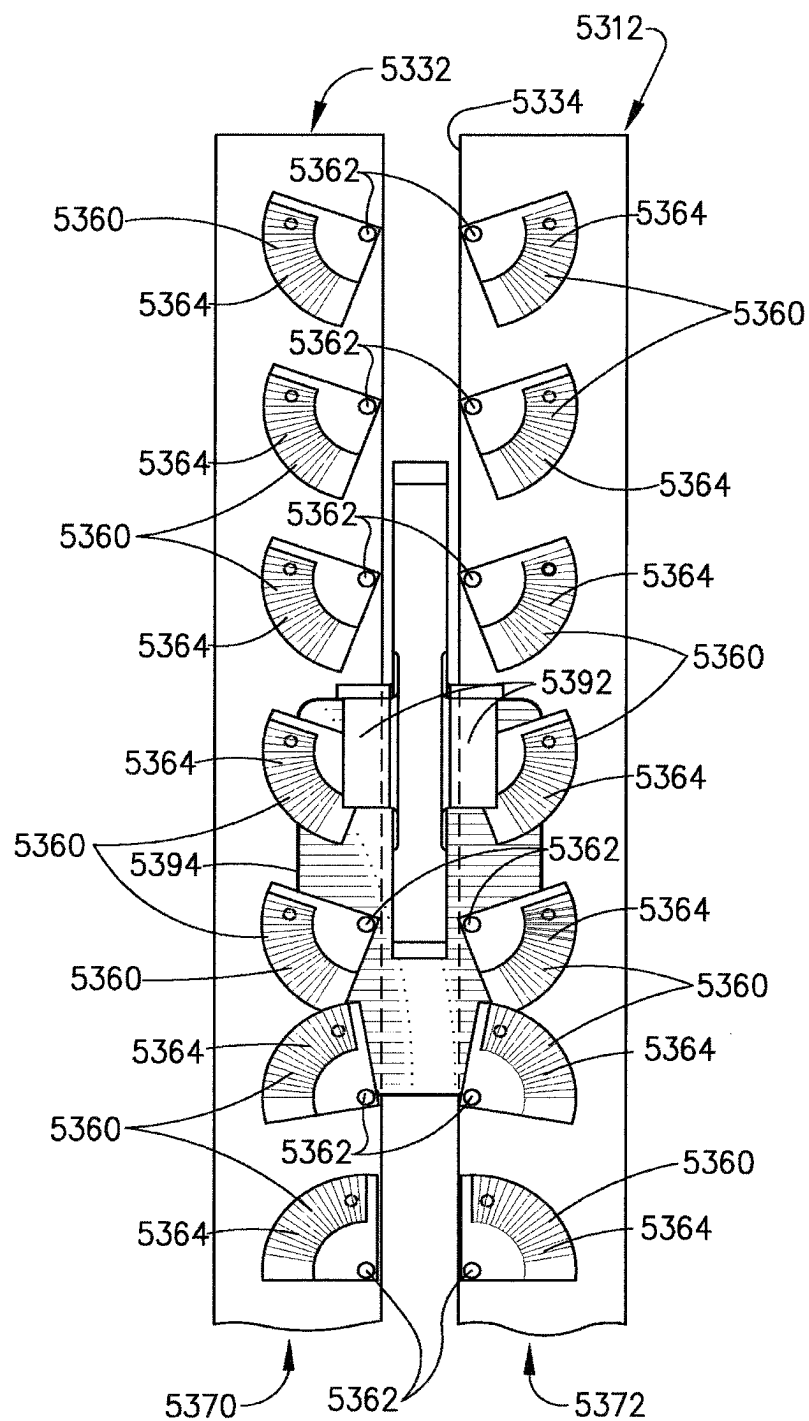


FIG. 111

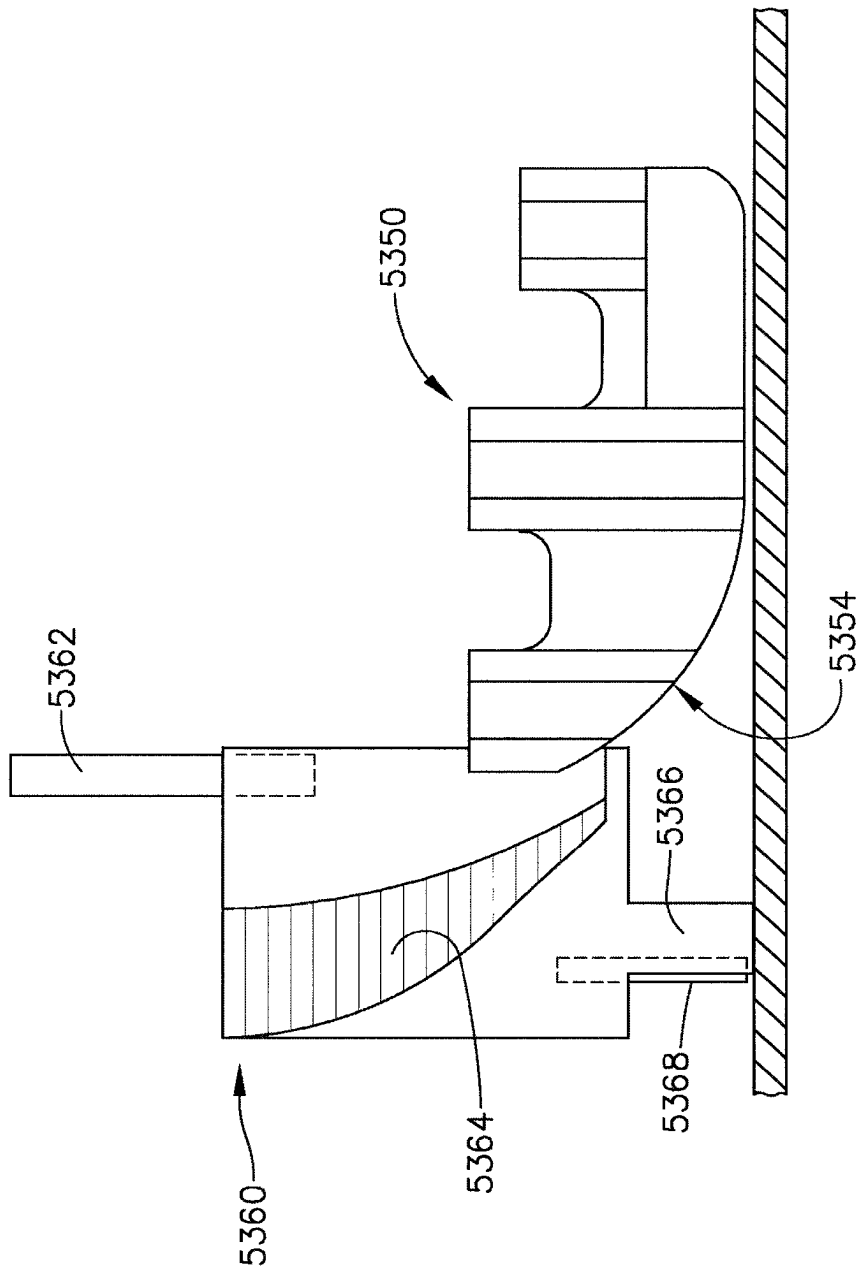


FIG. 112

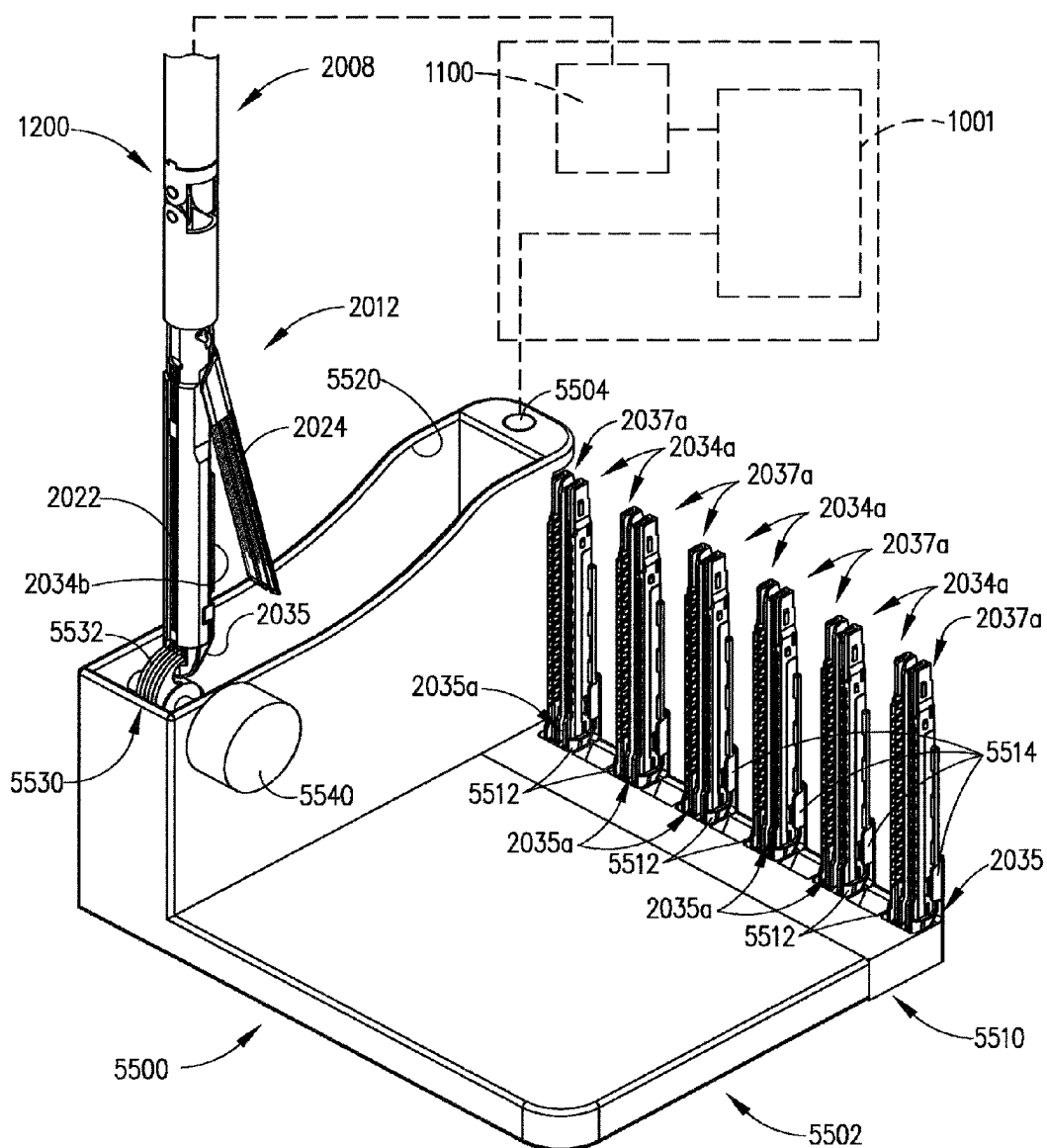


FIG. 113

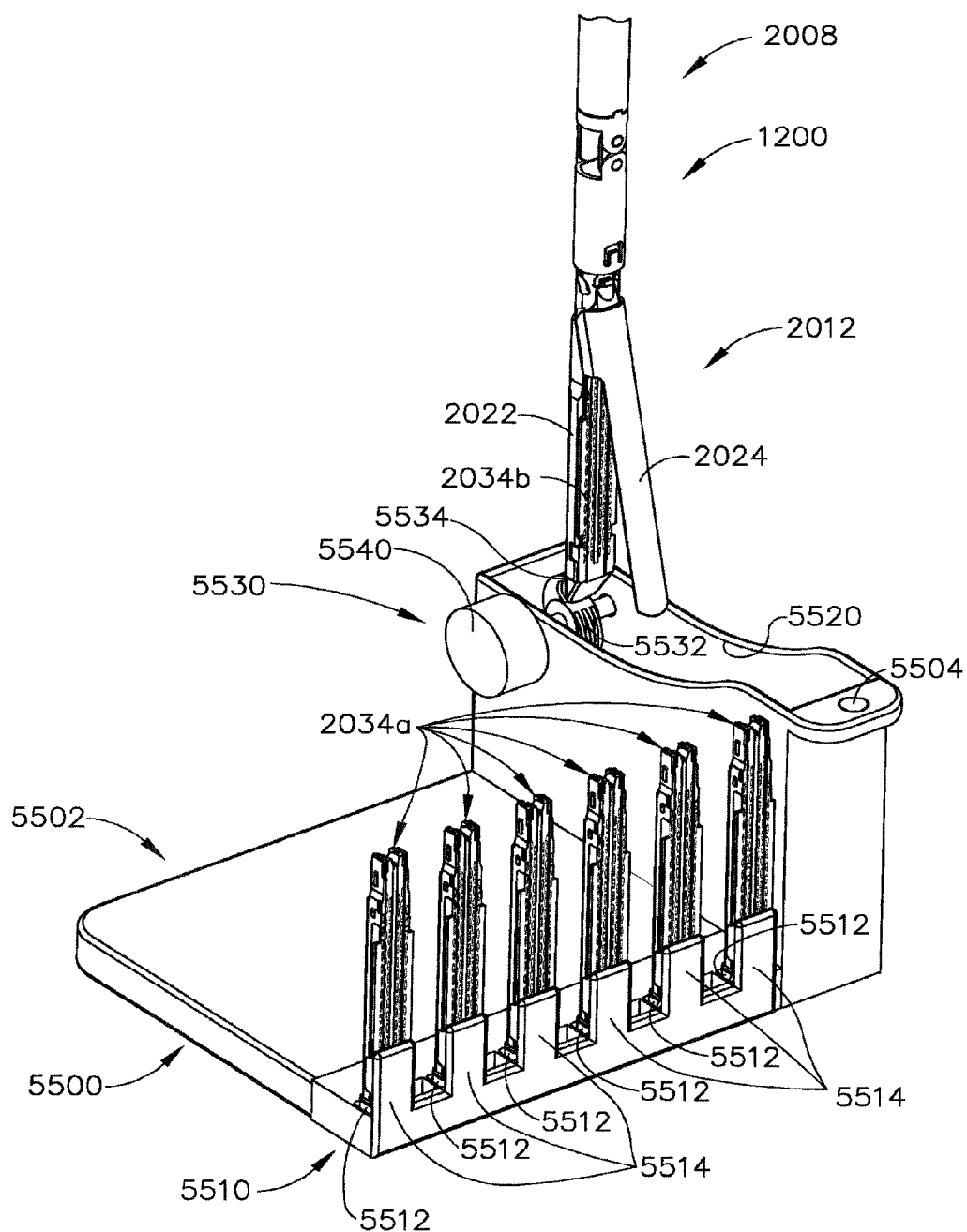
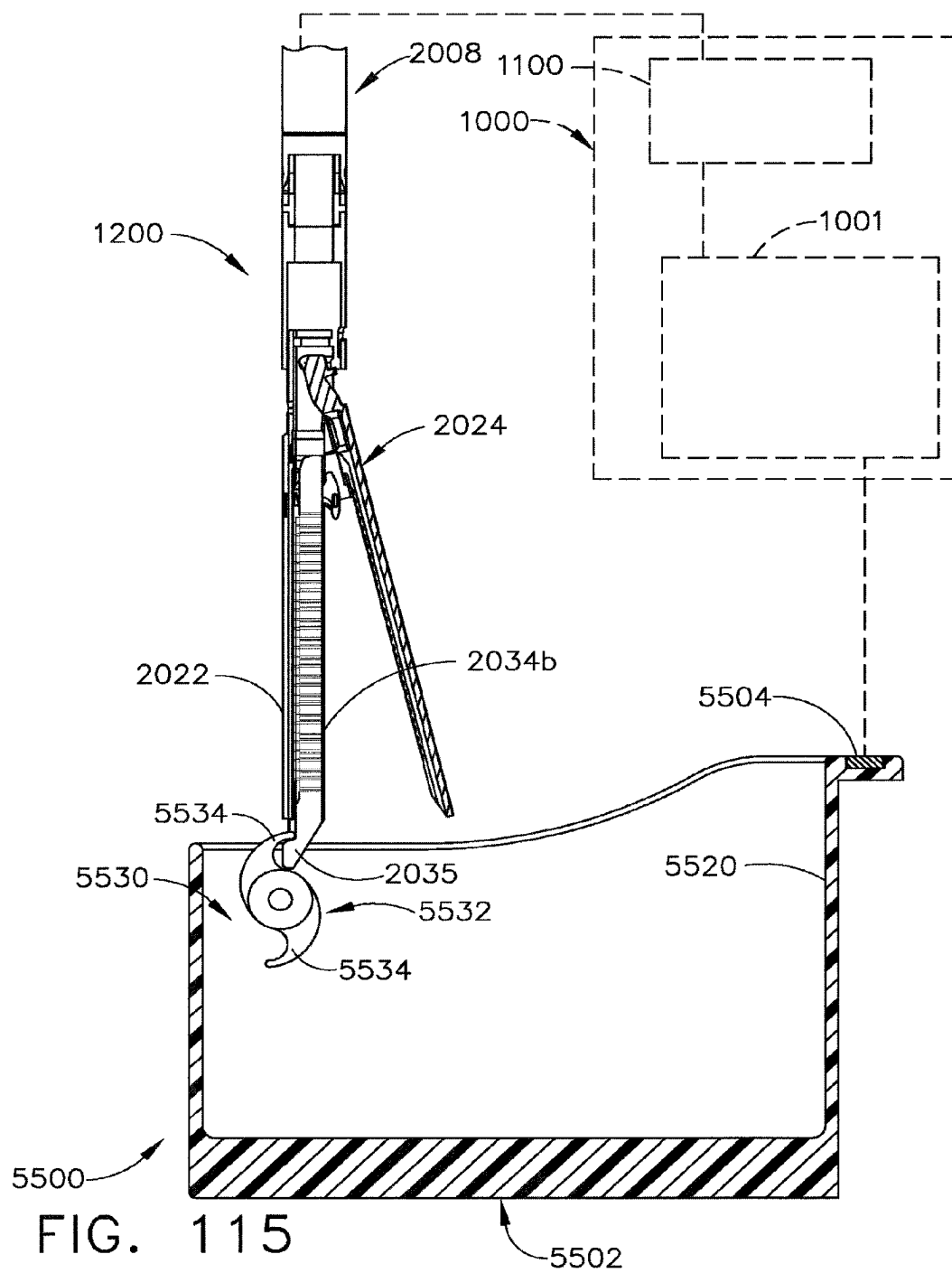


FIG. 114



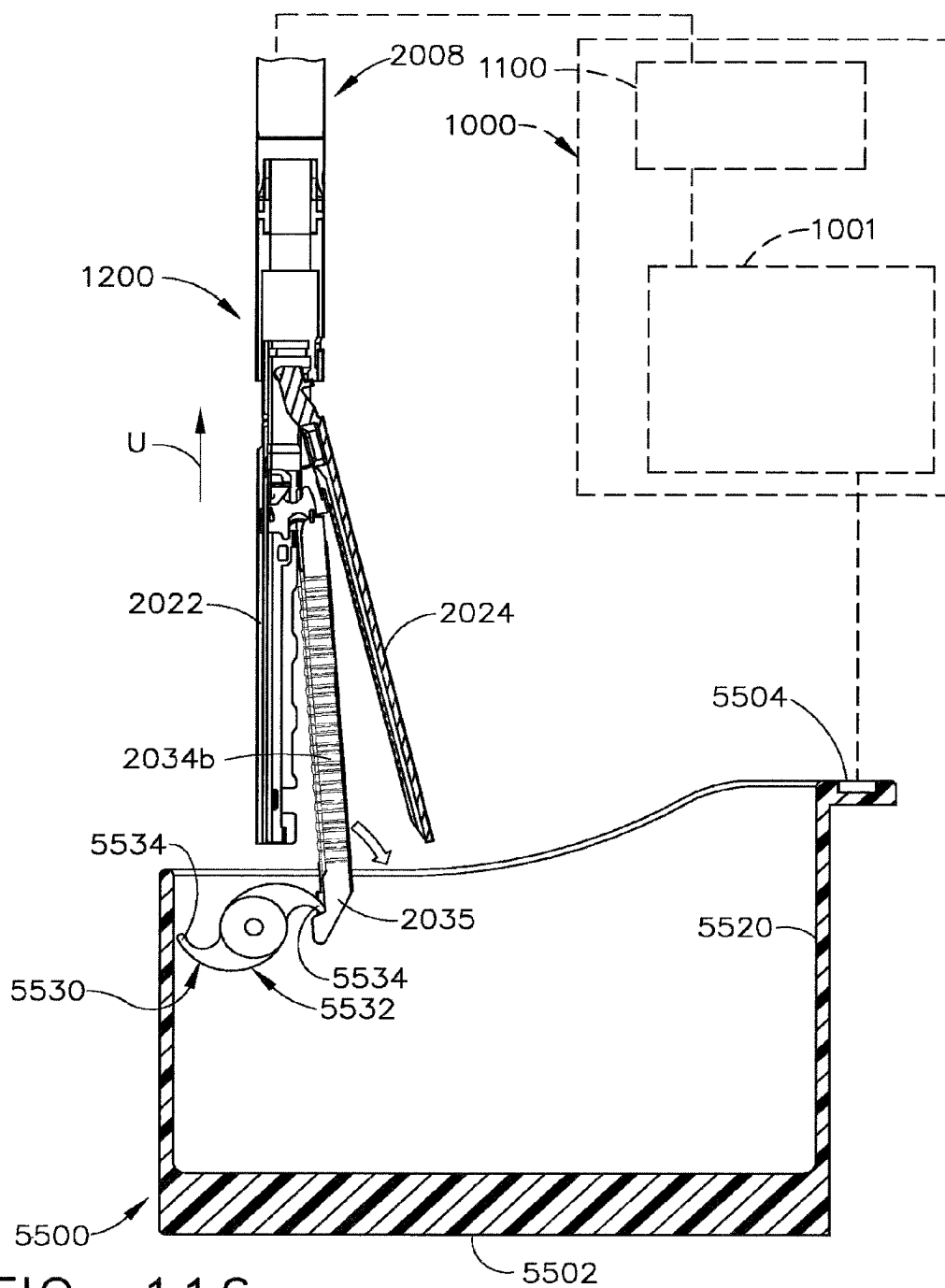
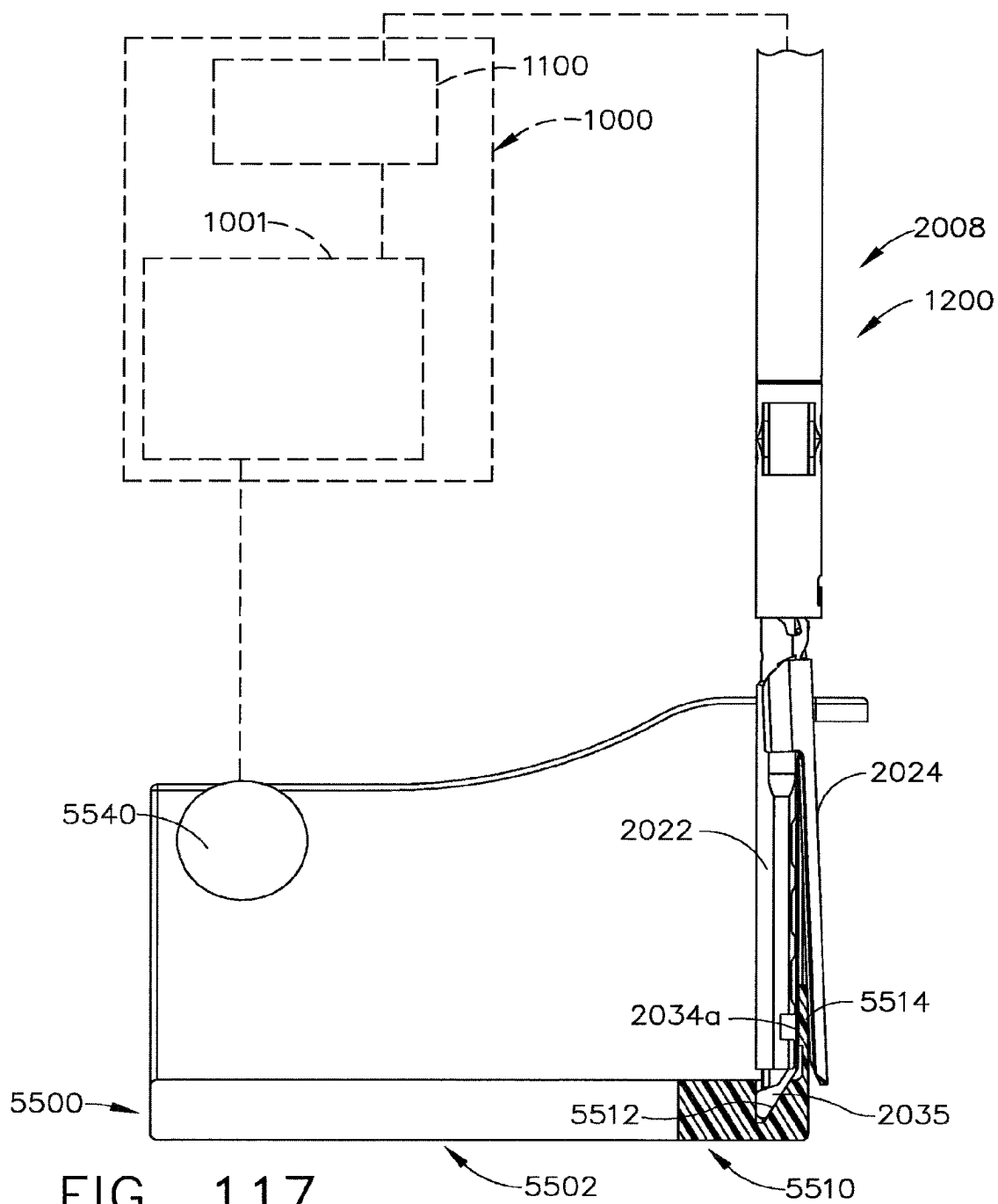
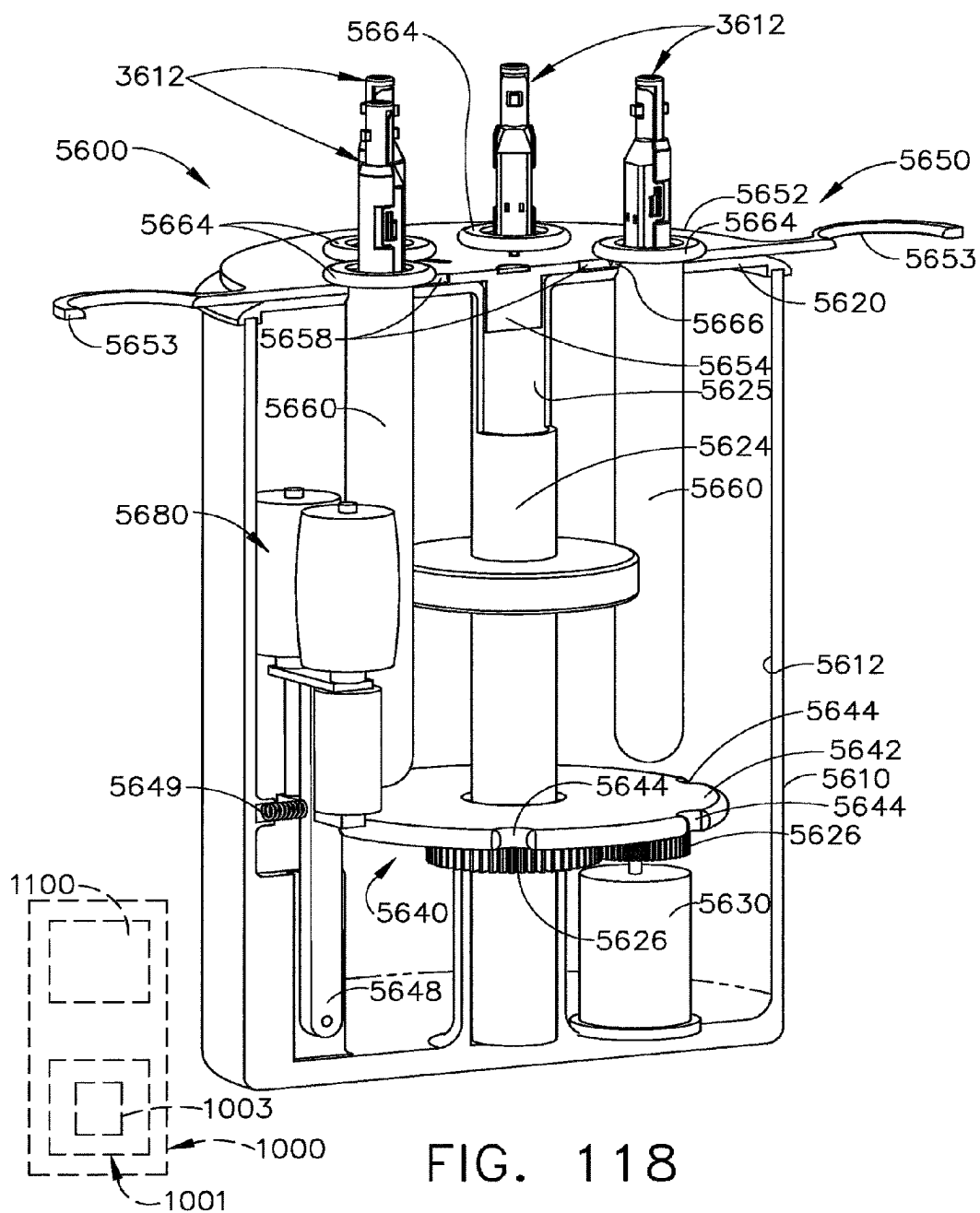


FIG. 116





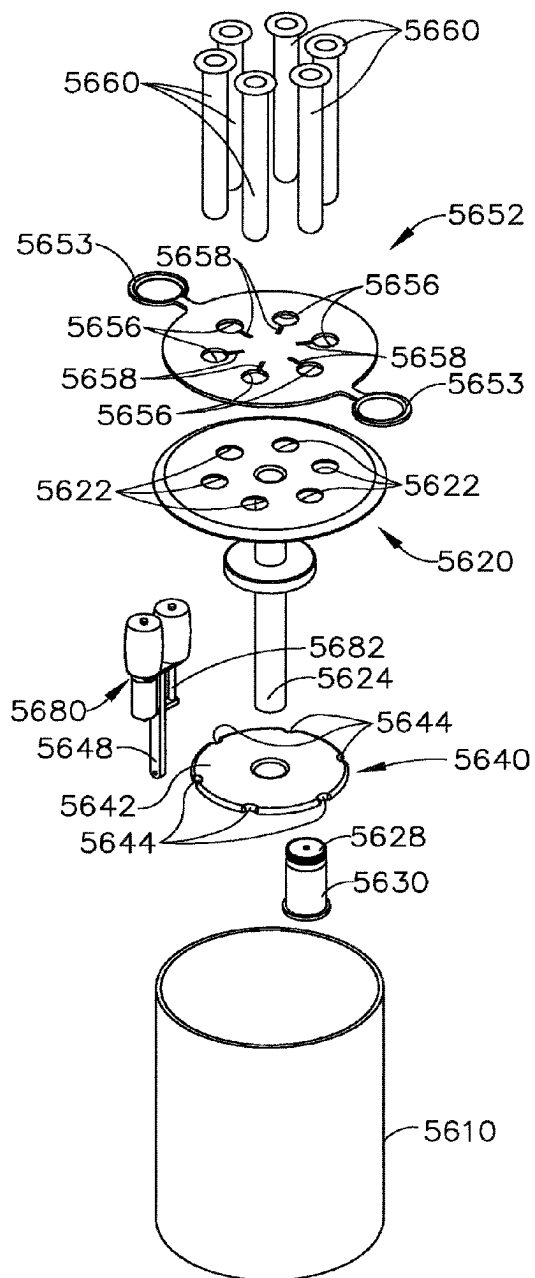


FIG. 119

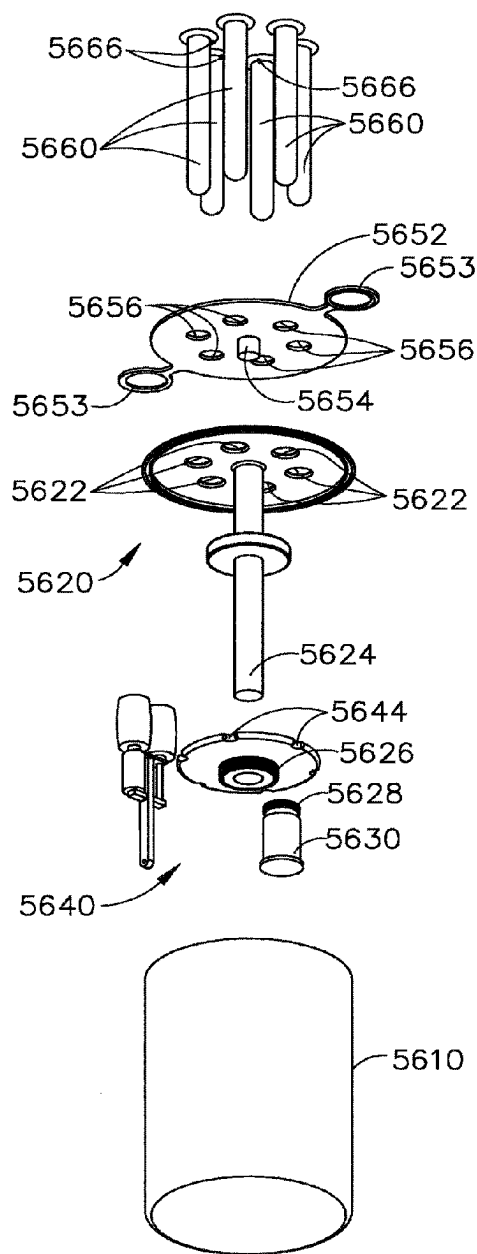


FIG. 120

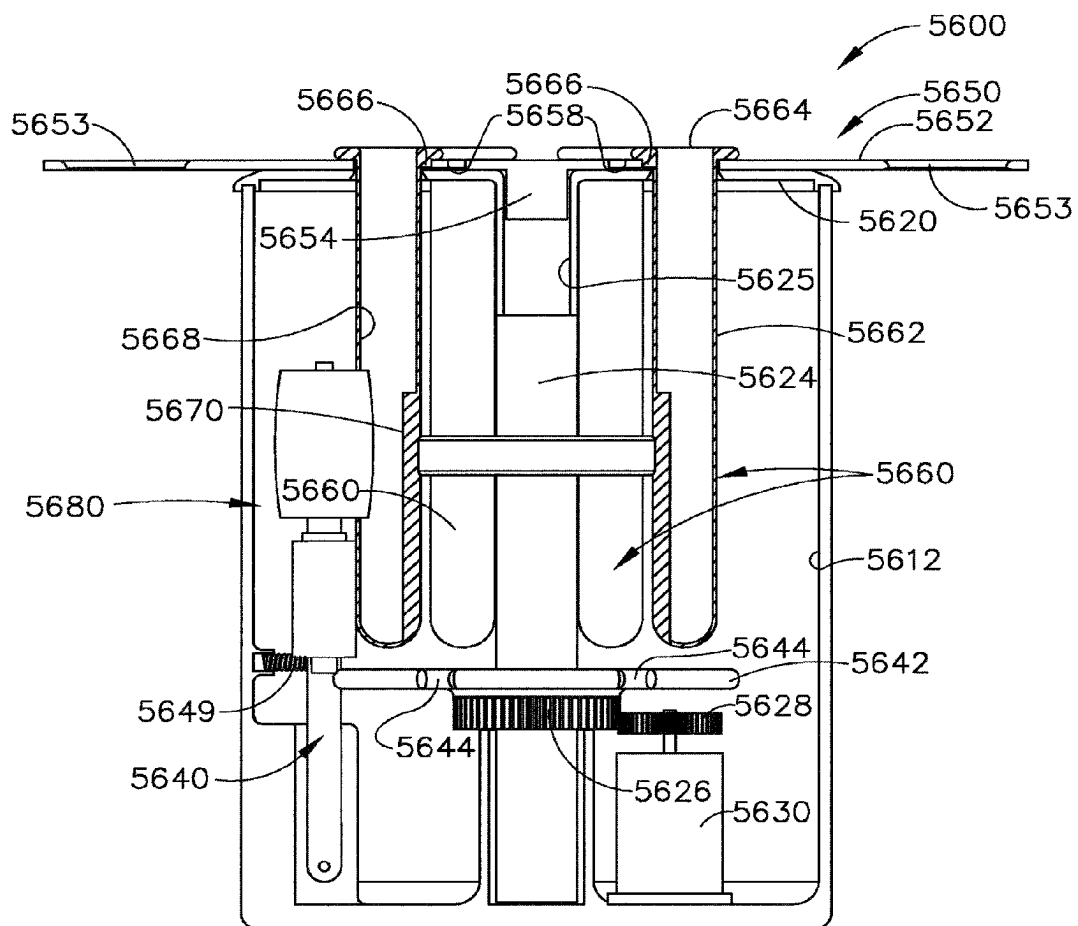


FIG. 121

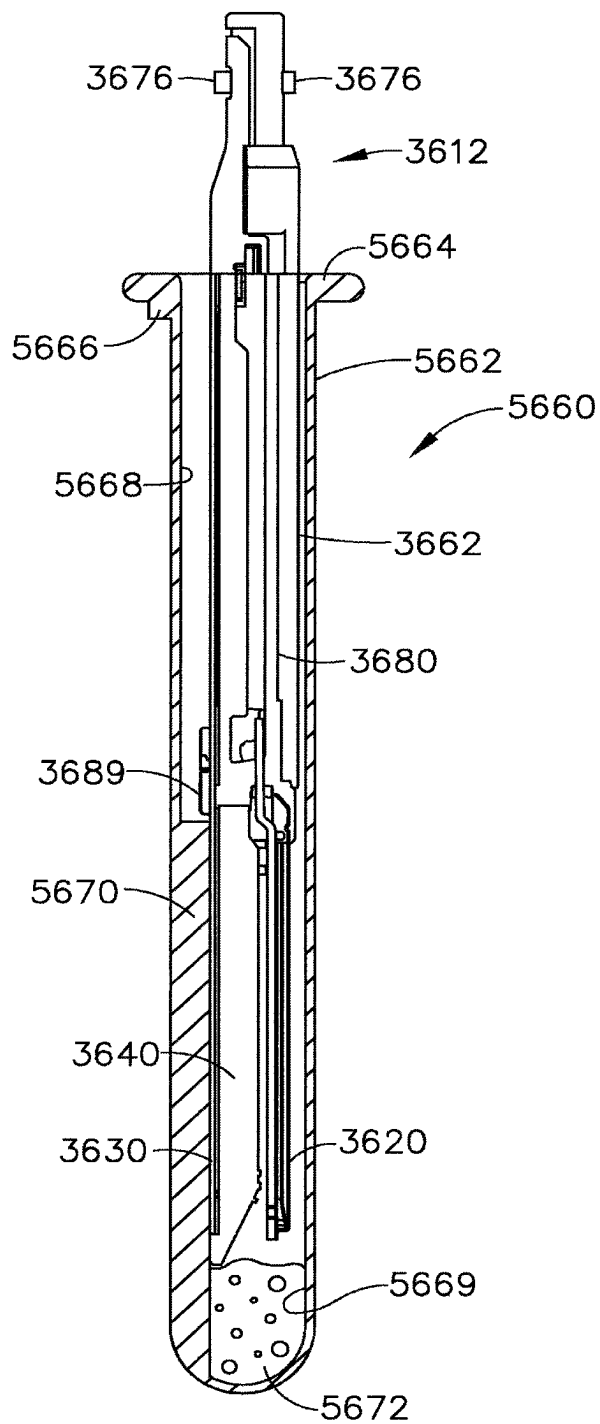


FIG. 122

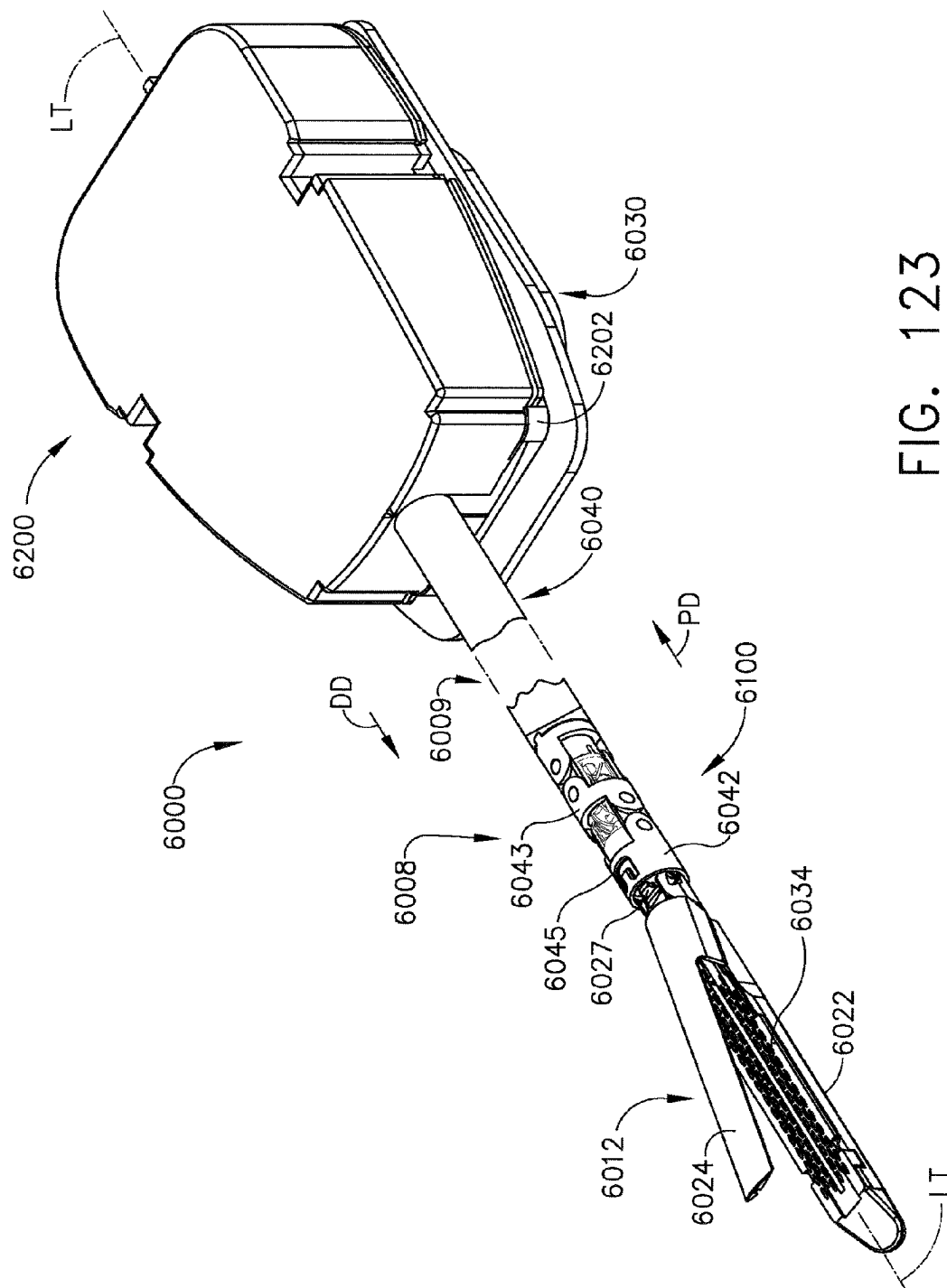


FIG. 123

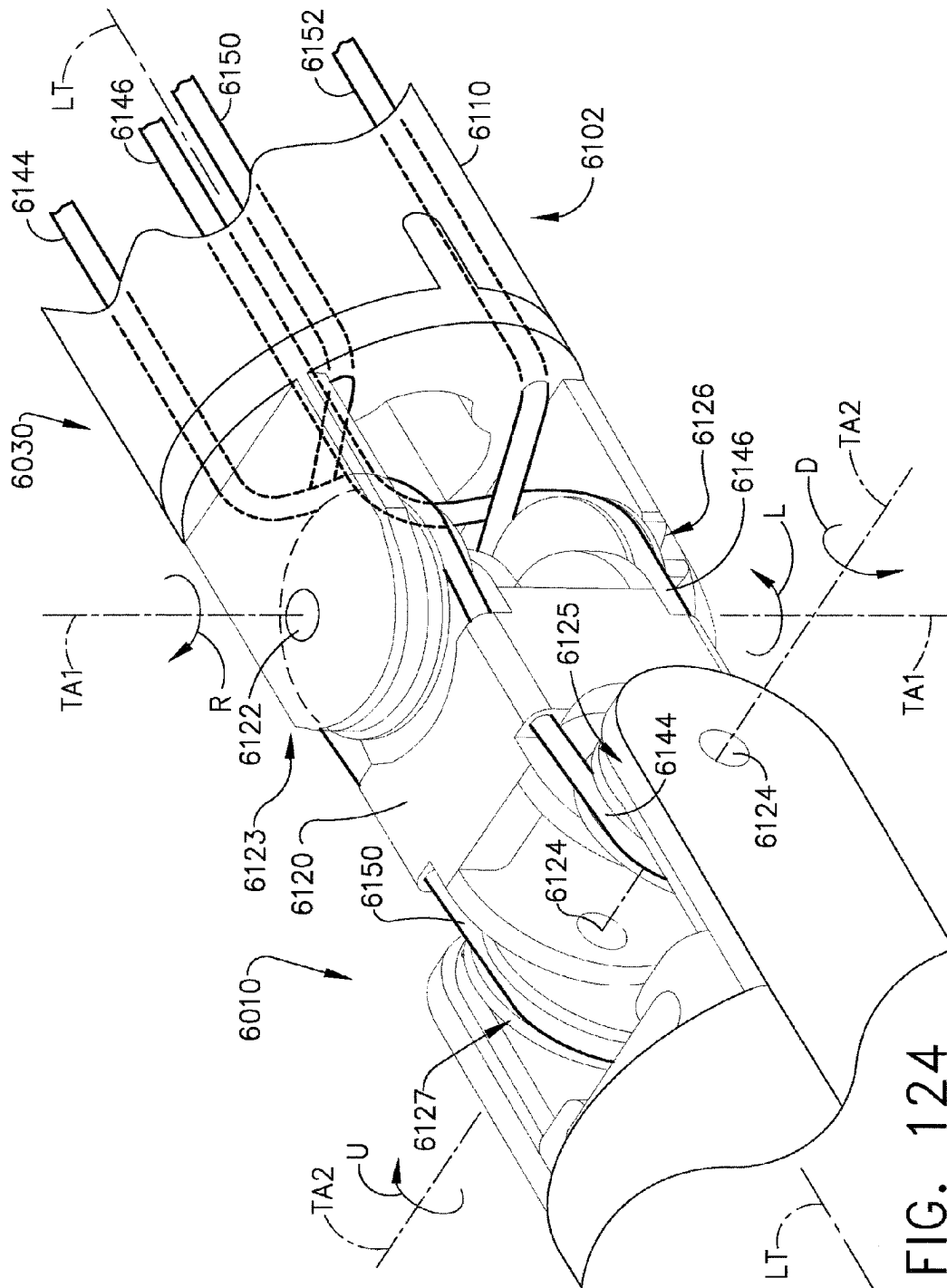


FIG. 124

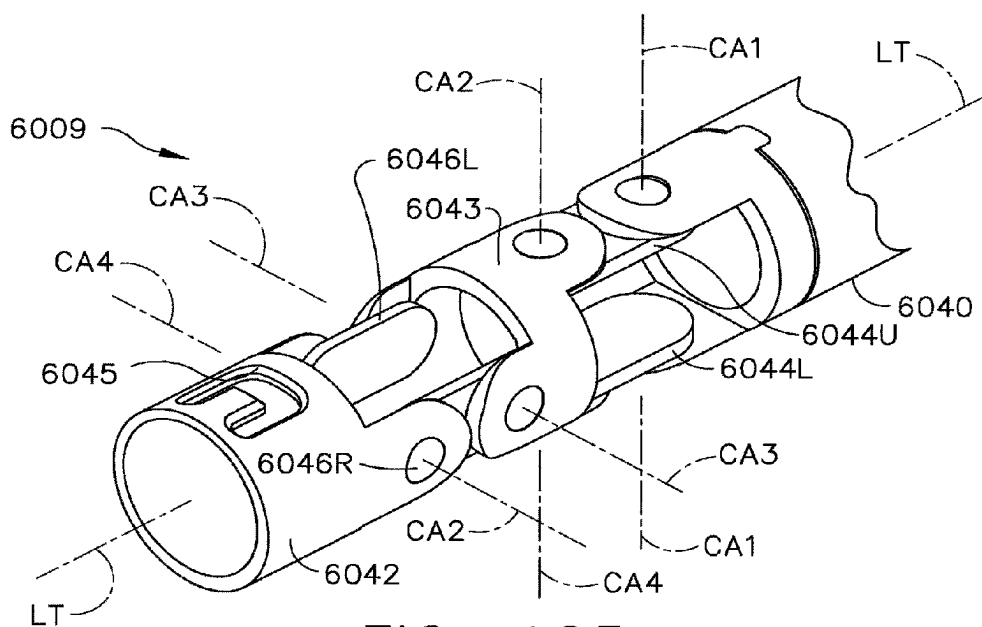


FIG. 125

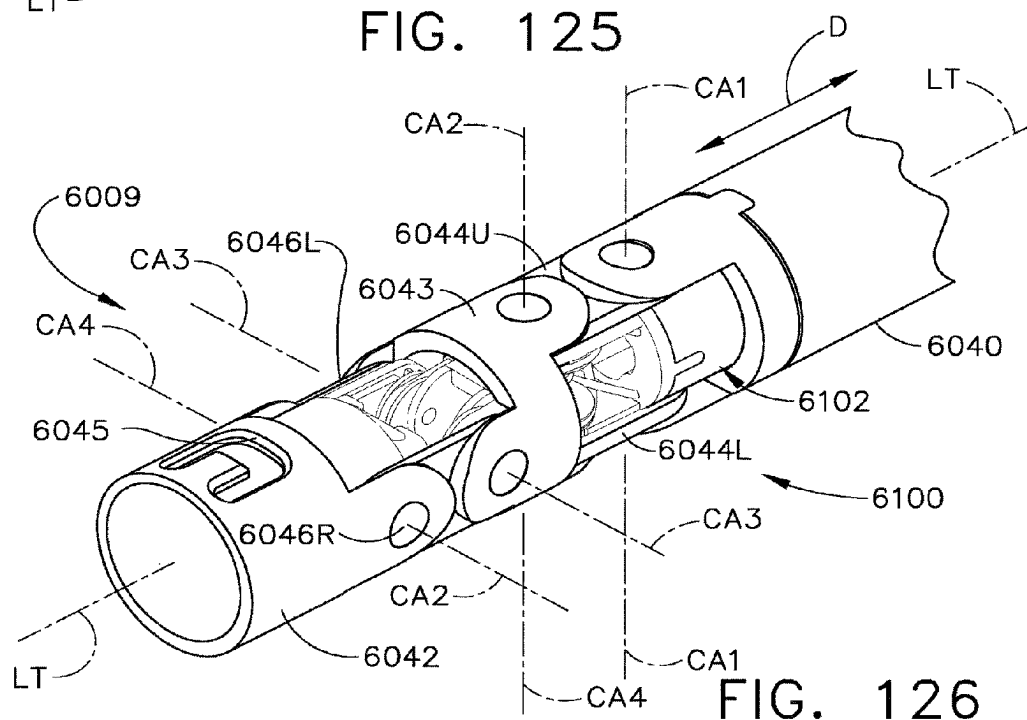


FIG. 126

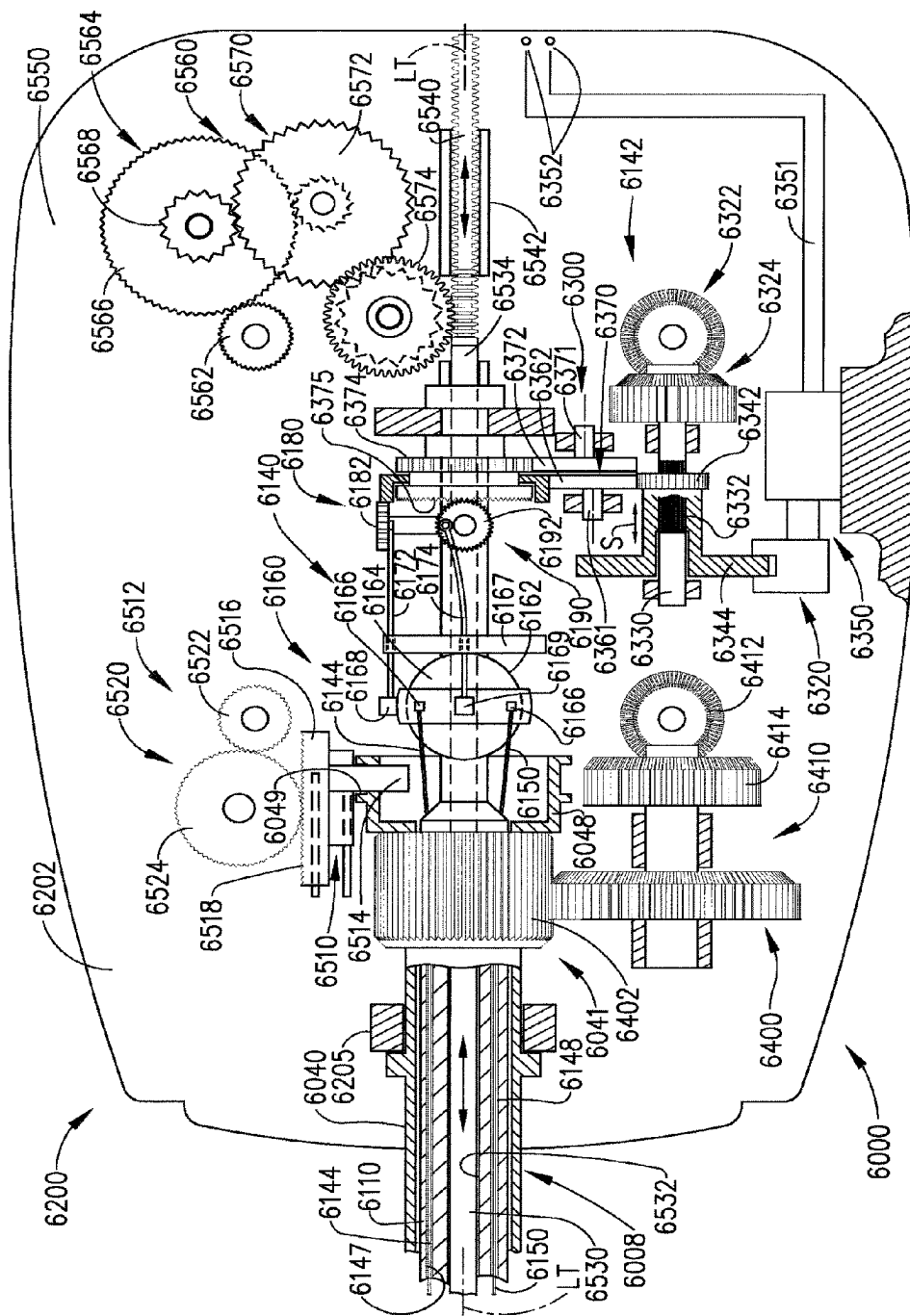
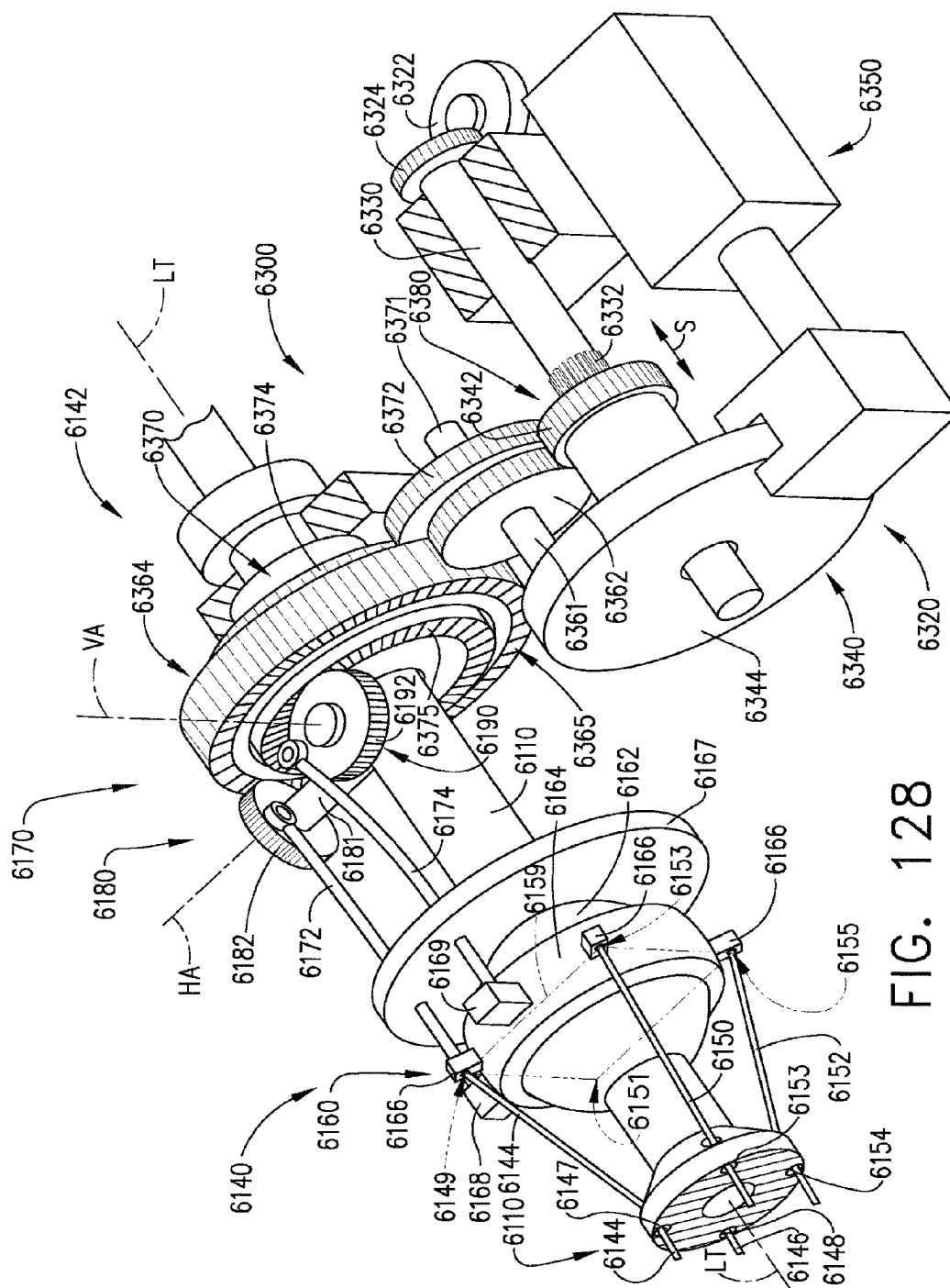


FIG. 127



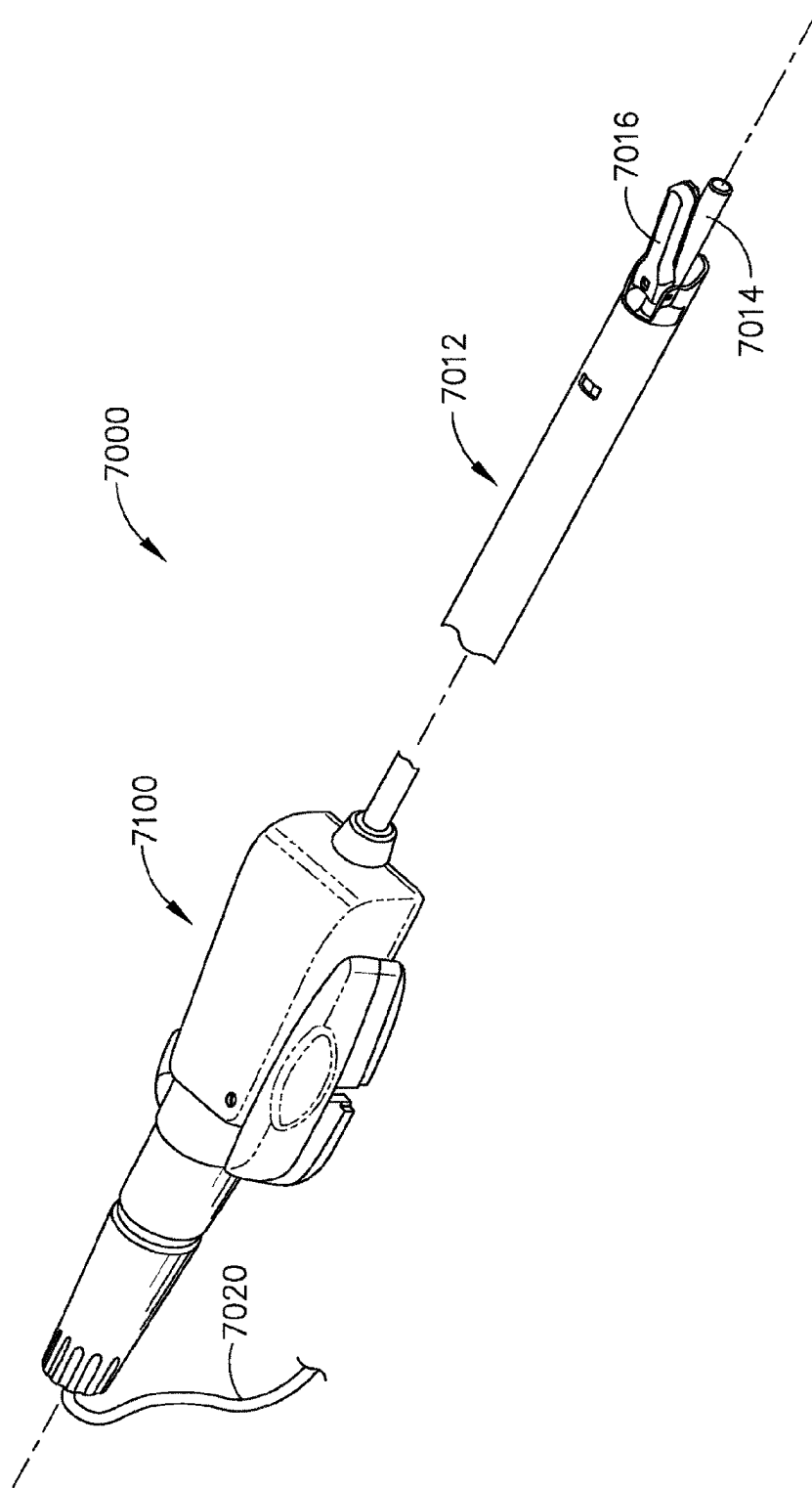
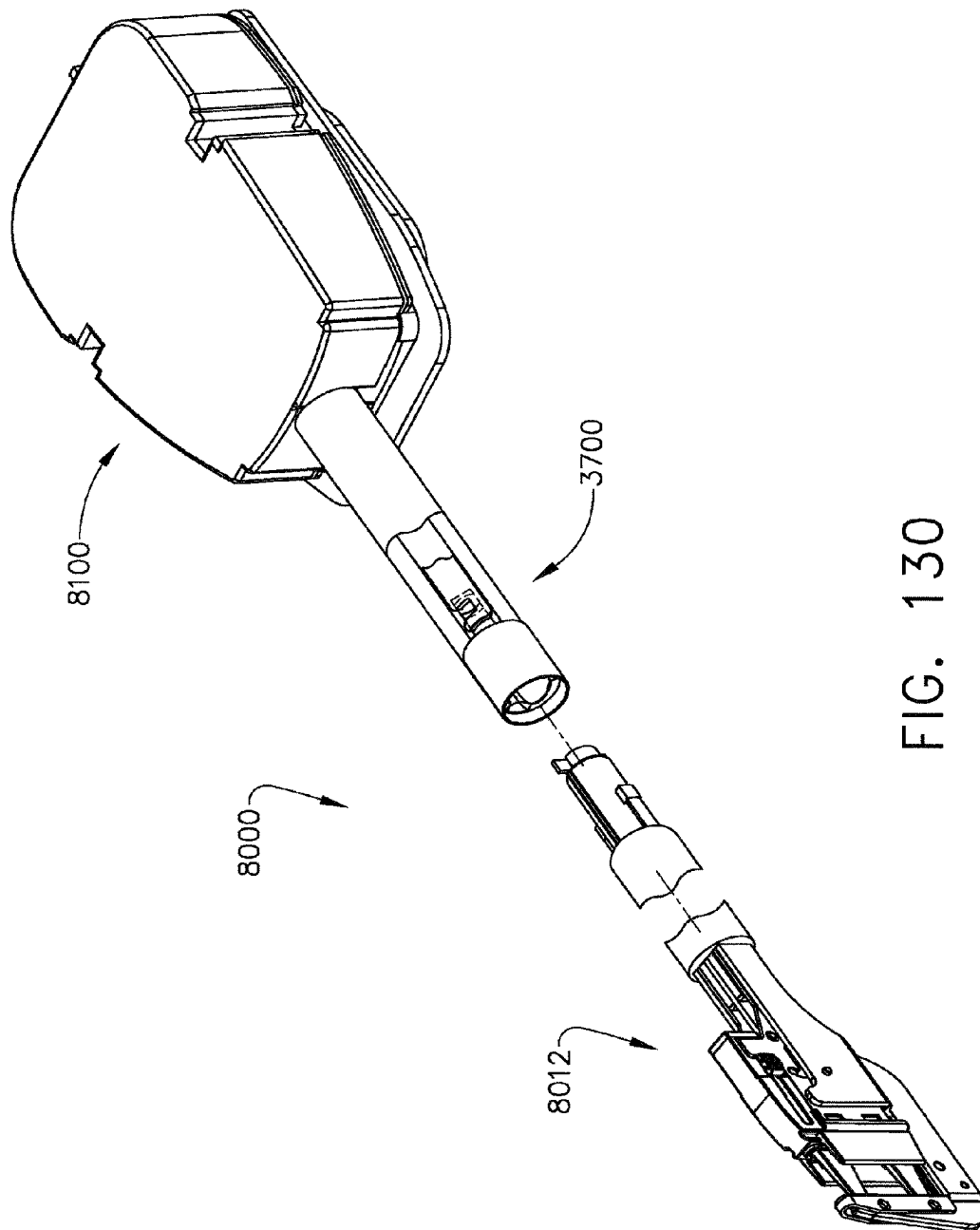


FIG. 129



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**DETACHABLE MOTOR POWERED
SURGICAL INSTRUMENT****CROSS-REFERENCE TO RELATED
APPLICATIONS**

This application is a continuation application claiming priority under 35 U.S.C. § 120 to U.S. patent application Ser. No. 13/832,522, entitled DETACHABLE MOTOR POWERED SURGICAL INSTRUMENT, filed on Mar. 15, 2013, now U.S. Patent Publication No. 2013/0200132, which is a continuation application claiming priority under 35 U.S.C. § 120 of U.S. patent application Ser. No. 13/118,210, entitled ROBOTICALLY-CONTROLLED DISPOSABLE MOTOR-DRIVEN LOADING UNIT, filed on May 27, 2011, now U.S. Pat. No. 8,752,749, which is a continuation-in-part application claiming priority under 35 U.S.C. § 120 of U.S. patent application Ser. No. 12/856,099, entitled DISPOSABLE MOTOR-DRIVEN LOADING UNIT FOR USE WITH A SURGICAL CUTTING AND STAPLING APPARATUS, filed on Aug. 13, 2010, now U.S. Pat. No. 8,196,795, which is a continuation application claiming priority under 35 U.S.C. § 120 of U.S. patent application Ser. No. 12/031,628, entitled DISPOSABLE MOTOR-DRIVEN LOADING UNIT FOR USE WITH A SURGICAL CUTTING AND STAPLING APPARATUS, filed on Feb. 14, 2008, now U.S. Pat. No. 7,793,812, the entire disclosures of which are hereby incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates in general to endoscopic surgical instruments including, but not limited to, surgical cutting and stapling apparatuses that have disposable loading units that are capable of applying lines of staples to tissue while cutting the tissue between those staple lines and, more particularly, to improvements relating to such disposable loading units.

BACKGROUND

Endoscopic surgical instruments are often preferred over traditional open surgical devices since a smaller incision tends to reduce the post-operative recovery time and complications. Consequently, significant development has gone into a range of endoscopic surgical instruments that are suitable for precise placement of a distal end effector at a desired surgical site through a cannula of a trocar. These distal end effectors engage the tissue in a number of ways to achieve a diagnostic or therapeutic effect (e.g., endocutter, grasper, cutter, staplers, clip applier, access device, drug/gene therapy delivery device, and energy device using ultrasound, RF, laser, etc.).

Known surgical staplers include an end effector that simultaneously makes a longitudinal incision in tissue and applies lines of staples on opposing sides of the incision. The end effector includes a pair of cooperating jaw members that, if the instrument is intended for endoscopic or laparoscopic applications, are capable of passing through a cannula passageway. One of the jaw members supports a staple cartridge that has at least two laterally spaced rows of staples. The other jaw member defines an anvil having staple-forming pockets aligned with the rows of staples in the cartridge. The instrument commonly includes a plurality of reciprocating wedges which, when driven distally, pass through openings in the staple cartridge and engage drivers supporting the staples to effect the firing of the staples toward the anvil.

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One type of surgical stapling apparatus is configured to operate with disposable loading units (DLU's) that are constructed to support a staple cartridge and knife assembly therein. Once the procedure is completed, the entire DLU is discarded. Such instruments that are designed to accommodate DLU's purport to offer the advantage of a "fresh" knife blade for each firing of the instrument. Examples of such surgical stapling apparatuses and DLU's are disclosed in U.S. Pat. No. 5,865,361, entitled SURGICAL STAPLING APPARATUS, which issued on Feb. 2, 1999, the disclosure of which is herein incorporated by reference in its entirety.

Such prior disposable loading units, however, require the clinician to continuously ratchet the handle to fire the staples and cut the tissue. There is a need for a surgical stapling apparatus configured for use with a disposable loading unit that is driven by a motor contained in the disposable loading unit.

SUMMARY

In accordance with at least one embodiment, a disposable loading unit configured to be operably attached to a surgical instrument which is configured to selectively generate at least one control motion for the operation of the disposable loading unit is provided. The disposable loading unit may comprise a carrier operably supporting a cartridge assembly therein, an anvil supported relative to the carrier and being movable from an open position to closed positions upon application of at least one control motion thereto, and a housing coupled to the carrier, the housing including means for removably attaching the housing to the surgical instrument. The disposable loading unit may further comprise a rotary drive at least partially supported within the housing and a motor supported within the housing and operably interfacing with the rotary drive to selectively apply a rotary motion thereto, wherein the motor is configured to receive power from a power source such that the motor can only selectively receive power from the power source when the means for removably attaching the housing to the surgical instrument is operably coupled to the surgical instrument. The disposable loading unit may further comprise a linear member coupled with the rotary drive which moves axially upon the application of a rotary motion thereto from the motor.

In accordance with at least one embodiment, a stapling sub-system configured to be operably engaged with a surgical instrument system is provided. The stapling sub-system may comprise a staple cartridge carrier, a staple cartridge assembly supported by the staple cartridge carrier, and an anvil supported relative to the staple cartridge carrier and movable from an open position to a closed position. The stapling sub-system may further comprise a housing, wherein the staple cartridge carrier extends from the housing, and wherein the housing comprises a housing connector removably attachable to the surgical instrument system. The stapling sub-system may further comprise a rotary drive system comprising a rotary shaft and a translatable drive member operably engaged with the rotary shaft, wherein the translatable drive member is selectively translatable through the staple cartridge assembly from a start position to an end position when a rotary motion is applied to the rotary shaft. The rotary drive system may further comprise an electric motor operably interfacing with the rotary shaft to selectively apply the rotary motion to the rotary shaft, wherein the electric motor is operably disconnected from a power source when the housing is not attached to the surgical instrument system, and wherein

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the electric motor is operably connected to the power source when the housing is attached to the surgical instrument system.

In accordance with at least one embodiment, a stapling attachment configured to be operably attached to a surgical instrument system is provided. The stapling attachment may comprise a staple cartridge carrier, a staple cartridge body supported by the staple cartridge carrier, wherein the staple cartridge body comprises a proximal end and a distal end, and a plurality of staples removably stored in the staple cartridge body. The stapling attachment may further comprise an anvil supported relative to the staple cartridge carrier and movable from an open position to a closed position, a housing, wherein the staple cartridge carrier extends from the housing, and wherein the housing is removably attachable to the surgical instrument system, and an electric motor configured to produce rotational motion, wherein the electric motor selectively receives power from a power source only when the housing is coupled to the surgical instrument system. The stapling attachment may further comprise drive means for converting the rotational motion produced by the electric motor to translational motion to elect the staples from the staple cartridge body.

In accordance with at least one embodiment, a loading unit configured to be operably attached to a surgical instrument which is configured to selectively generate at least one control motion for the operation of the loading unit is provided. The loading unit may comprise an end effector, a housing including means for removably attaching the housing to the surgical instrument, and a rotary drive at least partially supported within the housing. The loading unit may further comprise a motor supported within the housing and operably interfacing with the rotary drive to selectively apply a rotary motion thereto, wherein the motor is configured to receive power from a power source such that the motor can only selectively receive power from the power source when the means for removably attaching the housing to the surgical instrument is operably coupled to the surgical instrument, and a linear member coupled with the rotary drive which moves axially upon the application of a rotary motion thereto from the motor.

In accordance with at least one embodiment, a stapling sub-system configured to be operably engaged with a surgical instrument system is provided. The stapling sub-system may comprise a stapling portion, a housing, wherein the stapling portion extends from the housing, and wherein the housing comprises a housing connector removably attachable to the surgical instrument system, and a rotary drive system. The rotary drive system may comprise a rotary shaft, a translatable drive member operably engaged with the rotary shaft, wherein the translatable drive member is selectively translatable through the stapling portion from a start position to an end position when a rotary motion is applied to the rotary shaft, and an electric motor operably interfacing with the rotary shaft to selectively apply the rotary motion to the rotary shaft, wherein the electric motor is operably disconnected from a power source when the housing is not attached to the surgical instrument system, and wherein the electric motor is operably connected to the power source when the housing is attached to the surgical instrument system.

In accordance with at least one embodiment, a stapling attachment configured to be operably attached to a surgical instrument system is provided. The stapling attachment may comprise a staple cartridge body comprising a proximal end and a distal end, a plurality of staples removably stored in the staple cartridge body, and an anvil supported relative to the staple cartridge body. The stapling attachment may further

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comprise a housing removably attachable to the surgical instrument system, an electric motor configured to produce rotational motion, wherein the electric motor selectively receives power from a power source only when the housing is coupled to the surgical instrument system, and drive means for converting the rotational motion produced by the electric motor to translational motion to elect the staples from the staple cartridge body.

These and other objects and advantages of the present invention shall be made apparent from the accompanying drawings and the description thereof.

BRIEF DESCRIPTION OF THE FIGURES

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention, and, together with the general description of various embodiments of the invention given above, and the detailed description of the embodiments given below, serve to explain various principles of the present invention.

FIG. 1 is a perspective view of a disposable loading unit embodiment of the present invention coupled to a conventional surgical cutting and stapling apparatus;

FIG. 2 is a cross-sectional view of the disposable loading unit of FIG. 1 with several components shown in full view for clarity;

FIG. 3 is a cross-sectional view of a proximal end of the disposable loading unit embodiment of FIGS. 1 and 2 with various components shown in full view for clarity;

FIG. 4 is a schematic of a circuit embodiment of the disposable loading unit of FIGS. 1-3;

FIG. 5 is a cross-sectional view of the disposable loading unit of FIGS. 1-3 when the disposable loading unit has been attached to the elongated body of the surgical instrument;

FIG. 6 is a schematic view of the circuit illustrating the position of various components of the disposable loading unit after it has been attached to the surgical instrument;

FIG. 7 is a cross-sectional view of the disposable loading unit of FIGS. 1-6 when the drive beam has been moved to the anvil closed position;

FIG. 8 is a schematic view of the circuit illustrating the position of various components of the disposable loading unit after the drive beam has been moved to the anvil closed position;

FIG. 9 is a cross-sectional view of the disposable loading unit of FIGS. 1-8 when the drive beam has been moved to its distal-most fired position;

FIG. 10 is a schematic view of the circuit illustrating the position of various components of the disposable loading unit after the drive beam has been moved to its distal-most fired position;

FIG. 11 is a cross-sectional view of the disposable loading unit of FIGS. 1-10 as the drive beam is being returned to a starting position;

FIG. 12 is a schematic view of the circuit illustrating the position of various components of the disposable loading unit as the drive beam is being returned to a start position;

FIG. 13 is a perspective view of one robotic controller embodiment;

FIG. 14 is a perspective view of one robotic surgical arm cart/manipulator of a robotic system operably supporting a plurality of surgical tool embodiments of the present invention;

FIG. 15 is a side view of the robotic surgical arm cart/manipulator depicted in FIG. 14;

FIG. 16 is a perspective view of an exemplary cart structure with positioning linkages for operably supporting robotic

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manipulators that may be used with various surgical tool embodiments of the present invention;

FIG. 17 is a perspective view of a surgical tool embodiment of the present invention;

FIG. 18 is an exploded assembly view of an adapter and tool holder arrangement for attaching various surgical tool embodiments to a robotic system;

FIG. 19 is a side view of the adapter shown in FIG. 18;

FIG. 20 is a bottom view of the adapter shown in FIG. 18;

FIG. 21 is a top view of the adapter of FIGS. 18 and 19;

FIG. 22 is a partial bottom perspective view of the surgical tool embodiment of FIG. 17;

FIG. 23 is a partial exploded view of a portion of an articulating surgical end effector embodiment of the present invention;

FIG. 24 is a perspective view of the surgical tool embodiment of FIG. 22 with the tool mounting housing removed;

FIG. 25 is a rear perspective view of the surgical tool embodiment of FIG. 22 with the tool mounting housing removed;

FIG. 26 is a front perspective view of the surgical tool embodiment of FIG. 22 with the tool mounting housing removed;

FIG. 27 is a partial exploded perspective view of the surgical tool embodiment of FIG. 26;

FIG. 28 is a partial cross-sectional side view of the surgical tool embodiment of FIG. 22;

FIG. 29 is an enlarged cross-sectional view of a portion of the surgical tool depicted in FIG. 28;

FIG. 30 is an exploded perspective view of a portion of the tool mounting portion of the surgical tool embodiment depicted in FIG. 22;

FIG. 31 is an enlarged exploded perspective view of a portion of the tool mounting portion of FIG. 30;

FIG. 32 is a partial cross-sectional view of a portion of the elongated shaft assembly of the surgical tool of FIG. 22;

FIG. 33 is a side view of a half portion of a closure nut embodiment of a surgical tool embodiment of the present invention;

FIG. 34 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 35 is a cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 34 with the anvil in the open position and the closure clutch assembly in a neutral position;

FIG. 36 is another cross-sectional side view of the surgical end effector and elongated shaft assembly shown in FIG. 35 with the clutch assembly engaged in a closure position;

FIG. 37 is another cross-sectional side view of the surgical end effector and elongated shaft assembly shown in FIG. 35 with the clutch assembly engaged in a firing position;

FIG. 38 is a top view of a portion of a tool mounting portion embodiment of the present invention;

FIG. 39 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 40 is a cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 39 with the anvil in the open position;

FIG. 41 is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 39 with the anvil in the closed position;

FIG. 42 is a perspective view of a closure drive nut and portion of a knife bar embodiment of the present invention;

FIG. 43 is a top view of another tool mounting portion embodiment of the present invention;

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FIG. 44 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 45 is a cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 44 with the anvil in the open position;

FIG. 46 is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 45 with the anvil in the closed position;

FIG. 47 is a cross-sectional view of a mounting collar embodiment of a surgical tool embodiment of the present invention showing the knife bar and distal end portion of the closure drive shaft;

FIG. 48 is a cross-sectional view of the mounting collar embodiment of FIG. 47;

FIG. 49 is a top view of another tool mounting portion embodiment of another surgical tool embodiment of the present invention;

FIG. 49A is an exploded perspective view of a portion of a gear arrangement of another surgical tool embodiment of the present invention;

FIG. 49B is a cross-sectional perspective view of the gear arrangement shown in FIG. 49A;

FIG. 50 is a cross-sectional side view of a portion of a surgical end effector and elongated shaft assembly of another surgical tool embodiment of the present invention employing a pressure sensor arrangement with the anvil in the open position;

FIG. 51 is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 50 with the anvil in the closed position;

FIG. 52 is a side view of a portion of another surgical tool embodiment of the present invention in relation to a tool holder portion of a robotic system with some of the components thereof shown in cross-section;

FIG. 53 is a side view of a portion of another surgical tool embodiment of the present invention in relation to a tool holder portion of a robotic system with some of the components thereof shown in cross-section;

FIG. 54 is a side view of a portion of another surgical tool embodiment of the present invention with some of the components thereof shown in cross-section;

FIG. 55 is a side view of a portion of another surgical end effector embodiment of a portion of a surgical tool embodiment of the present invention with some components thereof shown in cross-section;

FIG. 56 is a side view of a portion of another surgical end effector embodiment of a portion of a surgical tool embodiment of the present invention with some components thereof shown in cross-section;

FIG. 57 is a side view of a portion of another surgical end effector embodiment of a portion of a surgical tool embodiment of the present invention with some components thereof shown in cross-section;

FIG. 58 is an enlarged cross-sectional view of a portion of the end effector of FIG. 57;

FIG. 59 is another cross-sectional view of a portion of the end effector of FIGS. 57 and 58;

FIG. 60 is a cross-sectional side view of a portion of a surgical end effector and elongated shaft assembly of another surgical tool embodiment of the present invention with the anvil in the open position;

FIG. 61 is an enlarged cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 60;

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FIG. 62 is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of FIGS. 60 and 61 with the anvil thereof in the closed position;

FIG. 63 is an enlarged cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIGS. 60-62;

FIG. 64 is a top view of a tool mounting portion embodiment of a surgical tool embodiment of the present invention;

FIG. 65 is a perspective assembly view of another surgical tool embodiment of the present invention;

FIG. 66 is a front perspective view of a disposable loading unit arrangement that may be employed with various surgical tool embodiments of the present invention;

FIG. 67 is a rear perspective view of the disposable loading unit of FIG. 66;

FIG. 68 is a bottom perspective view of the disposable loading unit of FIGS. 66 and 67;

FIG. 69 is a bottom perspective view of another disposable loading unit embodiment that may be employed with various surgical tool embodiments of the present invention;

FIG. 70 is an exploded perspective view of a mounting portion of a disposable loading unit depicted in FIGS. 66-68;

FIG. 71 is a perspective view of a portion of a disposable loading unit and an elongated shaft assembly embodiment of a surgical tool embodiment of the present invention with the disposable loading unit in a first position;

FIG. 72 is another perspective view of a portion of the disposable loading unit and elongated shaft assembly of FIG. 71 with the disposable loading unit in a second position;

FIG. 73 is a cross-sectional view of a portion of the disposable loading unit and elongated shaft assembly embodiment depicted in FIGS. 71 and 72;

FIG. 74 is another cross-sectional view of the disposable loading unit and elongated shaft assembly embodiment depicted in FIGS. 71-73;

FIG. 75 is a partial exploded perspective view of a portion of another disposable loading unit embodiment and an elongated shaft assembly embodiment of a surgical tool embodiment of the present invention;

FIG. 76 is a partial exploded perspective view of a portion of another disposable loading unit embodiment and an elongated shaft assembly embodiment of a surgical tool embodiment of the present invention;

FIG. 77 is another partial exploded perspective view of the disposable loading unit embodiment and an elongated shaft assembly embodiment of FIG. 76;

FIG. 78 is a top view of another tool mounting portion embodiment of a surgical tool embodiment of the present invention;

FIG. 79 is a side view of another surgical tool embodiment of the present invention with some of the components thereof shown in cross-section and in relation to a robotic tool holder of a robotic system;

FIG. 80 is an exploded assembly view of a surgical end effector embodiment that may be used in connection with various surgical tool embodiments of the present invention;

FIG. 81 is a side view of a portion of a cable-driven system for driving a cutting instrument employed in various surgical end effector embodiments of the present invention;

FIG. 82 is a top view of the cable-driven system and cutting instrument of FIG. 81;

FIG. 83 is a top view of a cable drive transmission embodiment of the present invention in a closure position;

FIG. 84 is another top view of the cable drive transmission embodiment of FIG. 83 in a neutral position;

FIG. 85 is another top view of the cable drive transmission embodiment of FIGS. 83 and 84 in a firing position;

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FIG. 86 is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. 83;

FIG. 87 is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. 84;

FIG. 88 is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. 85;

FIG. 89 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 90 is a side view of a portion of another cable-driven system embodiment for driving a cutting instrument employed in various surgical end effector embodiments of the present invention;

FIG. 91 is a top view of the cable-driven system embodiment of FIG. 90;

FIG. 92 is a top view of a tool mounting portion embodiment of another surgical tool embodiment of the present invention;

FIG. 93 is a top cross-sectional view of another surgical tool embodiment of the present invention;

FIG. 94 is a cross-sectional view of a portion of a surgical end effector embodiment of a surgical tool embodiment of the present invention;

FIG. 95 is a cross-sectional end view of the surgical end effector of FIG. 103 taken along line 95-95 in FIG. 94;

FIG. 96 is a perspective view of the surgical end effector of FIGS. 94 and 95 with portions thereof shown in cross-section;

FIG. 97 is a side view of a portion of the surgical end effector of FIGS. 94-96;

FIG. 98 is a perspective view of a sled assembly embodiment of various surgical tool embodiments of the present invention;

FIG. 99 is a cross-sectional view of the sled assembly embodiment of FIG. 98 and a portion of the elongated channel of FIG. 97;

FIGS. 100-105 diagrammatically depict the sequential firing of staples in a surgical tool embodiment of the present invention;

FIG. 106 is a partial perspective view of a portion of a surgical end effector embodiment of the present invention;

FIG. 107 is a partial cross-sectional perspective view of a portion of a surgical end effector embodiment of a surgical tool embodiment of the present invention;

FIG. 108 is another partial cross-sectional perspective view of the surgical end effector embodiment of FIG. 107 with a sled assembly axially advancing therethrough;

FIG. 109 is a perspective view of another sled assembly embodiment of another surgical tool embodiment of the present invention;

FIG. 110 is a partial top view of a portion of the surgical end effector embodiment depicted in FIGS. 107 and 108 with the sled assembly axially advancing therethrough;

FIG. 111 is another partial top view of the surgical end effector embodiment of FIG. 110 with the top surface of the surgical staple cartridge omitted for clarity;

FIG. 112 is a partial cross-sectional side view of a rotary driver embodiment and staple pusher embodiment of the surgical end effector depicted in FIGS. 107 and 108;

FIG. 113 is a perspective view of an automated reloading system embodiment of the present invention with a surgical end effector in extractive engagement with the extraction system thereof;

FIG. 114 is another perspective view of the automated reloading system embodiment depicted in FIG. 113;

FIG. 115 is a cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. 113 and 114;

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FIG. 116 is another cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. 113-115 with the extraction system thereof removing a spent surgical staple cartridge from the surgical end effector;

FIG. 117 is another cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. 113-116 illustrating the loading of a new surgical staple cartridge into a surgical end effector;

FIG. 118 is a perspective view of another automated reloading system embodiment of the present invention with some components shown in cross-section;

FIG. 119 is an exploded perspective view of a portion of the automated reloading system embodiment of FIG. 118;

FIG. 120 is another exploded perspective view of the portion of the automated reloading system embodiment depicted in FIG. 119;

FIG. 121 is a cross-sectional elevational view of the automated reloading system embodiment of FIGS. 118-120;

FIG. 122 is a cross-sectional view of an orientation tube embodiment supporting a disposable loading unit therein;

FIG. 123 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 124 is a partial perspective view of an articulation joint embodiment of a surgical tool embodiment of the present invention;

FIG. 125 is a perspective view of a closure tube embodiment of a surgical tool embodiment of the present invention;

FIG. 126 is a perspective view of the closure tube embodiment of FIG. 125 assembled on the articulation joint embodiment of FIG. 124;

FIG. 127 is a top view of a portion of a tool mounting portion embodiment of a surgical tool embodiment of the present invention;

FIG. 128 is a perspective view of an articulation drive assembly embodiment employed in the tool mounting portion embodiment of FIG. 127;

FIG. 129 is a perspective view of another surgical tool embodiment of the present invention; and

FIG. 130 is a perspective view of another surgical tool embodiment of the present invention.

DETAILED DESCRIPTION

Applicant of the present application also owns the following patent applications that have been filed on May 27, 2011 and which are each herein incorporated by reference in their respective entireties:

U.S. patent application Ser. No. 13/118,259, entitled SURGICAL INSTRUMENT WITH WIRELESS COMMUNICATION BETWEEN A CONTROL UNIT OF A ROBOTIC SYSTEM AND REMOTE SENSOR, U.S. Patent Application Publication No. US 2011-0295270 A1;

U.S. patent application Ser. No. 13/118,194, entitled ROBOTICALLY-CONTROLLED ENDOSCOPIC ACCESSORY CHANNEL, U.S. Patent Application Publication No. US 2011-0295242 A1;

U.S. patent application Ser. No. 13/118,253, entitled ROBOTICALLY-CONTROLLED MOTORIZED SURGICAL INSTRUMENT, U.S. Patent Application Publication No. US 2011-0295269 A1;

U.S. patent application Ser. No. 13/118,278, entitled ROBOTICALLY-CONTROLLED SURGICAL STAPLING DEVICES THAT PRODUCE FORMED STAPLES HAVING DIFFERENT LENGTHS, U.S. Patent Application Publication No. US 2011-0290851 A1;

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U.S. patent application Ser. No. 13/118,190, entitled ROBOTICALLY-CONTROLLED MOTORIZED CUTTING AND FASTENING INSTRUMENT, U.S. Patent Application Publication No. US 2011-0288573 A1;

U.S. patent application Ser. No. 13/118,223, entitled ROBOTICALLY-CONTROLLED SHAFT BASED ROTARY DRIVE SYSTEMS FOR SURGICAL INSTRUMENTS, U.S. Patent Application Publication No. US 2011-0290854 A1;

U.S. patent application Ser. No. 13/118,263, entitled ROBOTICALLY-CONTROLLED SURGICAL INSTRUMENT HAVING RECORDING CAPABILITIES, U.S. Patent Application Publication No. US 2011-0295295 A1;

U.S. patent application Ser. No. 13/118,272, entitled ROBOTICALLY-CONTROLLED SURGICAL INSTRUMENT WITH FORCE FEEDBACK CAPABILITIES, U.S. Patent Application Publication No. US 2011-0290856 A1;

U.S. patent application Ser. No. 13/118,246, entitled ROBOTICALLY-DRIVEN SURGICAL INSTRUMENT WITH E-BEAM DRIVER, U.S. Patent Application Publication No. US 2011-0290853 A1; and

U.S. patent application Ser. No. 13/118,241, entitled SURGICAL STAPLING INSTRUMENTS WITH ROTATABLE STAPLE DEPLOYMENT ARRANGEMENTS, U.S. Patent Application Publication No. US 2012-0298719 A1.

Certain exemplary embodiments will now be described to provide an overall understanding of the principles of the structure, function, manufacture, and use of the devices and methods disclosed herein. One or more examples of these embodiments are illustrated in the accompanying drawings. Those of ordinary skill in the art will understand that the devices and methods specifically described herein and illustrated in the accompanying drawings are non-limiting exemplary embodiments and that the scope of the various embodiments of the present invention is defined solely by the claims. The features illustrated or described in connection with one exemplary embodiment may be combined with the features of other embodiments. Such modifications and variations are intended to be included within the scope of the present invention.

Uses of the phrases “in various embodiments,” “in some embodiments,” “in one embodiment”, or “in an embodiment”, or the like, throughout the specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics of one or more embodiments may be combined in any suitable manner in one or more other embodiments. Such modifications and variations are intended to be included within the scope of the present invention.

Turning to the Drawings, wherein like numerals denote like components throughout the several views, FIG. 1 depicts a disposable loading unit 16 of the present invention that is coupled to a conventional surgical cutting and stapling apparatus 10. The construction and general operation of a cutting and stapling apparatus 10 is described in U.S. Pat. No. 5,865,361, the disclosure of which has been herein incorporated by reference. Thus, the present Detailed Description will not discuss the various components of the apparatus 10 and their operation herein beyond what is necessary to describe the operation of the disposable loading unit 16 of the present invention.

As the present Detailed Description proceeds, it will be appreciated that the terms “proximal” and “distal” are used

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herein with reference to a clinician gripping a handle assembly 12 of the surgical stapling apparatus 10 to which the disposable loading unit 16 is attached. Thus, the disposable loading unit 16 is distal with respect to the more proximal handle assembly 12. It will be further appreciated that, for convenience and clarity, spatial terms such as “vertical”, “horizontal”, “up”, “down”, “right”, and “left” are used herein with respect to the drawings. However, surgical instruments are used in many orientations and positions, and these terms are not intended to be limiting and absolute.

As can be seen in FIG. 1, the disposable loading unit 16 may generally comprise a tool assembly 17 for performing surgical procedures such as cutting tissue and applying staples on each side of the cut. The tool assembly 17 may include a cartridge assembly 18 that includes a staple cartridge 220 that is supported in a carrier 216. An anvil assembly 20 may be pivotally coupled to the carrier 216 in a known manner for selective pivotal travel between open and closed positions. The anvil assembly 20 includes an anvil portion 204 that has a plurality of staple deforming concavities (not shown) formed in the undersurface thereof. The staple cartridge 220 houses a plurality of pushers or drivers (not shown) that each have a staple or staples (not shown) supported thereon. An actuation sled 234 is supported within the tool assembly 17 and is configured to drive the pushers and staples in the staple cartridge 220 in a direction toward the anvil assembly 20 as the actuation sled 234 is driven from the proximal end of the tool assembly 17 to the distal end 220. See FIG. 2.

The disposable loading unit 16 may further include an axial drive assembly 212 that comprises a drive beam 266 that may be constructed from a single sheet of material or, preferably, from multiple stacked sheets. However, the drive beam 266 may be constructed from other suitable material configurations. The distal end of drive beam 266 may include a vertical support strut 271 which supports a knife blade 280 and an abutment surface 283 which engages the central portion of actuation sled 234 during a stapling procedure. Knife blade 280 may be generally positioned to translate slightly behind actuation sled 234 through a central longitudinal slot in staple cartridge 220 to form an incision between rows of stapled body tissue. A retention flange 284 may project distally from vertical strut 271 and support a camming pin or pins 286 at its distal end. Camming pin 286 may be dimensioned and configured to engage camming surface 209 on anvil portion 204 to clamp anvil portion 204 against body tissue. See FIGS. 5 and 7. In addition, a leaf spring (not shown) may be provided between the proximal end of the anvil portion 204 and the distal end portion of the housing 200 to bias the anvil assembly 20 to a normally open position. The carrier 216 may also have an elongated bottom slot therethrough through which a portion of the vertical support strut 271 extends to have a support member 287 attached thereto.

As can also be seen in FIG. 1, the disposable loading unit 16 may also have a housing portion 200 that is adapted to snap onto or otherwise be attached to the carrier 216. The proximal end 500 of housing 200 may include engagement nubs 254 for releasably engaging elongated body 14 of a surgical stapling apparatus. Nubs 254 form a bayonet type coupling with the distal end of the elongated body portion 14 of the surgical stapling apparatus as described in U.S. Pat. No. 5,865,361.

The housing 200 may further include a switch portion 520 that movably houses a battery 526 therein. More specifically and with reference to FIG. 3, the switch portion 520 of the housing 200 defines a battery cavity 522 that movably supports a battery holder 524 that houses a battery 526 therein. As can be seen in FIG. 3, a first battery contact 528 is supported

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in electrical contact with the battery 526 and protrudes out through the battery holder 524 for sliding engagement with the inside wall 523 of the battery cavity 522. Similarly, a second battery contact 530 is mounted in electrical contact with the battery 526 and also protrudes out of the battery holder 524 to slide along the inside wall 523 of the battery cavity 522. The battery holder 524 has a control rod socket 532 therein configured to receive the distal end 276 of control rod 52 when the proximal end of disposable loading unit 16 is coupled to the elongated body 14 of surgical stapling apparatus 10. As can also be seen in FIG. 3, a series of contacts 540, 542, 544 may be oriented within the wall 523 for contact with the battery contacts 530. The purpose of the contacts 540, 542, and 544 will be discussed in further detail below. As can also be seen in FIG. 3, a biasing member or switch spring 550 is positioned within the battery cavity 522 to bias the battery holder 524 in the proximal direction “PD” such that when the disposable reload 16 is not attached to the elongated body 14, the battery holder 524 is biased to its proximal-most position shown in FIG. 3. When retained in that “pre-use” or “disconnected” position by spring 550, the battery contacts 528 and 530 do not contact any of the contacts 540, 542, 544 within the battery cavity 522 to prevent the battery 526 from being drained during non-use.

As can also be seen in FIG. 3, the housing 200 may further have a motor cavity 560 therein that houses a motor 562 and a gear box 564. The gear box 564 has an output shaft 566 that protrudes through a hole 572 in a proximal bulkhead 570 formed in the housing 200. See FIG. 5. The output shaft 566 is keyed onto or otherwise non-rotatably coupled to a thrust disc 580. As can be seen in FIG. 5, the thrust disc 580 is rotatably supported within a thrust disc cavity 582 formed between the proximal bulkhead 570 and a distal bulkhead 590 formed in the housing 200. In addition, the thrust disc 580 is rotatably supported between a proximal thrust bearing 583 and a distal thrust bearing 584 as shown. As can also be seen in FIG. 5, the thrust disc 580 may be formed on a proximal end of a drive screw 600 that threadedly engages a drive nut 610 that is supported within an engagement section 270 formed on the distal end of the drive beam 266. In various embodiments, the engagement section 270 may include a pair of engagement fingers 270a and 270b that are dimensioned and configured to be received within a slot in the drive nut 610 to non-rotatably affix the drive nut 610 to the drive beam 266. Thus, rotation of the drive screw 600 within the drive nut 610 will drive the drive beam 266 in the distal direction “DD” or in the proximal direction “PD” depending upon the direction of rotation of the drive screw 600.

The disposable loading unit 16 may further include a return switch 630 that is mounted in the housing 200 and is adapted to be actuated by the knife nut 610. As can also be seen in FIG. 5, a switch 640 is mounted in the housing 200 and is also oriented to be actuated by the knife nut 610 to indicate when the anvil assembly 20 has been closed. A switch 650 is mounted in the housing 200 and is also adapted to be actuated by the knife nut 610 to indicate that the axial drive assembly 212 has moved to its finished position. The specific operations of switches 630, 640, 650 will be discussed in further detail below.

FIG. 4 illustrates a circuit embodiment 700 of the present invention that illustrates the positions of various components of the disposable loading unit 16 of the present invention when in a “pre-use” condition. For example, the various components of the disposable loading unit 16 may be in this pre-use orientation when the unit 16 is being stored or shipped. As can be seen in that Figure, when in this orientation, the battery contacts 528 and 530 do not contact any of the

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contacts 540, 542, 544 in the housing 200 which prevents the battery 526 from being drained during non-use.

FIGS. 5 and 6 illustrate the positions of various components of the disposable loading unit 16 after it has been coupled to the elongated body 14 of the surgical cutting and stapling instrument 10. In particular, as can be seen in FIG. 5, the distal end 276 of the control rod 52 has been coupled to the battery holder 524. When the control rod 52 is attached to the battery holder 524, the battery holder 524 is moved in the distal direction "DD" against the spring 550 such that the battery contacts 528, 530 are brought into contact with the return contacts 540 in the housing 200. Also, when in that position, the knife nut 610 actuates the return switch 630 into an open orientation. It will be appreciated that the return switch 630 is a normally closed switch that is actuated to the open position by the knife nut 610. As shown in FIG. 6, when the return switch 630 is open, the motor 562 is not powered.

FIGS. 7 and 8 illustrate the positions of various components of the disposable loading unit 16 after the clinician has actuated the movable handle 24 (shown in FIG. 1) of the surgical cutting and stapling instrument 10. As discussed in U.S. Pat. No. 5,865,361, when the movable handle 24 is initially moved toward the stationary handle member 22, the control rod 52 is caused to move in the distal direction "DD". As can be seen in FIG. 7, as the control rod 52 is initially moved in the distal direction during the anvil close stroke, the battery holder 524 moves the battery 526 to a position wherein the battery contacts 528, 530 contact the anvil close contacts 542. Power is now permitted to flow from the battery 526 to the motor 562 which rotates the drive screw 600 and causes the drive beam 266 to move distally. As the drive beam 266 moves distally in the "DD" direction, the camming pin 286 engages cam portion 209 of anvil portion 204 and causes the anvil assembly 20 to pivot to a closed position as illustrated in FIG. 7. As the drive beam 266 moves distally to the anvil closed position, the knife nut 610 moves out of contact with the return switch 630 which permits the return switch to resume its normally open position. The knife nut 610 then actuates the anvil closed switch 640 and moves it to an open position. See FIG. 8. In various embodiments one or more anvil closed lights 660 may be mounted in the housing 200 for providing a visual indication to the clinician that the anvil assembly 20 has been moved to the closed position.

When the clinician desires to fire the instrument 10 (i.e., actuate the instrument 10 to cause it to cut and staple tissue), the clinician first depresses the plunger 82 of the firing lock-out assembly 80 (FIG. 1) as discussed in U.S. Pat. No. 5,865,361. Thereafter, movable handle 24 may be actuated. As the movable handle 24 is depressed, the control rod 52 moves the battery holder 524 and battery 526 to the position illustrated in FIGS. 9 and 10. As can be seen in those Figures, when the battery 526 is moved into that position, the battery contacts 528, 530 are brought into contact with the fire contacts 544. The switch 650 is normally closed until it is actuated by the knife nut 610. Thus, when the battery contacts 528, 530 contact the firing contacts 544, power flows from the battery 526 to the motor 562 which drives the drive screw 600. As the drive screw 600 is rotated, the drive beam 266 and knife nut 610 are driven in the distal direction "DD" to advance actuation sled 234 through staple cartridge 220 to effect ejection of staples and cutting of tissue. Once the drive beam 266 reaches the end of the firing stroke (i.e., all of the staples in the staple cartridge 220 have been fired), knife nut 610 is positioned to actuate the normally closed switch 650 and move it to an open position (illustrated in FIG. 10) which stops the flow of power from the battery 526 to the motor 562. In various embodiments, a distal indication light or lights 670 may be mounted

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on the housing 200 to provide an indication to the clinician that the drive beam 266 has reached its distal-most fired position.

To retract the drive beam 266, the clinician grasps the retract knobs 32 (shown in FIG. 1) on the handle assembly 12 and pulls them in the proximal direction "PD". The operation and construction of the retract knobs 32 is discussed in U.S. Pat. No. 5,865,361. Once the clinician moves the drive beam 266 a sufficient distance in the proximal direction "PD" so as to move the battery to contacts 540 (FIG. 11), power will be supplied through switch 630 to reverse the motor 562. Knife nut then releases switch 650. The motor 562 then drives the drive beam 266 distal to switch 630, which opens. The return switch 630 is also in its normally closed position thereby permitting power to flow to the motor 562 and rotate the drive screw 610 in an opposite direction to drive the drive beam 266 in the proximal direction "PD". Once the knife nut 610 actuates the knife return switch 630, the knife return switch 630 is moved to an open position thereby stopping flow of power from the battery 526 to the motor 562. In various embodiments, a starting light 700 may be mounted in the housing 200 to provide an indication that the drive beam 266 is in the starting position.

FIGS. 11 and 12 illustrate the positions of various components of the disposable loading unit 16 of the present invention when the distal end of the drive beam 266 and blade 280 inadvertently becomes jammed during the firing stroke (i.e., when the blade 280 is being distally advanced through the tissue clamped in the tool assembly 17). To address such occurrence, a current limiter 680 may be provided as shown in FIG. 12. The current limiter 680 serves to turn off the motor 562 when the amount of current that it is drawing exceeds a predetermined threshold. It will be understood that the amount of current that the motor 562 draws during a jam would increase over the amount of current drawn during normal firing operations. Once the current limiter 680 shuts down the motor 562, the clinician can retract the drive beam 266 by grasping the retract knobs 32 (shown in FIG. 1) on the handle assembly 12 and pulling them in the proximal direction "PD" and the motor 562 will drive the drive screw 600 in reverse in the manner described above. Thus, the current limiter 680 serves to stop the motor 562 when the axial drive assembly 212 encounters resistance that exceeds a predetermined amount of resistance which is associated with the predetermined maximum amount of current that the motor 562 should draw under normal operating circumstances. This feature also saves the battery power so the drive beam 266 can be retracted.

Thus, the disposable loading unit 16 of the present invention comprises a self-contained motor driven disposable loading unit that may be used in connection with conventional surgical cutting and stapling instruments that traditionally required the clinician to manually advance and retract the drive assembly and cutting blade of a disposable loading unit coupled thereto. Various embodiments of the disposable loading unit 16 may be constructed to facilitate the automatic retraction of the axial drive assembly should the blade encounter a predetermined amount of resistance.

While several embodiments of the invention have been described, it should be apparent, however, that various modifications, alterations and adaptations to those embodiments may occur to persons skilled in the art with the attainment of some or all of the advantages of the invention. For example, according to various embodiments, a single component may be replaced by multiple components, and multiple components may be replaced by a single component, to perform a given function or functions. This application is therefore

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intended to cover all such modifications, alterations and adaptations without departing from the scope and spirit of the disclosed invention as defined by the appended claims.

Any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated materials does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

The invention which is intended to be protected is not to be construed as limited to the particular embodiments disclosed. The embodiments are therefore to be regarded as illustrative rather than restrictive. Variations and changes may be made by others without departing from the spirit of the present invention. Accordingly, it is expressly intended that all such equivalents, variations and changes which fall within the spirit and scope of the present invention as defined in the claims be embraced thereby.

Over the years a variety of minimally invasive robotic (or “telesurgical”) systems have been developed to increase surgical dexterity as well as to permit a surgeon to operate on a patient in an intuitive manner. Many of such systems are disclosed in the following U.S. patents which are each herein incorporated by reference in their respective entirety: U.S. Pat. No. 5,792,135, entitled ARTICULATED SURGICAL INSTRUMENT FOR PERFORMING MINIMALLY INVASIVE SURGERY WITH ENHANCED DEXTERITY AND SENSITIVITY, which issued Aug. 11, 1998; U.S. Pat. No. 6,231,565, entitled ROBOTIC ARM DLUS FOR PERFORMING SURGICAL TASKS, which issued May 15, 2001; U.S. Pat. No. 6,783,524, entitled ROBOTIC SURGICAL TOOL WITH ULTRASOUND CAUTERIZING AND CUTTING INSTRUMENT, which issued on Aug. 31, 2004; U.S. Pat. No. 6,364,888, entitled ALIGNMENT OF MASTER AND SLAVE IN A MINIMALLY INVASIVE SURGICAL APPARATUS, which issued on Apr. 2, 2002; U.S. Pat. No. 7,524,320, entitled MECHANICAL ACTUATOR INTERFACE SYSTEM FOR ROBOTIC SURGICAL TOOLS, which issued on Apr. 28, 2009; U.S. Pat. No. 7,691,098, entitled PLATFORM LINK WRIST MECHANISM, which issued on Apr. 6, 2010; U.S. Pat. No. 7,806,891, entitled REPOSITIONING AND REORIENTATION OF MASTER/SLAVE RELATIONSHIP IN MINIMALLY INVASIVE TELESURGERY, which issued on Oct. 5, 2010; and U.S. Pat. No. 7,824,401, entitled SURGICAL TOOL WITH WRITED MONOPOLAR ELECTROSURGICAL END EFFECTORS, which issued on Nov. 2, 2010. Many of such systems, however, have in the past been unable to generate the magnitude of forces required to effectively cut and fasten tissue.

FIG. 13 depicts one version of a master controller **1001** that may be used in connection with a robotic arm slave cart **1100** of the type depicted in FIG. 14. Master controller **1001** and robotic arm slave cart **1100**, as well as their respective components and control systems are collectively referred to herein as a robotic system **1000**. Examples of such systems and devices are disclosed in U.S. Pat. No. 7,524,320 which has been herein incorporated by reference. Thus, various details of such devices will not be described in detail herein beyond that which may be necessary to understand various

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embodiments and forms of the present invention. As is known, the master controller **1001** generally includes master controllers (generally represented as **1003** in FIG. 13) which are grasped by the surgeon and manipulated in space while the surgeon views the procedure via a stereo display **1002**. The master controllers **1001** generally comprise manual input devices which preferably move with multiple degrees of freedom, and which often further have an actuable handle for actuating tools (for example, for closing grasping saws, applying an electrical potential to an electrode, or the like).

As can be seen in FIG. 14, in one form, the robotic arm cart **1100** is configured to actuate a plurality of surgical tools, generally designated as **1200**. Various robotic surgery systems and methods employing master controller and robotic arm cart arrangements are disclosed in U.S. Pat. No. 6,132,368, entitled MULTI-COMPONENT TELEPRESENCE SYSTEM AND METHOD, which issued on Oct. 17, 2000, the full disclosure of which is incorporated herein by reference. In various forms, the robotic arm cart **1100** includes a base **1002** from which, in the illustrated embodiment, three surgical tools **1200** are supported. In various forms, the surgical tools **1200** are each supported by a series of manually articulatable linkages, generally referred to as set-up joints **1104**, and a robotic manipulator **1106**. These structures are herein illustrated with protective covers extending over much of the robotic linkage. These protective covers may be optional, and may be limited in size or entirely eliminated in some embodiments to minimize the inertia that is encountered by the servo mechanisms used to manipulate such devices, to limit the volume of moving components so as to avoid collisions, and to limit the overall weight of the cart **1100**. Cart **1100** will generally have dimensions suitable for transporting the cart **1100** between operating rooms. The cart **1100** may be configured to typically fit through standard operating room doors and onto standard hospital elevators. In various forms, the cart **1100** would preferably have a weight and include a wheel (or other transportation) system that allows the cart **1100** to be positioned adjacent an operating table by a single attendant.

Referring now to FIG. 15, in at least one form, robotic manipulators **1106** may include a linkage **1108** that constrains movement of the surgical tool **1200**. In various embodiments, linkage **1108** includes rigid links coupled together by rotational joints in a parallelogram arrangement so that the surgical tool **1200** rotates around a point in space **1110**, as more fully described in issued U.S. Pat. No. 5,817,084, entitled REMOTE CENTER POSITIONING DEVICE WITH FLEXIBLE DRIVE, which issued on Oct. 6, 1998, the full disclosure of which is herein incorporated by reference. The parallelogram arrangement constrains rotation to pivoting about an axis **1112a**, sometimes called the pitch axis. The links supporting the parallelogram linkage are pivotally mounted to set-up joints **1104** (FIG. 14) so that the surgical tool **1200** further rotates about an axis **1112b**, sometimes called the yaw axis. The pitch and yaw axes **1112a**, **1112b** intersect at the remote center **1114**, which is aligned along a shaft **1208** of the surgical tool **1200**. The surgical tool **1200** may have further degrees of driven freedom as supported by manipulator **1106**, including sliding motion of the surgical tool **1200** along the longitudinal tool axis “LT-LT”. As the surgical tool **1200** slides along the tool axis LT-LT relative to manipulator **1106** (arrow **1112c**), remote center **1114** remains fixed relative to base **1116** of manipulator **1106**. Hence, the entire manipulator is generally moved to re-position remote center **1114**. Linkage **1108** of manipulator **1106** is driven by a series of motors **1120**. These motors actively move linkage **1108** in response to commands from a processor of a control

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system. As will be discussed in further detail below, motors **1120** are also employed to manipulate the surgical tool **1200**.

An alternative set-up joint structure is illustrated in FIG. **16**. In this embodiment, a surgical tool **1200** is supported by an alternative manipulator structure **1106'** between two tissue manipulation tools. Those of ordinary skill in the art will appreciate that various embodiments of the present invention may incorporate a wide variety of alternative robotic structures, including those described in U.S. Pat. No. 5,878,193, entitled AUTOMATED ENDOSCOPE SYSTEM FOR OPTIMAL POSITIONING, which issued on Mar. 2, 1999, the full disclosure of which is incorporated herein by reference. Additionally, while the data communication between a robotic component and the processor of the robotic surgical system is primarily described herein with reference to communication between the surgical tool **1200** and the master controller **1001**, it should be understood that similar communication may take place between circuitry of a manipulator, a set-up joint, an endoscope or other image capture device, or the like, and the processor of the robotic surgical system for component compatibility verification, component-type identification, component calibration (such as off-set or the like) communication, confirmation of coupling of the component to the robotic surgical system, or the like.

An exemplary non-limiting surgical tool **1200** that is well-adapted for use with a robotic system **1000** that has a tool drive assembly **1010** (FIG. **18**) that is operatively coupled to a master controller **1001** that is operable by inputs from an operator (i.e., a surgeon) is depicted in FIG. **17**. As can be seen in that Figure, the surgical tool **1200** includes a surgical end effector **2012** that comprises an endocutter. In at least one form, the surgical tool **1200** generally includes an elongated shaft assembly **2008** that has a proximal closure tube **2040** and a distal closure tube **2042** that are coupled together by an articulation joint **2011**. The surgical tool **1200** is operably coupled to the manipulator by a tool mounting portion, generally designated as **1300**. The surgical tool **1200** further includes an interface **1230** which mechanically and electrically couples the tool mounting portion **1300** to the manipulator. One form of interface **1230** is illustrated in FIGS. **16-22**. In various embodiments, the tool mounting portion **1300** includes a tool mounting plate **1302** that operably supports a plurality of (four are shown in FIG. **22**) rotatable body portions, driven discs or elements **1304**, that each include a pair of pins **1306** that extend from a surface of the driven element **1304**. One pin **1306** is closer to an axis of rotation of each driven element **1304** than the other pin **1306** on the same driven element **1304**, which helps to ensure positive angular alignment of the driven element **1304**. Interface **1230** includes an adaptor portion **1240** that is configured to mountingly engage the mounting plate **1302** as will be further discussed below. The adaptor portion **1240** may include an array of electrical connecting pins **1242** (FIG. **20**) which may be coupled to a memory structure by a circuit board within the tool mounting portion **1300**. While interface **1230** is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

As can be seen in FIGS. **18-21**, the adapter portion **1240** generally includes a tool side **1244** and a holder side **1246**. In various forms, a plurality of rotatable bodies **1250** are mounted to a floating plate **1248** which has a limited range of movement relative to the surrounding adaptor structure normal to the major surfaces of the adaptor **1240**. Axial movement of the floating plate **1248** helps decouple the rotatable bodies **1250** from the tool mounting portion **1300** when the

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levers **1303** along the sides of the tool mounting portion housing **1301** are actuated (See FIG. **17**). Other mechanisms/arrangements may be employed for releasably coupling the tool mounting portion **1300** to the adaptor **1240**. In at least one form, rotatable bodies **1250** are resiliently mounted to floating plate **1248** by resilient radial members which extend into a circumferential indentation about the rotatable bodies **1250**. The rotatable bodies **1250** can move axially relative to plate **1248** by deflection of these resilient structures. When disposed in a first axial position (toward tool side **1244**) the rotatable bodies **1250** are free to rotate without angular limitation. However, as the rotatable bodies **1250** move axially toward tool side **1244**, tabs **1252** (extending radially from the rotatable bodies **1250**) laterally engage detents on the floating plates so as to limit angular rotation of the rotatable bodies **1250** about their axes. This limited rotation can be used to help drivingly engage the rotatable bodies **1250** with drive pins **1272** of a corresponding tool holder portion **1270** of the robotic system **1000**, as the drive pins **1272** will push the rotatable bodies **1250** into the limited rotation position until the pins **1234** are aligned with (and slide into) openings **1256'**. Openings **1256** on the tool side **1244** and openings **1256'** on the holder side **1246** of rotatable bodies **1250** are configured to accurately align the driven elements **1304** (FIG. **22**) of the tool mounting portion **1300** with the drive elements **1271** of the tool holder **1270**. As described above regarding inner and outer pins **1306** of driven elements **1304**, the openings **1256**, **1256'** are at differing distances from the axis of rotation on their respective rotatable bodies **1250** so as to ensure that the alignment is not 180 degrees from its intended position. Additionally, each of the openings **1256** is slightly radially elongated so as to fittingly receive the pins **1306** in the circumferential orientation. This allows the pins **1306** to slide radially within the openings **1256**, **1256'** and accommodate some axial misalignment between the tool **1200** and tool holder **1270**, while minimizing any angular misalignment and backlash between the drive and driven elements. Openings **1256** on the tool side **1244** are offset by about 90 degrees from the openings **1256'** (shown in broken lines) on the holder side **1246**, as can be seen most clearly in FIG. **21**.

Various embodiments may further include an array of electrical connector pins **1242** located on holder side **1246** of adaptor **1240**, and the tool side **1244** of the adaptor **1240** may include slots **1258** (FIG. **21**) for receiving a pin array (not shown) from the tool mounting portion **1300**. In addition to transmitting electrical signals between the surgical tool **1200** and the tool holder **1270**, at least some of these electrical connections may be coupled to an adaptor memory device **1260** (FIG. **20**) by a circuit board of the adaptor **1240**.

A detachable latch arrangement **1239** may be employed to releasably affix the adaptor **1240** to the tool holder **1270**. As used herein, the term "tool drive assembly" when used in the context of the robotic system **1000**, at least encompasses various embodiments of the adapter **1240** and tool holder **1270** and which has been generally designated as **1010** in FIG. **18**. For example, as can be seen in FIG. **18**, the tool holder **1270** may include a first latch pin arrangement **1274** that is sized to be received in corresponding clevis slots **1241** provided in the adaptor **1240**. In addition, the tool holder **1270** may further have second latch pins **1276** that are sized to be retained in corresponding latch clevises **1243** in the adaptor **1240**. See FIG. **20**. In at least one form, a latch assembly **1245** is movably supported on the adapter **1240** and is biasable between a first latched position wherein the latch pins **1276** are retained within their respective latch clevis **1243** and an unlatched position wherein the second latch pins **1276** may be into or removed from the latch clevises **1243**. A spring or

springs (not shown) are employed to bias the latch assembly into the latched position. A lip on the tool side **1244** of adaptor **1240** may slidably receive laterally extending tabs of tool mounting housing **1301**.

Turning next to FIGS. **22-29**, in at least one embodiment, the surgical tool **1200** includes a surgical end effector **2012** that comprises in this example, among other things, at least one component **2024** that is selectively movable between first and second positions relative to at least one other component **2022** in response to various control motions applied thereto as will be discussed in further detail below. In various embodiments, component **2022** comprises an elongated channel **2022** configured to operably support a surgical staple cartridge **2034** therein and component **2024** comprises a pivotally translatable clamping member, such as an anvil **2024**. Various embodiments of the surgical end effector **2012** are configured to maintain the anvil **2024** and elongated channel **2022** at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector **2012**. As can be seen in FIG. **28**, the surgical end effector **2012** further includes a cutting instrument **2032** and a sled **2033**. The cutting instrument **2032** may be, for example, a knife. The surgical staple cartridge **2034** operably houses a plurality of surgical staples (not shown) therein that are supported on movable staple drivers (not shown). As the cutting instrument **2032** is driven distally through a centrally-disposed slot (not shown) in the surgical staple cartridge **2034**, it forces the sled **2033** distally as well. As the sled **2033** is driven distally, its “wedge-shaped” configuration contacts the movable staple drivers and drives them vertically toward the closed anvil **2024**. The surgical staples are formed as they are driven into the forming surface located on the underside of the anvil **2024**. The sled **2033** may be part of the surgical staple cartridge **2034**, such that when the cutting instrument **2032** is retracted following the cutting operation, the sled **2033** does not retract. The anvil **2024** may be pivotably opened and closed at a pivot point **2025** located at the proximal end of the elongated channel **2022**. The anvil **2024** may also include a tab **2027** at its proximal end that interacts with a component of the mechanical closure system (described further below) to facilitate the opening of the anvil **2024**. The elongated channel **2022** and the anvil **2024** may be made of an electrically conductive material (such as metal) so that they may serve as part of an antenna that communicates with sensor(s) in the end effector, as described above. The surgical staple cartridge **2034** could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge **2034**, as was also described above.

As can be seen in FIGS. **22-29**, the surgical end effector **2012** is attached to the tool mounting portion **1300** by an elongated shaft assembly **2008** according to various embodiments. As shown in the illustrated embodiment, the shaft assembly **2008** includes an articulation joint generally indicated as **2011** that enables the surgical end effector **2012** to be selectively articulated about an articulation axis AA-AA that is substantially transverse to a longitudinal tool axis LT-LT. See FIG. **23**. In other embodiments, the articulation joint is omitted. In various embodiments, the shaft assembly **2008** may include a closure tube assembly **2009** that comprises a proximal closure tube **2040** and a distal closure tube **2042** that are pivotably linked by a pivot links **2044** and operably supported on a spine assembly generally depicted as **2049**. In the illustrated embodiment, the spine assembly **2049** comprises a distal spine portion **2050** that is attached to the elongated channel **2022** and is pivotally coupled to the proximal spine portion **2052**. The closure tube assembly **2009** is configured to axially slide on the spine assembly **2049** in response to

actuation motions applied thereto. The distal closure tube **2042** includes an opening **2045** into which the tab **2027** on the anvil **2024** is inserted in order to facilitate opening of the anvil **2024** as the distal closure tube **2042** is moved axially in the proximal direction “PD”. The closure tubes **2040**, **2042** may be made of electrically conductive material (such as metal) so that they may serve as part of the antenna, as described above. Components of the main drive shaft assembly (e.g., the drive shafts **2048**, **2050**) may be made of a nonconductive material (such as plastic).

In use, it may be desirable to rotate the surgical end effector **2012** about the longitudinal tool axis LT-LT. In at least one embodiment, the tool mounting portion **1300** includes a rotational transmission assembly **2069** that is configured to receive a corresponding rotary output motion from the tool drive assembly **1010** of the robotic system **1000** and convert that rotary output motion to a rotary control motion for rotating the elongated shaft assembly **2008** (and surgical end effector **2012**) about the longitudinal tool axis LT-LT. In various embodiments, for example, the proximal end **2060** of the proximal closure tube **2040** is rotatably supported on the tool mounting plate **1302** of the tool mounting portion **1300** by a forward support cradle **1309** and a closure sled **2100** that is also movably supported on the tool mounting plate **1302**. In at least one form, the rotational transmission assembly **2069** includes a tube gear segment **2062** that is formed on (or attached to) the proximal end **2060** of the proximal closure tube **2040** for operable engagement by a rotational gear assembly **2070** that is operably supported on the tool mounting plate **1302**. As can be seen in FIG. **25**, the rotational gear assembly **2070**, in at least one embodiment, comprises a rotation drive gear **2072** that is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **1302** when the tool mounting portion **1300** is coupled to the tool drive assembly **1010**. See FIG. **22**. The rotational gear assembly **2070** further comprises a rotary driven gear **2074** that is rotatably supported on the tool mounting plate **1302** in meshing engagement with the tube gear segment **2062** and the rotation drive gear **2072**. Application of a first rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **2072**. Rotation of the rotation drive gear **2072** ultimately results in the rotation of the elongated shaft assembly **2008** (and the surgical end effector **2012**) about the longitudinal tool axis LT-LT (represented by arrow “R” in FIG. **25**). It will be appreciated that the application of a rotary output motion from the tool drive assembly **1010** in one direction will result in the rotation of the elongated shaft assembly **2008** and surgical end effector **2012** about the longitudinal tool axis LT-LT in a first direction and an application of the rotary output motion in an opposite direction will result in the rotation of the elongated shaft assembly **2008** and surgical end effector **2012** in a second direction that is opposite to the first direction.

In at least one embodiment, the closure of the anvil **2024** relative to the staple cartridge **2034** is accomplished by axially moving the closure tube assembly **2009** in the distal direction “DD” on the spine assembly **2049**. As indicated above, in various embodiments, the proximal end **2060** of the proximal closure tube **2040** is supported by the closure sled **2100** which comprises a portion of a closure transmission, generally depicted as **2099**. In at least one form, the closure sled **2100** is configured to support the closure tube **2009** on the tool mounting plate **1320** such that the proximal closure tube **2040** can rotate relative to the closure sled **2100**, yet travel axially with the closure sled **2100**. In particular, as can

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be seen in FIG. 30, the closure sled 2100 has an upstanding tab 2101 that extends into a radial groove 2063 in the proximal end portion of the proximal closure tube 2040. In addition, as can be seen in FIGS. 27 and 30, the closure sled 2100 has a tab portion 2102 that extends through a slot 1305 in the tool mounting plate 1302. The tab portion 2102 is configured to retain the closure sled 2100 in sliding engagement with the tool mounting plate 1302. In various embodiments, the closure sled 2100 has an upstanding portion 2104 that has a closure rack gear 2106 formed thereon. The closure rack gear 2106 is configured for driving engagement with a closure gear assembly 2110. See FIG. 27.

In various forms, the closure gear assembly 2110 includes a closure spur gear 2112 that is coupled to a corresponding second one of the driven discs or elements 1304 on the adapter side 1307 of the tool mounting plate 1302. See FIG. 22. Thus, application of a second rotary output motion from the tool drive assembly 1010 of the robotic system 1000 to the corresponding second driven element 1304 will cause rotation of the closure spur gear 2112 when the tool mounting portion 1300 is coupled to the tool drive assembly 1010. The closure gear assembly 2110 further includes a closure reduction gear set 2114 that is supported in meshing engagement with the closure spur gear 2112. As can be seen in FIGS. 26 and 27, the closure reduction gear set 2114 includes a driven gear 2116 that is rotatably supported in meshing engagement with the closure spur gear 2112. The closure reduction gear set 2114 further includes a first closure drive gear 2118 that is in meshing engagement with a second closure drive gear 2120 that is rotatably supported on the tool mounting plate 1302 in meshing engagement with the closure rack gear 2106. Thus, application of a second rotary output motion from the tool drive assembly 1010 of the robotic system 1000 to the corresponding second driven element 1304 will cause rotation of the closure spur gear 2112 and the closure transmission 2110 and ultimately drive the closure sled 2100 and closure tube assembly 2009 axially. The axial direction in which the closure tube assembly 2009 moves ultimately depends upon the direction in which the second driven element 1304 is rotated. For example, in response to one rotary output motion received from the tool drive assembly 1010 of the robotic system 1000, the closure sled 2100 will be driven in the distal direction "DD" and ultimately drive the closure tube assembly 1009 in the distal direction. As the distal closure tube 2042 is driven distally, the end of the closure tube segment 2042 will engage a portion of the anvil 2024 and cause the anvil 2024 to pivot to a closed position. Upon application of an "opening" output motion from the tool drive assembly 1010 of the robotic system 1000, the closure sled 2100 and shaft assembly 2008 will be driven in the proximal direction "PD". As the distal closure tube 2042 is driven in the proximal direction, the opening 2045 therein interacts with the tab 2027 on the anvil 2024 to facilitate the opening thereof. In various embodiments, a spring (not shown) may be employed to bias the anvil to the open position when the distal closure tube 2042 has been moved to its starting position. In various embodiments, the various gears of the closure gear assembly 2110 are sized to generate the necessary closure forces needed to satisfactorily close the anvil 2024 onto the tissue to be cut and stapled by the surgical end effector 2012. For example, the gears of the closure transmission 2110 may be sized to generate approximately 70-120 pounds.

In various embodiments, the cutting instrument 2032 is driven through the surgical end effector 2012 by a knife bar 2200. See FIGS. 28 and 30. In at least one form, the knife bar 2200 may be fabricated from, for example, stainless steel or other similar material and has a substantially rectangular

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cross-sectional shape. Such knife bar configuration is sufficiently rigid to push the cutting instrument 2032 through tissue clamped in the surgical end effector 2012, while still being flexible enough to enable the surgical end effector 2012 to articulate relative to the proximal closure tube 2040 and the proximal spine portion 2052 about the articulation axis AA-AA as will be discussed in further detail below. As can be seen in FIGS. 31 and 32, the proximal spine portion 2052 has a rectangular-shaped passage 2054 extending therethrough to provide support to the knife bar 2200 as it is axially pushed therethrough. The proximal spine portion 2052 has a proximal end 2056 that is rotatably mounted to a spine mounting bracket 2057 attached to the tool mounting plate 1032. See FIG. 30. Such arrangement permits the proximal spine portion 2052 to rotate, but not move axially, within the proximal closure tube 2040.

As shown in FIG. 28, the distal end 2202 of the knife bar 2200 is attached to the cutting instrument 2032. The proximal end 2204 of the knife bar 2200 is rotatably affixed to a knife rack gear 2206 such that the knife bar 2200 is free to rotate relative to the knife rack gear 2206. See FIG. 39. As can be seen in FIGS. 24-29, the knife rack gear 2206 is slidably supported within a rack housing 2210 that is attached to the tool mounting plate 1302 such that the knife rack gear 2206 is retained in meshing engagement with a knife gear assembly 2220. More specifically and with reference to FIG. 27, in at least one embodiment, the knife gear assembly 2220 includes a knife spur gear 2222 that is coupled to a corresponding third one of the driven discs or elements 1304 on the adapter side 1307 of the tool mounting plate 1302. See FIG. 22. Thus, application of another rotary output motion from the robotic system 1000 through the tool drive assembly 1010 to the corresponding third driven element 1304 will cause rotation of the knife spur gear 2222. The knife gear assembly 2220 further includes a knife gear reduction set 2224 that includes a first knife driven gear 2226 and a second knife drive gear 2228. The knife gear reduction set 2224 is rotatably mounted to the tool mounting plate 1302 such that the first knife driven gear 2226 is in meshing engagement with the knife spur gear 2222. Likewise, the second knife drive gear 2228 is in meshing engagement with a third knife drive gear 2230 that is rotatably supported on the tool mounting plate 1302 in meshing engagement with the knife rack gear 2206. In various embodiments, the gears of the knife gear assembly 2220 are sized to generate the forces needed to drive the cutting element 2032 through the tissue clamped in the surgical end effector 2012 and actuate the staples therein. For example, the gears of the knife drive assembly 2230 may be sized to generate approximately 40 to 100 pounds. It will be appreciated that the application of a rotary output motion from the tool drive assembly 1010 in one direction will result in the axial movement of the cutting instrument 2032 in a distal direction and application of the rotary output motion in an opposite direction will result in the axial travel of the cutting instrument 2032 in a proximal direction.

In various embodiments, the surgical tool 1200 employs and articulation system 2007 that includes an articulation joint 2011 that enables the surgical end effector 2012 to be articulated about an articulation axis AA-AA that is substantially transverse to the longitudinal tool axis LT-LT. In at least one embodiment, the surgical tool 1200 includes first and second articulation bars 2250a, 2250b that are slidably supported within corresponding passages 2053 provided through the proximal spine portion 2052. See FIGS. 30 and 32. In at least one form, the first and second articulation bars 2250a, 2250b are actuated by an articulation transmission generally designated as 2249 that is operably supported on the tool

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mounting plate 1032. Each of the articulation bars 2250a, 2250b has a proximal end 2252 that has a guide rod protruding therefrom which extend laterally through a corresponding slot in the proximal end portion of the proximal spine portion 2052 and into a corresponding arcuate slot in an articulation nut 2260 which comprises a portion of the articulation transmission. FIG. 40 illustrates articulation bar 2250a. It will be understood that articulation bar 2250b is similarly constructed. As can be seen in FIG. 31, for example, the articulation bar 2250a has a guide rod 2254 which extends laterally through a corresponding slot 2058 in the proximal end portion 2056 of the distal spine portion 2050 and into a corresponding arcuate slot 2262 in the articulation nut 2260. In addition, the articulation bar 2250a has a distal end 2251a that is pivotally coupled to the distal spine portion 2050 by, for example, a pin 2253a and articulation bar 2250b has a distal end 2251b that is pivotally coupled to the distal spine portion 2050 by, for example, a pin 2253b. In particular, the articulation bar 2250a is laterally offset in a first lateral direction from the longitudinal tool axis LT-LT and the articulation bar 2250b is laterally offset in a second lateral direction from the longitudinal tool axis LT-LT. Thus, axial movement of the articulation bars 2250a and 2250b in opposing directions will result in the articulation of the distal spine portion 2050 as well as the surgical end effector 2012 attached thereto about the articulation axis AA-AA as will be discussed in further detail below.

Articulation of the surgical end effector 2012 is controlled by rotating the articulation nut 2260 about the longitudinal tool axis LT-LT. The articulation nut 2260 is rotatably journaled on the proximal end portion 2056 of the distal spine portion 2050 and is rotatably driven thereon by an articulation gear assembly 2270. More specifically and with reference to FIG. 25, in at least one embodiment, the articulation gear assembly 2270 includes an articulation spur gear 2272 that is coupled to a corresponding fourth one of the driven discs or elements 1304 on the adapter side 1307 of the tool mounting plate 1302. See FIG. 22. Thus, application of another rotary input motion from the robotic system 1000 through the tool drive assembly 1010 to the corresponding fourth driven element 1304 will cause rotation of the articulation spur gear 2272 when the interface 1230 is coupled to the tool holder 1270. An articulation drive gear 2274 is rotatably supported on the tool mounting plate 1302 in meshing engagement with the articulation spur gear 2272 and a gear portion 2264 of the articulation nut 2260 as shown. As can be seen in FIGS. 30 and 31, the articulation nut 2260 has a shoulder 2266 formed thereon that defines an annular groove 2267 for receiving retaining posts 2268 therein. Retaining posts 2268 are attached to the tool mounting plate 1302 and serve to prevent the articulation nut 2260 from moving axially on the proximal spine portion 2052 while maintaining the ability to be rotated relative thereto. Thus, rotation of the articulation nut 2260 in a first direction, will result in the axial movement of the articulation bar 2250a in a distal direction "DD" and the axial movement of the articulation bar 2250b in a proximal direction "PD" because of the interaction of the guide rods 2254 with the spiral slots 2262 in the articulation gear 2260. Similarly, rotation of the articulation nut 2260 in a second direction that is opposite to the first direction will result in the axial movement of the articulation bar 2250a in the proximal direction "PD" as well as cause articulation bar 2250b to axially move in the distal direction "DD". Thus, the surgical end effector 2012 may be selectively articulated about articulation axis "AA-AA" in a first direction "FD" by simultaneously moving the articulation bar 2250a in the distal direction "DD" and the articulation bar 2250b in the proximal

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direction "PD". Likewise, the surgical end effector 2012 may be selectively articulated about the articulation axis "AA-AA" in a second direction "SD" by simultaneously moving the articulation bar 2250a in the proximal direction "PD" and the articulation bar 2250b in the distal direction "DD." See FIG. 23.

The tool embodiment described above employs an interface arrangement that is particularly well-suited for mounting the robotically controllable medical tool onto at least one form of robotic arm arrangement that generates at least four different rotary control motions. Those of ordinary skill in the art will appreciate that such rotary output motions may be selectively controlled through the programmable control systems employed by the robotic system/controller. For example, the tool arrangement described above may be well-suited for use with those robotic systems manufactured by Intuitive Surgical, Inc. of Sunnyvale, Calif., U.S.A., many of which may be described in detail in various patents incorporated herein by reference. The unique and novel aspects of various embodiments of the present invention serve to utilize the rotary output motions supplied by the robotic system to generate specific control motions having sufficient magnitudes that enable end effectors to cut and staple tissue. Thus, the unique arrangements and principles of various embodiments of the present invention may enable a variety of different forms of the tool systems disclosed and claimed herein to be effectively employed in connection with other types and forms of robotic systems that supply programmed rotary or other output motions. In addition, as will become further apparent as the present Detailed Description proceeds, various end effector embodiments of the present invention that require other forms of actuation motions may also be effectively actuated utilizing one or more of the control motions generated by the robotic system.

FIGS. 34-38 illustrate yet another surgical tool 2300 that may be effectively employed in connection with the robotic system 1000 that has a tool drive assembly that is operably coupled to a controller of the robotic system that is operable by inputs from an operator and which is configured to provide at least one rotary output motion to at least one rotatable body portion supported on the tool drive assembly. In various forms, the surgical tool 2300 includes a surgical end effector 2312 that includes an elongated channel 2322 and a pivotally translatable clamping member, such as an anvil 2324, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 2312. As shown in the illustrated embodiment, the surgical end effector 2312 may include, in addition to the previously-mentioned elongated channel 2322 and anvil 2324, a cutting instrument 2332 that has a sled portion 2333 formed thereon, a surgical staple cartridge 2334 that is seated in the elongated channel 2322, and a rotary end effector drive shaft 2336 that has a helical screw thread formed thereon. The cutting instrument 2332 may be, for example, a knife. As will be discussed in further detail below, rotation of the end effector drive shaft 2336 will cause the cutting instrument 2332 and sled portion 2333 to axially travel through the surgical staple cartridge 2334 to move between a starting position and an ending position. The direction of axial travel of the cutting instrument 2332 depends upon the direction in which the end effector drive shaft 2336 is rotated. The anvil 2324 may be pivotably opened and closed at a pivot point 2325 connected to the proximate end of the elongated channel 2322. The anvil 2324 may also include a tab 2327 at its proximate end that operably interfaces with a component of the mechanical closure system (described further below) to open and close the anvil 2324. When the end effector drive shaft 2336 is rotated, the

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cutting instrument **2332** and sled **2333** will travel longitudinally through the surgical staple cartridge **2334** from the starting position to the ending position, thereby cutting tissue clamped within the surgical end effector **2312**. The movement of the sled **2333** through the surgical staple cartridge **2334** causes the staples therein to be driven through the severed tissue and against the closed anvil **2324**, which turns the staples to fasten the severed tissue. In one form, the elongated channel **2322** and the anvil **2324** may be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with sensor(s) in the end effector, as described above. The surgical staple cartridge **2334** could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge **2334**, as described above.

It should be noted that although the embodiments of the surgical tool **2300** described herein employ a surgical end effector **2312** that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Pat. No. 5,709,680, entitled ELECTROSURGICAL HEMOSTATIC DEVICE, which issued on Jan. 20, 1998, and U.S. Pat. No. 5,688,270, entitled ELECTROSURGICAL HEMOSTATIC DEVICE WITH RECESSED AND/OR OFFSET ELECTRODES which issued on Nov. 18, 1997, which are incorporated herein by reference, discloses cutting instruments that use RF energy to fasten the severed tissue. U.S. patent application Ser. No. 11/267,811, entitled SURGICAL STAPLING INSTRUMENTS STRUCTURED FOR DELIVERY OF MEDICAL AGENTS, now U.S. Pat. No. 7,673,783, which issued on Mar. 9, 2010 and U.S. patent application Ser. No. 11/267,383, to Shelton et al., now U.S. Pat. No. 7,607,557, which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

In the illustrated embodiment, the surgical end effector **2312** is coupled to an elongated shaft assembly **2308** that is coupled to a tool mounting portion **2460** and defines a longitudinal tool axis LT-LT. In this embodiment, the elongated shaft assembly **2308** does not include an articulation joint. Those of ordinary skill in the art will understand that other embodiments may have an articulation joint therein. In at least one embodiment, the elongated shaft assembly **2308** comprises a hollow outer tube **2340** that is rotatably supported on a tool mounting plate **2462** of a tool mounting portion **2460** as will be discussed in further detail below. In various embodiments, the elongated shaft assembly **2308** further includes a distal spine shaft **2350**. Distal spine shaft **2350** has a distal end portion **2354** that is coupled to, or otherwise integrally formed with, a distal stationary base portion **2360** that is non-movably coupled to the channel **2322**. See FIGS. 35-37.

As shown in FIG. 35, the distal spine shaft **2350** has a proximal end portion **2351** that is slidably received within a slot **2355** in a proximal spine shaft **2353** that is non-movably supported within the hollow outer tube **2340** by at least one support collar **2357**. As can be further seen in FIGS. 35 and 36, the surgical tool **2300** includes a closure tube **2370** that is constrained to only move axially relative to the distal stationary base portion **2360**. The closure tube **2370** has a proximal end **2372** that has an internal thread **2374** formed therein that

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is in threaded engagement with a transmission arrangement, generally depicted as **2375** that is operably supported on the tool mounting plate **2462**. In various forms, the transmission arrangement **2375** includes a rotary drive shaft assembly, generally designated as **2381**. When rotated, the rotary drive shaft assembly **2381** will cause the closure tube **2370** to move axially as will be describe in further detail below. In at least one form, the rotary drive shaft assembly **2381** includes a closure drive nut **2382** of a closure clutch assembly generally designated as **2380**. More specifically, the closure drive nut **2382** has a proximal end portion **2384** that is rotatably supported relative to the outer tube **2340** and is in threaded engagement with the closure tube **2370**. For assembly purposes, the proximal end portion **2384** may be threadably attached to a retention ring **2386**. Retention ring **2386**, in cooperation with an end **2387** of the closure drive nut **2382**, defines an annular slot **2388** into which a shoulder **2392** of a locking collar **2390** extends. The locking collar **2390** is non-movably attached (e.g., welded, glued, etc.) to the end of the outer tube **2340**. Such arrangement serves to affix the closure drive nut **2382** to the outer tube **2340** while enabling the closure drive nut **2382** to rotate relative to the outer tube **2340**. The closure drive nut **2382** further has a distal end **2383** that has a threaded portion **2385** that threadably engages the internal thread **2374** of the closure tube **2370**. Thus, rotation of the closure drive nut **2382** will cause the closure tube **2370** to move axially as represented by arrow "D" in FIG. 36.

Closure of the anvil **2324** and actuation of the cutting instrument **2332** are accomplished by control motions that are transmitted by a hollow drive sleeve **2400**. As can be seen in FIGS. 35 and 36, the hollow drive sleeve **2400** is rotatably and slidably received on the distal spine shaft **2350**. The drive sleeve **2400** has a proximal end portion **2401** that is rotatably mounted to the proximal spine shaft **2353** that protrudes from the tool mounting portion **2460** such that the drive sleeve **2400** may rotate relative thereto. See FIG. 35. As can also be seen in FIGS. 35-37, the drive sleeve **2400** is rotated about the longitudinal tool axis "LT-LT" by a drive shaft **2440**. The drive shaft **2440** has a drive gear **2444** that is attached to its distal end **2442** and is in meshing engagement with a driven gear **2450** that is attached to the drive sleeve **2400**.

The drive sleeve **2400** further has a distal end portion **2402** that is coupled to a closure clutch **2410** portion of the closure clutch assembly **2380** that has a proximal face **2412** and a distal face **2414**. The proximal face **2412** has a series of proximal teeth **2416** formed thereon that are adapted for selective engagement with corresponding proximal teeth cavities **2418** formed in the proximal end portion **2384** of the closure drive nut **2382**. Thus, when the proximal teeth **2416** are in meshing engagement with the proximal teeth cavities **2418** in the closure drive nut **2382**, rotation of the drive sleeve **2400** will result in rotation of the closure drive nut **2382** and ultimately cause the closure tube **2370** to move axially as will be discussed in further detail below.

As can be most particularly seen in FIGS. 35 and 36, the distal face **2414** of the drive clutch portion **2410** has a series of distal teeth **2415** formed thereon that are adapted for selective engagement with corresponding distal teeth cavities **2426** formed in a face plate portion **2424** of a knife drive shaft assembly **2420**. In various embodiments, the knife drive shaft assembly **2420** comprises a hollow knife shaft segment **2430** that is rotatably received on a corresponding portion of the distal spine shaft **2350** that is attached to or protrudes from the stationary base **2360**. When the distal teeth **2415** of the closure clutch portion **2410** are in meshing engagement with the distal teeth cavities **2426** in the face plate portion **2424**, rotation of the drive sleeve **2400** will result in rotation of the drive

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shaft segment **2430** about the stationary shaft **2350**. As can be seen in FIGS. **35-37**, a knife drive gear **2432** is attached to the drive shaft segment **2430** and is meshing engagement with a drive knife gear **2434** that is attached to the end effector drive shaft **2336**. Thus, rotation of the drive shaft segment **2430** will result in the rotation of the end effector drive shaft **2336** to drive the cutting instrument **2332** and sled **2333** distally through the surgical staple cartridge **2334** to cut and staple tissue clamped within the surgical end effector **2312**. The sled **2333** may be made of, for example, plastic, and may have a sloped distal surface. As the sled **2333** traverses the elongated channel **2322**, the sloped forward surface of the sled **2333** pushes up or “drive” the staples in the surgical staple cartridge **2334** through the clamped tissue and against the anvil **2324**. The anvil **2324** turns or “forms” the staples, thereby stapling the severed tissue. As used herein, the term “fire” refers to the initiation of actions required to drive the cutting instrument and sled portion in a distal direction through the surgical staple cartridge to cut the tissue clamped in the surgical end effector and drive the staples through the severed tissue.

In use, it may be desirable to rotate the surgical end effector **2312** about the longitudinal tool axis LT-LT. In at least one embodiment, the transmission arrangement **2375** includes a rotational transmission assembly **2465** that is configured to receive a corresponding rotary output motion from the tool drive assembly **1010** of the robotic system **1000** and convert that rotary output motion to a rotary control motion for rotating the elongated shaft assembly **2308** (and surgical end effector **2312**) about the longitudinal tool axis LT-LT. As can be seen in FIG. **38**, a proximal end **2341** of the outer tube **2340** is rotatably supported within a cradle arrangement **2343** attached to the tool mounting plate **2462** of the tool mounting portion **2460**. A rotation gear **2345** is formed on or attached to the proximal end **2341** of the outer tube **2340** of the elongated shaft assembly **2308** for meshing engagement with a rotation gear assembly **2470** operably supported on the tool mounting plate **2462**. In at least one embodiment, a rotation drive gear **2472** is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **2462** when the tool mounting portion **2460** is coupled to the tool drive assembly **1010**. See FIGS. **22** and **38**. The rotation drive assembly **2470** further comprises a rotary driven gear **2474** that is rotatably supported on the tool mounting plate **2462** in meshing engagement with the rotation gear **2345** and the rotation drive gear **2472**. Application of a first rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **2472** by virtue of being operably coupled thereto. Rotation of the rotation drive gear **2472** ultimately results in the rotation of the elongated shaft assembly **2308** (and the end effector **2312**) about the longitudinal tool axis LT-LT (primary rotary motion).

Closure of the anvil **2324** relative to the staple cartridge **2034** is accomplished by axially moving the closure tube **2370** in the distal direction “DD”. Axial movement of the closure tube **2370** in the distal direction “DD” is accomplished by applying a rotary control motion to the closure drive nut **2382**. To apply the rotary control motion to the closure drive nut **2382**, the closure clutch **2410** must first be brought into meshing engagement with the proximal end portion **2384** of the closure drive nut **2382**. In various embodiments, the transmission arrangement **2375** further includes a shifter drive assembly **2480** that is operably supported on the tool mounting plate **2462**. More specifically and with reference to FIG. **38**, it can be seen that a proximal end portion **2359** of the proximal spine portion **2353** extends through the

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rotation gear **2345** and is rotatably coupled to a shifter gear rack **2481** that is slidably affixed to the tool mounting plate **2462** through slots **2482**. The shifter drive assembly **2480** further comprises a shifter drive gear **2483** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **2462** when the tool mounting portion **2460** is coupled to the tool holder **1270**. See FIGS. **22** and **38**. The shifter drive assembly **2480** further comprises a shifter driven gear **2478** that is rotatably supported on the tool mounting plate **2462** in meshing engagement with the shifter drive gear **2483** and the shifter rack gear **2482**. Application of a second rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding driven element **1304** will thereby cause rotation of the shifter drive gear **2483** by virtue of being operably coupled thereto. Rotation of the shifter drive gear **2483** ultimately results in the axial movement of the shifter gear rack **2482** and the proximal spine portion **2353** as well as the drive sleeve **2400** and the closure clutch **2410** attached thereto. The direction of axial travel of the closure clutch **2410** depends upon the direction in which the shifter drive gear **2483** is rotated by the robotic system **1000**. Thus, rotation of the shifter drive gear **2483** in a first rotary direction will result in the axial movement of the closure clutch **2410** in the proximal direction “PD” to bring the proximal teeth **2416** into meshing engagement with the proximal teeth cavities **2418** in the closure drive nut **2382**. Conversely, rotation of the shifter drive gear **2483** in a second rotary direction (opposite to the first rotary direction) will result in the axial movement of the closure clutch **2410** in the distal direction “DD” to bring the distal teeth **2415** into meshing engagement with corresponding distal teeth cavities **2426** formed in the face plate portion **2424** of the knife drive shaft assembly **2420**.

Once the closure clutch **2410** has been brought into meshing engagement with the closure drive nut **2382**, the closure drive nut **2382** is rotated by rotating the closure clutch **2410**. Rotation of the closure clutch **2410** is controlled by applying rotary output motions to a rotary drive transmission portion **2490** of transmission arrangement **2375** that is operably supported on the tool mounting plate **2462** as shown in FIG. **38**. In at least one embodiment, the rotary drive transmission **2490** includes a rotary drive assembly **2490'** that includes a gear **2491** that is coupled to a corresponding third one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **2462** when the tool mounting portion **2460** is coupled to the tool holder **1270**. See FIGS. **22** and **38**. The rotary drive transmission **2490** further comprises a first rotary driven gear **2492** that is rotatably supported on the tool mounting plate **2462** in meshing engagement with a second rotary driven gear **2493** and the rotary drive gear **2491**. The second rotary driven gear **2493** is coupled to a proximal end portion **2443** of the drive shaft **2440**.

Rotation of the rotary drive gear **2491** in a first rotary direction will result in the rotation of the drive shaft **2440** in a first direction. Conversely, rotation of the rotary drive gear **2491** in a second rotary direction (opposite to the first rotary direction) will cause the drive shaft **2440** to rotate in a second direction. As indicated above, the drive shaft **2440** has a drive gear **2444** that is attached to its distal end **2442** and is in meshing engagement with a driven gear **2450** that is attached to the drive sleeve **2400**. Thus, rotation of the drive shaft **2440** results in rotation of the drive sleeve **2400**.

A method of operating the surgical tool **2300** will now be described. Once the tool mounting portion **2462** has been operably coupled to the tool holder **1270** of the robotic system **1000** and oriented into position adjacent the target tissue to be cut and stapled, if the anvil **2334** is not already in the open

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position (FIG. 35), the robotic system 1000 may apply the first rotary output motion to the shifter drive gear 2483 which results in the axial movement of the closure clutch 2410 into meshing engagement with the closure drive nut 2382 (if it is not already in meshing engagement therewith). See FIG. 36. Once the controller 1001 of the robotic system 1000 has confirmed that the closure clutch 2410 is meshing engagement with the closure drive nut 2382 (e.g., by means of sensor(s)) in the surgical end effector 2312 that are in communication with the robotic control system), the robotic controller 1001 may then apply a second rotary output motion to the rotary drive gear 2492 which, as was described above, ultimately results in the rotation of the rotary drive nut 2382 in the first direction which results in the axial travel of the closure tube 2370 in the distal direction "DD". As the closure tube 2370 moved in the distal direction, it contacts a portion of the anvil 2323 and causes the anvil 2324 to pivot to the closed position to clamp the target tissue between the anvil 2324 and the surgical staple cartridge 2334. Once the robotic controller 1001 determines that the anvil 2334 has been pivoted to the closed position by corresponding sensor(s) in the surgical end effector 2312 in communication therewith, the robotic system 1000 discontinues the application of the second rotary output motion to the rotary drive gear 2491. The robotic controller 1001 may also provide the surgeon with an indication that the anvil 2334 has been fully closed. The surgeon may then initiate the firing procedure. In alternative embodiments, the firing procedure may be automatically initiated by the robotic controller 1001. The robotic controller 1001 then applies the primary rotary control motion 2483 to the shifter drive gear 2483 which results in the axial movement of the closure clutch 2410 into meshing engagement with the face plate portion 2424 of the knife drive shaft assembly 2420. See FIG. 46. Once the controller 1001 of the robotic system 1000 has confirmed that the closure clutch 2410 is meshing engagement with the face plate portion 2424 (by means of sensor(s)) in the end effector 2312 that are in communication with the robotic controller 1001), the robotic controller 1001 may then apply the second rotary output motion to the rotary drive gear 2492 which, as was described above, ultimately results in the axial movement of the cutting instrument 2332 and sled portion 2333 in the distal direction "DD" through the surgical staple cartridge 2334. As the cutting instrument 2332 moves distally through the surgical staple cartridge 2334, the tissue clamped therein is severed. As the sled portion 2333 is driven distally, it causes the staples within the surgical staple cartridge to be driven through the severed tissue into forming contact with the anvil 2324. Once the robotic controller 1001 has determined that the cutting instrument 2324 has reached the end position within the surgical staple cartridge 2334 (by means of sensor(s)) in the end effector 2312 that are in communication with the robotic controller 1001), the robotic controller 1001 discontinues the application of the second rotary output motion to the rotary drive gear 2491. Thereafter, the robotic controller 1001 applies the secondary rotary output motion to the rotary drive gear 2491 which ultimately results in the axial travel of the cutting instrument 2332 and sled portion 2333 in the proximal direction "PD" to the starting position. Once the robotic controller 1001 has determined that the cutting instrument 2324 has reached the starting position by means of sensor(s) in the surgical end effector 2312 that are in communication with the robotic controller 1001, the robotic controller 1001 discontinues the application of the secondary rotary output motion to the rotary drive gear 2491. Thereafter, the robotic controller 1001 applies the primary rotary output motion to the shifter drive gear 2483 to cause the closure clutch 2410 to

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move into engagement with the rotary drive nut 2382. Once the closure clutch 2410 has been moved into meshing engagement with the rotary drive nut 2382, the robotic controller 1001 then applies the secondary output motion to the rotary drive gear 2491 which ultimately results in the rotation of the rotary drive nut 2382 in the second direction to cause the closure tube 2370 to move in the proximal direction "PD". As can be seen in FIGS. 35-37, the closure tube 2370 has an opening 2345 therein that engages the tab 2327 on the anvil 2324 to cause the anvil 2324 to pivot to the open position. In alternative embodiments, a spring may also be employed to pivot the anvil 2324 to the open position when the closure tube 2370 has been returned to the starting position (FIG. 35).

FIGS. 39-43 illustrate yet another surgical tool 2500 that may be effectively employed in connection with the robotic system 1000. In various forms, the surgical tool 2500 includes a surgical end effector 2512 that includes a "first portion" in the form of an elongated channel 2522 and a "second movable portion" in the form of a pivotally translatable clamping member, such as an anvil 2524, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 2512. As shown in the illustrated embodiment, the surgical end effector 2512 may include, in addition to the previously-mentioned elongated channel 2522 and anvil 2524, a "third movable portion" in the form of a cutting instrument 2532, a sled (not shown), and a surgical staple cartridge 2534 that is removably seated in the elongated channel 2522. The cutting instrument 2532 may be, for example, a knife. The anvil 2524 may be pivotably opened and closed at a pivot point 2525 connected to the proximate end of the elongated channel 2522. The anvil 2524 may also include a tab 2527 at its proximate end that is configured to operably interface with a component of the mechanical closure system (described further below) to open and close the anvil 2524. When actuated, the knife 2532 and sled travel longitudinally along the elongated channel 2522, thereby cutting tissue clamped within the surgical end effector 2512. The movement of the sled along the elongated channel 2522 causes the staples of the surgical staple cartridge 2534 to be driven through the severed tissue and against the closed anvil 2524, which turns the staples to fasten the severed tissue. In one form, the elongated channel 2522 and the anvil 2524 may be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with sensor(s) in the surgical end effector, as described above. The surgical staple cartridge 2534 could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge 2534, as described above.

It should be noted that although the embodiments of the surgical tool 2500 described herein employ a surgical end effector 2512 that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Pat. No. 5,709,680, entitled ELECTROSURGICAL HEMOSTATIC DEVICE which issued on Jan. 20, 1998, and U.S. Pat. No. 5,688,270, entitled ELECTROSURGICAL HEMOSTATIC DEVICE WITH RECESSED AND/OR OFFSET ELECTRODES, which issued on Nov. 18, 1997, which are incorporated herein by reference, discloses cutting instruments that use RF energy to fasten the severed tissue. U.S. patent application Ser. No. 11/267,811, entitled SURGICAL STAPLING INSTRUMENTS STRUCTURED FOR DELIVERY OF MEDICAL AGENTS, now U.S. Pat. No. 7,673,783, which issued on Mar. 9, 2010, and U.S. patent application Ser. No. 11/267,383, to Shelton et al., now U.S.

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Pat. No. 7,607,557, which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

In the illustrated embodiment, the elongated channel 2522 of the surgical end effector 2512 is coupled to an elongated shaft assembly 2508 that is coupled to a tool mounting portion 2600. In at least one embodiment, the elongated shaft assembly 2508 comprises a hollow spine tube 2540 that is non-movably coupled to a tool mounting plate 2602 of the tool mounting portion 2600. As can be seen in FIGS. 40 and 41, the proximal end 2523 of the elongated channel 2522 comprises a hollow tubular structure configured to be attached to the distal end 2541 of the spine tube 2540. In one embodiment, for example, the proximal end 2523 of the elongated channel 2522 is welded or glued to the distal end of the spine tube 2540.

As can be further seen in FIGS. 40 and 41, in at least one non-limiting embodiment, the surgical tool 2500 further includes an axially movable actuation member in the form of a closure tube 2550 that is constrained to move axially relative to the elongated channel 2522 and the spine tube 2540. The closure tube 2550 has a proximal end 2552 that has an internal thread 2554 formed therein that is in threaded engagement with a rotatably movable portion in the form of a closure drive nut 2560. More specifically, the closure drive nut 2560 has a proximal end portion 2562 that is rotatably supported relative to the elongated channel 2522 and the spine tube 2540. For assembly purposes, the proximal end portion 2562 is threadably attached to a retention ring 2570. The retention ring 2570 is received in a groove 2529 formed between a shoulder 2527 on the proximal end 2523 of the elongated channel 2522 and the distal end 2541 of the spine tube 2540. Such arrangement serves to rotatably support the closure drive nut 2560 within the elongated channel 2522. Rotation of the closure drive nut 2560 will cause the closure tube 2550 to move axially as represented by arrow "D" in FIG. 40.

Extending through the spine tube 2540 and the closure drive nut 2560 is a drive member which, in at least one embodiment, comprises a knife bar 2580 that has a distal end portion 2582 that is rotatably coupled to the cutting instrument 2532 such that the knife bar 2580 may rotate relative to the cutting instrument 2582. As can be seen in FIG. 40-42, the closure drive nut 2560 has a slot 2564 therein through which the knife bar 2580 can slidably extend. Such arrangement permits the knife bar 2580 to move axially relative to the closure drive nut 2560. However, rotation of the knife bar 2580 about the longitudinal tool axis LT-LT will also result in the rotation of the closure drive nut 2560. The axial direction in which the closure tube 2550 moves ultimately depends upon the direction in which the knife bar 2580 and the closure drive nut 2560 are rotated. As the closure tube 2550 is driven distally, the distal end thereof will contact the anvil 2524 and cause the anvil 2524 to pivot to a closed position. Upon application of an opening rotary output motion from the robotic system 1000, the closure tube 2550 will be driven in the proximal direction "PD" and pivot the anvil 2524 to the open position by virtue of the engagement of the tab 2527 with the opening 2555 in the closure tube 2550.

In use, it may be desirable to rotate the surgical end effector 2512 about the longitudinal tool axis LT-LT. In at least one embodiment, the tool mounting portion 2600 is configured to receive a corresponding first rotary output motion from the robotic system 1000 and convert that first rotary output

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motion to a rotary control motion for rotating the elongated shaft assembly 2508 about the longitudinal tool axis LT-LT. As can be seen in FIG. 38, a proximal end 2542 of the hollow spine tube 2540 is rotatably supported within a cradle arrangement 2603 attached to a tool mounting plate 2602 of the tool mounting portion 2600. Various embodiments of the surgical tool 2500 further include a transmission arrangement, generally depicted as 2605, that is operably supported on the tool mounting plate 2602. In various forms the transmission arrangement 2605 include a rotation gear 2544 that is formed on or attached to the proximal end 2542 of the spine tube 2540 for meshing engagement with a rotation drive assembly 2610 that is operably supported on the tool mounting plate 2602. In at least one embodiment, a rotation drive gear 2612 is coupled to a corresponding first one of the rotational bodies, driven discs or elements 1304 on the adapter side of the tool mounting plate 2602 when the tool mounting portion 2600 is coupled to the tool holder 1270. See FIGS. 22 and 43. The rotation drive assembly 2610 further comprises a rotary driven gear 2614 that is rotatably supported on the tool mounting plate 2602 in meshing engagement with the rotation gear 2544 and the rotation drive gear 2612. Application of a first rotary output motion from the robotic system 1000 through the tool drive assembly 1010 to the corresponding driven rotational body 1304 will thereby cause rotation of the rotation drive gear 2612 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 2612 ultimately results in the rotation of the elongated shaft assembly 2508 (and the end effector 2512) about the longitudinal tool axis LT-LT.

Closure of the anvil 2524 relative to the surgical staple cartridge 2534 is accomplished by axially moving the closure tube 2550 in the distal direction "DD". Axial movement of the closure tube 2550 in the distal direction "DD" is accomplished by applying a rotary control motion to the closure drive nut 2382. In various embodiments, the closure drive nut 2560 is rotated by applying a rotary output motion to the knife bar 2580. Rotation of the knife bar 2580 is controlled by applying rotary output motions to a rotary closure system 2620 that is operably supported on the tool mounting plate 2602 as shown in FIG. 43. In at least one embodiment, the rotary closure system 2620 includes a closure drive gear 2622 that is coupled to a corresponding second one of the driven rotatable body portions discs or elements 1304 on the adapter side of the tool mounting plate 2462 when the tool mounting portion 2600 is coupled to the tool holder 1270. See FIGS. 22 and 43. The closure drive gear 2622, in at least one embodiment, is in meshing driving engagement with a closure gear train, generally depicted as 2623. The closure gear drive train 2623 comprises a first driven closure gear 2624 that is rotatably supported on the tool mounting plate 2602. The first closure driven gear 2624 is attached to a second closure driven gear 2626 by a drive shaft 2628. The second closure driven gear 2626 is in meshing engagement with a third closure driven gear 2630 that is rotatably supported on the tool mounting plate 2602. Rotation of the closure drive gear 2622 in a second rotary direction will result in the rotation of the third closure driven gear 2630 in a second direction. Conversely, rotation of the closure drive gear 2483 in a secondary rotary direction (opposite to the second rotary direction) will cause the third closure driven gear 2630 to rotate in a secondary direction.

As can be seen in FIG. 43, a drive shaft assembly 2640 is coupled to a proximal end of the knife bar 2580. In various embodiments, the drive shaft assembly 2640 includes a proximal portion 2642 that has a square cross-sectional shape. The proximal portion 2642 is configured to slideably engage a

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correspondingly shaped aperture in the third driven gear 2630. Such arrangement results in the rotation of the drive shaft assembly 2640 (and knife bar 2580) when the third driven gear 2630 is rotated. The drive shaft assembly 2640 is axially advanced in the distal and proximal directions by a knife drive assembly 2650. One form of the knife drive assembly 2650 comprises a rotary drive gear 2652 that is coupled to a corresponding third one of the driven rotatable body portions, discs or elements 1304 on the adapter side of the tool mounting plate 2462 when the tool mounting portion 2600 is coupled to the tool holder 1270. See FIGS. 22 and 43. The rotary driven gear 2652 is in meshing driving engagement with a gear train, generally depicted as 2653. In at least one form, the gear train 2653 further comprises a first rotary driven gear assembly 2654 that is rotatably supported on the tool mounting plate 2602. The first rotary driven gear assembly 2654 is in meshing engagement with a third rotary driven gear assembly 2656 that is rotatably supported on the tool mounting plate 2602 and which is in meshing engagement with a fourth rotary driven gear assembly 2658 that is in meshing engagement with a threaded portion 2644 of the drive shaft assembly 2640. Rotation of the rotary drive gear 2652 in a third rotary direction will result in the axial advancement of the drive shaft assembly 2640 and knife bar 2580 in the distal direction "DD". Conversely, rotation of the rotary drive gear 2652 in a tertiary rotary direction (opposite to the third rotary direction) will cause the drive shaft assembly 2640 and the knife bar 2580 to move in the proximal direction.

A method of operating the surgical tool 2500 will now be described. Once the tool mounting portion 2600 has been operably coupled to the tool holder 1270 of the robotic system 1000, the robotic system 1000 can orient the surgical end effector 2512 in position adjacent the target tissue to be cut and stapled. If the anvil 2524 is not already in the open position (FIG. 49), the robotic system 1000 may apply the second rotary output motion to the closure drive gear 2622 which results in the rotation of the knife bar 2580 in a second direction. Rotation of the knife bar 2580 in the second direction results in the rotation of the closure drive nut 2560 in a second direction. As the closure drive nut 2560 rotates in the second direction, the closure tube 2550 moves in the proximal direction "PD". As the closure tube 2550 moves in the proximal direction "PD", the tab 2527 on the anvil 2524 interfaces with the opening 2555 in the closure tube 2550 and causes the anvil 2524 to pivot to the open position. In addition or in alternative embodiments, a spring (not shown) may be employed to pivot the anvil 2354 to the open position when the closure tube 2550 has been returned to the starting position (FIG. 40). The opened surgical end effector 2512 may then be manipulated by the robotic system 1000 to position the target tissue between the open anvil 2524 and the surgical staple cartridge 2534. Thereafter, the surgeon may initiate the closure process by activating the robotic control system 1000 to apply the second rotary output motion to the closure drive gear 2622 which, as was described above, ultimately results in the rotation of the closure drive nut 2382 in the second direction which results in the axial travel of the closure tube 2250 in the distal direction "DD". As the closure tube 2550 moves in the distal direction, it contacts a portion of the anvil 2524 and causes the anvil 2524 to pivot to the closed position to clamp the target tissue between the anvil 2524 and the staple cartridge 2534. Once the robotic controller 1001 determines that the anvil 2524 has been pivoted to the closed position by corresponding sensor(s) in the end effector 2512 that are in communication therewith, the robotic controller 1001 discontinues the application of the second rotary output

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motion to the closure drive gear 2622. The robotic controller 1001 may also provide the surgeon with an indication that the anvil 2524 has been fully closed. The surgeon may then initiate the firing procedure. In alternative embodiments, the firing procedure may be automatically initiated by the robotic controller 1001.

After the robotic controller 1001 has determined that the anvil 2524 is in the closed position, the robotic controller 1001 then applies the third rotary output motion to the rotary drive gear 2652 which results in the axial movement of the drive shaft assembly 2640 and knife bar 2580 in the distal direction "DD". As the cutting instrument 2532 moves distally through the surgical staple cartridge 2534, the tissue clamped therein is severed. As the sled portion (not shown) is driven distally, it causes the staples within the surgical staple cartridge 2534 to be driven through the severed tissue into forming contact with the anvil 2524. Once the robotic controller 1001 has determined that the cutting instrument 2532 has reached the end position within the surgical staple cartridge 2534 by means of sensor(s) in the surgical end effector 2512 that are in communication with the robotic controller 1001, the robotic controller 1001 discontinues the application of the second rotary output motion to the rotary drive gear 2652. Thereafter, the robotic controller 1001 applies the secondary rotary control motion to the rotary drive gear 2652 which ultimately results in the axial travel of the cutting instrument 2532 and sled portion in the proximal direction "PD" to the starting position. Once the robotic controller 1001 has determined that the cutting instrument 2524 has reached the starting position by means of sensor(s) in the end effector 2512 that are in communication with the robotic controller 1001, the robotic controller 1001 discontinues the application of the secondary rotary output motion to the rotary drive gear 2652. Thereafter, the robotic controller 1001 may apply the secondary rotary output motion to the closure drive gear 2622 which results in the rotation of the knife bar 2580 in a secondary direction. Rotation of the knife bar 2580 in the secondary direction results in the rotation of the closure drive nut 2560 in a secondary direction. As the closure drive nut 2560 rotates in the secondary direction, the closure tube 2550 moves in the proximal direction "PD" to the open position.

FIGS. 44-49B illustrate yet another surgical tool 2700 that may be effectively employed in connection with the robotic system 1000. In various forms, the surgical tool 2700 includes a surgical end effector 2712 that includes a "first portion" in the form of an elongated channel 2722 and a "second movable portion" in on form comprising a pivotally translatable clamping member, such as an anvil 2724, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 2712. As shown in the illustrated embodiment, the surgical end effector 2712 may include, in addition to the previously-mentioned channel 2722 and anvil 2724, a "third movable portion" in the form of a cutting instrument 2732, a sled (not shown), and a surgical staple cartridge 2734 that is removably seated in the elongated channel 2722. The cutting instrument 2732 may be, for example, a knife. The anvil 2724 may be pivotably opened and closed at a pivot point 2725 connected to the proximal end of the elongated channel 2722. The anvil 2724 may also include a tab 2727 at its proximal end that interfaces with a component of the mechanical closure system (described further below) to open and close the anvil 2724. When actuated, the knife 2732 and sled to travel longitudinally along the elongated channel 2722, thereby cutting tissue clamped within the surgical end effector 2712. The movement of the sled along the elongated channel 2722 causes the staples of

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the surgical staple cartridge 2734 to be driven through the severed tissue and against the closed anvil 2724, which turns the staples to fasten the severed tissue. In one form, the elongated channel 2722 and the anvil 2724 may be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with sensor(s) in the surgical end effector, as described above. The surgical staple cartridge 2734 could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge 2734, as described above.

It should be noted that although the embodiments of the surgical tool 2500 described herein employ a surgical end effector 2712 that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Pat. No. 5,709,680, entitled ELECTROSURGICAL HEMOSTATIC DEVICE, which issued on Jan. 20, 1998, and U.S. Pat. No. 5,688,270, entitled ELECTROSURGICAL HEMOSTATIC DEVICE WITH RECESSED AND/OR OFFSET ELECTRODES which issued on Nov. 18, 1997, which are incorporated herein by reference, discloses cutting instruments that use RF energy to fasten the severed tissue. U.S. patent application Ser. No. 11/267,811 entitled SURGICAL STAPLING INSTRUMENTS STRUCTURED FOR DELIVERY OF MEDICAL AGENTS, now U.S. Pat. No. 7,673,783, which issued on Mar. 9, 2010 and U.S. patent application Ser. No. 11/267,383, to Shelton et al., now U.S. Pat. No. 7,607,557, which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

In the illustrated embodiment, the elongated channel 2722 of the surgical end effector 2712 is coupled to an elongated shaft assembly 2708 that is coupled to a tool mounting portion 2900. Although not shown, the elongated shaft assembly 2708 may include an articulation joint to permit the surgical end effector 2712 to be selectively articulated about an axis that is substantially transverse to the tool axis LT-LT. In at least one embodiment, the elongated shaft assembly 2708 comprises a hollow spine tube 2740 that is non-movably coupled to a tool mounting plate 2902 of the tool mounting portion 2900. As can be seen in FIGS. 45 and 46, the proximal end 2723 of the elongated channel 2722 comprises a hollow tubular structure that is attached to the spine tube 2740 by means of a mounting collar 2790. A cross-sectional view of the mounting collar 2790 is shown in FIG. 47. In various embodiments, the mounting collar 2790 has a proximal flanged end 2791 that is configured for attachment to the distal end of the spine tube 2740. In at least one embodiment, for example, the proximal flanged end 2791 of the mounting collar 2790 is welded or glued to the distal end of the spine tube 2740. As can be further seen in FIGS. 45 and 46, the mounting collar 2790 further has a mounting hub portion 2792 that is sized to receive the proximal end 2723 of the elongated channel 2722 thereon. The proximal end 2723 of the elongated channel 2722 is non-movably attached to the mounting hub portion 2792 by, for example, welding, adhesive, etc.

As can be further seen in FIGS. 45 and 46, the surgical tool 2700 further includes an axially movable actuation member in the form of a closure tube 2750 that is constrained to move axially relative to the elongated channel 2722. The closure

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tube 2750 has a proximal end 2752 that has an internal thread 2754 formed therein that is in threaded engagement with a rotatably movable portion in the form of a closure drive nut 2760. More specifically, the closure drive nut 2760 has a proximal end portion 2762 that is rotatably supported relative to the elongated channel 2722 and the spine tube 2740. For assembly purposes, the proximal end portion 2762 is threadably attached to a retention ring 2770. The retention ring 2770 is received in a groove 2729 formed between a shoulder 2727 on the proximal end 2723 of the channel 2722 and the mounting hub 2729 of the mounting collar 2790. Such arrangement serves to rotatably support the closure drive nut 2760 within the channel 2722. Rotation of the closure drive nut 2760 will cause the closure tube 2750 to move axially as represented by arrow "D" in FIG. 45.

Extending through the spine tube 2740, the mounting collar 2790, and the closure drive nut 2760 is a drive member, which in at least one embodiment, comprises a knife bar 2780 that has a distal end portion 2782 that is coupled to the cutting instrument 2732. As can be seen in FIGS. 45 and 46, the mounting collar 2790 has a passage 2793 therethrough for permitting the knife bar 2780 to slidably pass therethrough. Similarly, the closure drive nut 2760 has a slot 2764 therein through which the knife bar 2780 can slidably extend. Such arrangement permits the knife bar 2780 to move axially relative to the closure drive nut 2760.

Actuation of the anvil 2724 is controlled by a rotary driven closure shaft 2800. As can be seen in FIGS. 45 and 46, a distal end portion 2802 of the closure drive shaft 2800 extends through a passage 2794 in the mounting collar 2790 and a closure gear 2804 is attached thereto. The closure gear 2804 is configured for driving engagement with the inner surface 2761 of the closure drive nut 2760. Thus, rotation of the closure shaft 2800 will also result in the rotation of the closure drive nut 2760. The axial direction in which the closure tube 2750 moves ultimately depends upon the direction in which the closure shaft 2800 and the closure drive nut 2760 are rotated. For example, in response to one rotary closure motion received from the robotic system 1000, the closure tube 2750 will be driven in the distal direction "DD". As the closure tube 2750 is driven distally, the opening 2745 will engage the tab 2727 on the anvil 2724 and cause the anvil 2724 to pivot to a closed position. Upon application of an opening rotary motion from the robotic system 1000, the closure tube 2750 will be driven in the proximal direction "PD" and pivot the anvil 2724 to the open position. In various embodiments, a spring (not shown) may be employed to bias the anvil 2724 to the open position (FIG. 45).

In use, it may be desirable to rotate the surgical end effector 2712 about the longitudinal tool axis LT-LT. In at least one embodiment, the tool mounting portion 2900 is configured to receive a corresponding first rotary output motion from the robotic system 1000 for rotating the elongated shaft assembly 2708 about the tool axis LT-LT. As can be seen in FIG. 49, a proximal end 2742 of the hollow spine tube 2740 is rotatably supported within a cradle arrangement 2903 and a bearing assembly 2904 that are attached to a tool mounting plate 2902 of the tool mounting portion 2900. A rotation gear 2744 is formed on or attached to the proximal end 2742 of the spine tube 2740 for meshing engagement with a rotation drive assembly 2910 that is operably supported on the tool mounting plate 2902. In at least one embodiment, a rotation drive gear 2912 is coupled to a corresponding first one of the driven discs or elements 1304 on the adapter side of the tool mounting plate 2602 when the tool mounting portion 2600 is coupled to the tool holder 1270. See FIGS. 22 and 49. The rotation drive assembly 2910 further comprises a rotary

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driven gear 2914 that is rotatably supported on the tool mounting plate 2902 in meshing engagement with the rotation gear 2744 and the rotation drive gear 2912. Application of a first rotary control motion from the robotic system 1000 through the tool holder 1270 and the adapter 1240 to the corresponding driven element 1304 will thereby cause rotation of the rotation drive gear 2912 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 2912 ultimately results in the rotation of the elongated shaft assembly 2708 (and the end effector 2712) about the longitudinal tool axis LT-LT (primary rotary motion).

Closure of the anvil 2724 relative to the staple cartridge 2734 is accomplished by axially moving the closure tube 2750 in the distal direction "DD". Axial movement of the closure tube 2750 in the distal direction "DD" is accomplished by applying a rotary control motion to the closure drive nut 2760. In various embodiments, the closure drive nut 2760 is rotated by applying a rotary output motion to the closure drive shaft 2800. As can be seen in FIG. 49, a proximal end portion 2806 of the closure drive shaft 2800 has a driven gear 2808 thereon that is in meshing engagement with a closure drive assembly 2920. In various embodiments, the closure drive system 2920 includes a closure drive gear 2922 that is coupled to a corresponding second one of the driven rotational bodies or elements 1304 on the adapter side of the tool mounting plate 2462 when the tool mounting portion 2900 is coupled to the tool holder 1270. See FIGS. 22 and 49. The closure drive gear 2922 is supported in meshing engagement with a closure gear train, generally depicted as 2923. In at least one form, the closure gear train 2923 comprises a first driven closure gear 2924 that is rotatably supported on the tool mounting plate 2902. The first closure driven gear 2924 is attached to a second closure driven gear 2926 by a drive shaft 2928. The second closure driven gear 2926 is in meshing engagement with a planetary gear assembly 2930. In various embodiments, the planetary gear assembly 2930 includes a driven planetary closure gear 2932 that is rotatably supported within the bearing assembly 2904 that is mounted on tool mounting plate 2902. As can be seen in FIGS. 49 and 49B, the proximal end portion 2806 of the closure drive shaft 2800 is rotatably supported within the proximal end portion 2742 of the spine tube 2740 such that the driven gear 2808 is in meshing engagement with central gear teeth 2934 formed on the planetary gear 2932. As can also be seen in FIG. 49A, two additional support gears 2936 are attached to or rotatably supported relative to the proximal end portion 2742 of the spine tube 2740 to provide bearing support thereto. Such arrangement with the planetary gear assembly 2930 serves to accommodate rotation of the spine shaft 2740 by the rotation drive assembly 2910 while permitting the closure driven gear 2808 to remain in meshing engagement with the closure drive system 2920. In addition, rotation of the closure drive gear 2922 in a first direction will ultimately result in the rotation of the closure drive shaft 2800 and closure drive nut 2760 which will ultimately result in the closure of the anvil 2724 as described above. Conversely, rotation of the closure drive gear 2922 in a second opposite direction will ultimately result in the rotation of the closure drive nut 2760 in an opposite direction which results in the opening of the anvil 2724.

As can be seen in FIG. 49, the proximal end 2784 of the knife bar 2780 has a threaded shaft portion 2786 attached thereto which is in driving engagement with a knife drive assembly 2940. In various embodiments, the threaded shaft portion 2786 is rotatably supported by a bearing 2906 attached to the tool mounting plate 2902. Such arrangement permits the threaded shaft portion 2786 to rotate and move axially relative to the tool mounting plate 2902. The knife bar

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2780 is axially advanced in the distal and proximal directions by the knife drive assembly 2940. One form of the knife drive assembly 2940 comprises a rotary drive gear 2942 that is coupled to a corresponding third one of the rotatable bodies, driven discs or elements 1304 on the adapter side of the tool mounting plate 2902 when the tool mounting portion 2900 is coupled to the tool holder 1270. See FIGS. 22 and 49. The rotary drive gear 2942 is in meshing engagement with a knife gear train, generally depicted as 2943. In various embodiments, the knife gear train 2943 comprises a first rotary driven gear assembly 2944 that is rotatably supported on the tool mounting plate 2902. The first rotary driven gear assembly 2944 is in meshing engagement with a third rotary driven gear assembly 2946 that is rotatably supported on the tool mounting plate 2902 and which is in meshing engagement with a fourth rotary driven gear assembly 2948 that is in meshing engagement with the threaded portion 2786 of the knife bar 2780. Rotation of the rotary drive gear 2942 in one direction will result in the axial advancement of the knife bar 2780 in the distal direction "DD". Conversely, rotation of the rotary drive gear 2942 in an opposite direction will cause the knife bar 2780 to move in the proximal direction. Tool 2700 may otherwise be used as described above.

FIGS. 50 and 51 illustrate a surgical tool embodiment 2700' that is substantially identical to tool 2700 that was described in detail above. However tool 2700' includes a pressure sensor 2950 that is configured to provide feedback to the robotic controller 1001 concerning the amount of clamping pressure experienced by the anvil 2724. In various embodiments, for example, the pressure sensor may comprise a spring biased contact switch. For a continuous signal, it would use either a cantilever beam with a strain gage on it or a dome button top with a strain gage on the inside. Another version may comprise an off switch that contacts only at a known desired load. Such arrangement would include a dome on the base wherein the dome is one electrical pole and the base is the other electrical pole. Such arrangement permits the robotic controller 1001 to adjust the amount of clamping pressure being applied to the tissue within the surgical end effector 2712 by adjusting the amount of closing pressure applied to the anvil 2724. Those of ordinary skill in the art will understand that such pressure sensor arrangement may be effectively employed with several of the surgical tool embodiments described herein as well as their equivalent structures.

FIG. 52 illustrates a portion of another surgical tool 3000 that may be effectively used in connection with a robotic system 1000. The surgical tool 3003 employs on-board motor(s) for powering various components of a surgical end effector cutting instrument. In at least one non-limiting embodiment for example, the surgical tool 3000 includes a surgical end effector in the form of an endocutter (not shown) that has an anvil (not shown) and surgical staple cartridge arrangement (not shown) of the types and constructions described above. The surgical tool 3000 also includes an elongated shaft (not shown) and anvil closure arrangement (not shown) of the types described above. Thus, this portion of the Detailed Description will not repeat the description of those components beyond that which is necessary to appreciate the unique and novel attributes of the various embodiments of surgical tool 3000.

In the depicted embodiment, the end effector includes a cutting instrument 3002 that is coupled to a knife bar 3003. As can be seen in FIG. 52, the surgical tool 3000 includes a tool mounting portion 3010 that includes a tool mounting plate 3012 that is configured to mountably interface with the adaptor portion 1240' which is coupled to the robotic system 1000

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in the various manners described above. The tool mounting portion **3010** is configured to operably support a transmission arrangement **3013** thereon. In at least one embodiment, the adaptor portion **1240'** may be identical to the adaptor portion **1240** described in detail above without the powered rotation bodies and disc members employed by adapter **1240**. In other embodiments, the adaptor portion **1240'** may be identical to adaptor portion **1240**. Still other modifications which are considered to be within the spirit and scope of the various forms of the present invention may employ one or more of the mechanical motions (i.e., rotary motion(s)) from the tool holder portion **1270** (as described hereinabove) to power/actuate the transmission arrangement **3013** while also employing one or more motors within the tool mounting portion **3010** to power one or more other components of the surgical end effector. In addition, while the end effector of the depicted embodiment comprises an endocutter, those of ordinary skill in the art will understand that the unique and novel attributes of the depicted embodiment may be effectively employed in connection with other types of surgical end effectors without departing from the spirit and scope of various forms of the present invention.

In various embodiments, the tool mounting plate **3012** is configured to at least house a first firing motor **3011** for supplying firing and retraction motions to the knife bar **3003** which is coupled to or otherwise operably interfaces with the cutting instrument **3002**. The tool mounting plate **3012** has an array of electrical connecting pins **3014** which are configured to interface with the slots **1258** (FIG. **21**) in the adapter **1240'**. Such arrangement permits the controller **1001** of the robotic system **1000** to provide control signals to the electronic control circuit **3020** of the surgical tool **3000**. While the interface is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

Control circuit **3020** is shown in schematic form in FIG. **52**. In one form or embodiment, the control circuit **3020** includes a power supply in the form of a battery **3022** that is coupled to an on-off solenoid powered switch **3024**. Control circuit **3020** further includes an on/off firing solenoid **3026** that is coupled to a double pole switch **3028** for controlling the rotational direction of the motor **3011**. Thus, when the controller **1001** of the robotic system **1000** supplies an appropriate control signal, switch **3024** will permit battery **3022** to supply power to the double pole switch **3028**. The controller **1001** of the robotic system **1000** will also supply an appropriate signal to the double pole switch **3028** to supply power to the motor **3011**. When it is desired to fire the surgical end effector (i.e., drive the cutting instrument **3002** distally through tissue clamped in the surgical end effector, the double pole switch **3028** will be in a first position. When it is desired to retract the cutting instrument **3002** to the starting position, the double pole switch **3028** will be moved to the second position by the controller **1001**.

Various embodiments of the surgical tool **3000** also employ a gear box **3030** that is sized, in cooperation with a firing gear train **3031** that, in at least one non-limiting embodiment, comprises a firing drive gear **3032** that is in meshing engagement with a firing driven gear **3034** for generating a desired amount of driving force necessary to drive the cutting instrument **3002** through tissue and to drive and form staples in the various manners described herein. In the embodiment depicted in FIG. **52**, the driven gear **3034** is coupled to a screw shaft **3036** that is in threaded engagement with a screw nut arrangement **3038** that is constrained to move axially (represented by arrow "D"). The screw nut arrangement **3038** is

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attached to the firing bar **3003**. Thus, by rotating the screw shaft **3036** in a first direction, the cutting instrument **3002** is driven in the distal direction "DD" and rotating the screw shaft in an opposite second direction, the cutting instrument **3002** may be retracted in the proximal direction "PD".

FIG. **53** illustrates a portion of another surgical tool **3000'** that is substantially identical to tool **3000** described above, except that the driven gear **3034** is attached to a drive shaft **3040**. The drive shaft **3040** is attached to a second driver gear **3042** that is in meshing engagement with a third driven gear **3044** that is in meshing engagement with a screw **3046** coupled to the firing bar **3003**.

FIG. **54** illustrates another surgical tool **3200** that may be effectively used in connection with a robotic system **1000**. In this embodiment, the surgical tool **3200** includes a surgical end effector **3212** that in one non-limiting form, comprises a component portion that is selectively movable between first and second positions relative to at least one other end effector component portion. As will be discussed in further detail below, the surgical tool **3200** employs on-board motors for powering various components of a transmission arrangement **3305**. The surgical end effector **3212** includes an elongated channel **3222** that operably supports a surgical staple cartridge **3234**. The elongated channel **3222** has a proximal end **3223** that slidably extends into a hollow elongated shaft assembly **3208** that is coupled to a tool mounting portion **3300**. In addition, the surgical end effector **3212** includes an anvil **3224** that is pivotally coupled to the elongated channel **3222** by a pair of trunnions **3225** that are received within corresponding openings **3229** in the elongated channel **3222**. A distal end portion **3209** of the shaft assembly **3208** includes an opening **3245** into which a tab **3227** on the anvil **3224** is inserted in order to open the anvil **3224** as the elongated channel **3222** is moved axially in the proximal direction "PD" relative to the distal end portion **3209** of the shaft assembly **3208**. In various embodiments, a spring (not shown) may be employed to bias the anvil **3224** to the open position.

As indicated above, the surgical tool **3200** includes a tool mounting portion **3300** that includes a tool mounting plate **3302** that is configured to operably support the transmission arrangement **3305** and to mountingly interface with the adaptor portion **1240'** which is coupled to the robotic system **1000** in the various manners described above. In at least one embodiment, the adaptor portion **1240'** may be identical to the adaptor portion **1240** described in detail above without the powered disc members employed by adapter **1240**. In other embodiments, the adaptor portion **1240'** may be identical to adaptor portion **1240**. However, in such embodiments, because the various components of the surgical end effector **3212** are all powered by motor(s) in the tool mounting portion **3300**, the surgical tool **3200** will not employ or require any of the mechanical (i.e., non-electrical) actuation motions from the tool holder portion **1270** to power the surgical end effector **3200** components. Still other modifications which are considered to be within the spirit and scope of the various forms of the present invention may employ one or more of the mechanical motions from the tool holder portion **1270** (as described hereinabove) to power/actuate one or more of the surgical end effector components while also employing one or more motors within the tool mounting portion to power one or more other components of the surgical end effector.

In various embodiments, the tool mounting plate **3302** is configured to support a first firing motor **3310** for supplying firing and retraction motions to the transmission arrangement **3305** to drive a knife bar **3335** that is coupled to a cutting instrument **3332** of the type described above. As can be seen in FIG. **54**, the tool mounting plate **3212** has an array of

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electrical connecting pins **3014** which are configured to interface with the slots **1258** (FIG. 21) in the adapter **1240'**. Such arrangement permits the controller **1001** of the robotic system **1000** to provide control signals to the electronic control circuits **3320**, **3340** of the surgical tool **3200**. While the interface is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

In one form or embodiment, the first control circuit **3320** includes a first power supply in the form of a first battery **3322** that is coupled to a first on-off solenoid powered switch **3324**. The first firing control circuit **3320** further includes a first on/off firing solenoid **3326** that is coupled to a first double pole switch **3328** for controlling the rotational direction of the first firing motor **3310**. Thus, when the robotic controller **1001** supplies an appropriate control signal, the first switch **3324** will permit the first battery **3322** to supply power to the first double pole switch **3328**. The robotic controller **1001** will also supply an appropriate signal to the first double pole switch **3328** to supply power to the first firing motor **3310**. When it is desired to fire the surgical end effector (i.e., drive the cutting instrument **3232** distally through tissue clamped in the surgical end effector **3212**, the first switch **3328** will be positioned in a first position by the robotic controller **1001**. When it is desired to retract the cutting instrument **3232** to the starting position, the robotic controller **1001** will send the appropriate control signal to move the first switch **3328** to the second position.

Various embodiments of the surgical tool **3200** also employ a first gear box **3330** that is sized, in cooperation with a firing drive gear **3332** coupled thereto that operably interfaces with a firing gear train **3333**. In at least one non-limiting embodiment, the firing gear train **333** comprises a firing driven gear **3334** that is in meshing engagement with drive gear **3332**, for generating a desired amount of driving force necessary to drive the cutting instrument **3232** through tissue and to drive and form staples in the various manners described herein. In the embodiment depicted in FIG. 54, the driven gear **3334** is coupled to a drive shaft **3335** that has a second driven gear **3336** coupled thereto. The second driven gear **3336** is supported in meshing engagement with a third driven gear **3337** that is in meshing engagement with a fourth driven gear **3338**. The fourth driven gear **3338** is in meshing engagement with a threaded proximal portion **3339** of the knife bar **3235** that is constrained to move axially. Thus, by rotating the drive shaft **3335** in a first direction, the cutting instrument **3232** is driven in the distal direction "DD" and rotating the drive shaft **3335** in an opposite second direction, the cutting instrument **3232** may be retracted in the proximal direction "PD".

As indicated above, the opening and closing of the anvil **3224** is controlled by axially moving the elongated channel **3222** relative to the elongated shaft assembly **3208**. The axial movement of the elongated channel **3222** is controlled by a closure control system **3339**. In various embodiments, the closure control system **3339** includes a closure shaft **3340** which has a hollow threaded end portion **3341** that threadably engages a threaded closure rod **3342**. The threaded end portion **3341** is rotatably supported in a spine shaft **3343** that operably interfaces with the tool mounting portion **3300** and extends through a portion of the shaft assembly **3208** as shown. The closure system **3339** further comprises a closure control circuit **3350** that includes a second power supply in the form of a second battery **3352** that is coupled to a second on-off solenoid powered switch **3354**. Closure control circuit **3350** further includes a second on/off firing solenoid **3356** that is coupled to a second double pole switch **3358** for

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controlling the rotation of a second closure motor **3360**. Thus, when the robotic controller **1001** supplies an appropriate control signal, the second switch **3354** will permit the second battery **3352** to supply power to the second double pole switch **3354**. The robotic controller **1001** will also supply an appropriate signal to the second double pole switch **3358** to supply power to the second motor **3360**. When it is desired to close the anvil **3224**, the second switch **3348** will be in a first position. When it is desired to open the anvil **3224**, the second switch **3348** will be moved to a second position.

Various embodiments of tool mounting portion **3300** also employ a second gear box **3362** that is coupled to a closure drive gear **3364**. The closure drive gear **3364** is in meshing engagement with a closure gear train **3363**. In various non-limiting forms, the closure gear train **3363** includes a closure driven gear **3365** that is attached to a closure drive shaft **3366**. Also attached to the closure drive shaft **3366** is a closure drive gear **3367** that is in meshing engagement with a closure shaft gear **3360** attached to the closure shaft **3340**. FIG. 54 depicts the end effector **3212** in the open position. As indicated above, when the threaded closure rod **3342** is in the position depicted in FIG. 54, a spring (not shown) biases the anvil **3224** to the open position. When it is desired to close the anvil **3224**, the robotic controller **1001** will activate the second motor **3360** to rotate the closure shaft **3340** to draw the threaded closure rod **3342** and the channel **3222** in the proximal direction "PD". As the anvil **3224** contacts the distal end portion **3209** of the shaft **3208**, the anvil **3224** is pivoted to the closed position.

A method of operating the surgical tool **3200** will now be described. Once the tool mounting portion **3302** has been operably coupled to the tool holder **1270** of the robotic system **1000**, the robotic system **1000** can orient the end effector **3212** in position adjacent the target tissue to be cut and stapled. If the anvil **3224** is not already in the open position, the robotic controller **1001** may activate the second closure motor **3360** to drive the channel **3222** in the distal direction to the position depicted in FIG. 54. Once the robotic controller **1001** determines that the surgical end effector **3212** is in the open position by sensor(s) in the end effector and/or the tool mounting portion **3300**, the robotic controller **1001** may provide the surgeon with a signal to inform the surgeon that the anvil **3224** may then be closed. Once the target tissue is positioned between the open anvil **3224** and the surgical staple cartridge **3234**, the surgeon may then commence the closure process by activating the robotic controller **1001** to apply a closure control signal to the second closure motor **3360**. The second closure motor **3360** applies a rotary motion to the closure shaft **3340** to draw the channel **3222** in the proximal direction "PD" until the anvil **3224** has been pivoted to the closed position. Once the robotic controller **1001** determines that the anvil **3224** has been moved to the closed position by sensor(s) in the surgical end effector **3212** and/or in the tool mounting portion **3300** that are in communication with the robotic control system, the motor **3360** may be deactivated. Thereafter, the firing process may be commenced either manually by the surgeon activating a trigger, button, etc. on the controller **1001** or the controller **1001** may automatically commence the firing process.

To commence the firing process, the robotic controller **1001** activates the firing motor **3310** to drive the firing bar **3235** and the cutting instrument **3232** in the distal direction "DD". Once robotic controller **1001** has determined that the cutting instrument **3232** has moved to the ending position within the surgical staple cartridge **3234** by means of sensors in the surgical end effector **3212** and/or the motor drive portion **3300**, the robotic controller **1001** may provide the surgeon with an indication signal. Thereafter the surgeon may

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manually activate the first motor **3310** to retract the cutting instrument **3232** to the starting position or the robotic controller **1001** may automatically activate the first motor **3310** to retract the cutting element **3232**.

The embodiment depicted in FIG. **54** does not include an articulation joint. FIGS. **55** and **56** illustrate surgical tools **3200'** and **3200"** that have end effectors **3212'**, **3212"**, respectively that may be employed with an elongated shaft embodiment that has an articulation joint of the various types disclosed herein. For example, as can be seen in FIG. **55**, a threaded closure shaft **3342** is coupled to the proximal end **3223** of the elongated channel **3222** by a flexible cable or other flexible member **3345**. The location of an articulation joint (not shown) within the elongated shaft assembly **3208** will coincide with the flexible member **3345** to enable the flexible member **3345** to accommodate such articulation. In addition, in the above-described embodiment, the flexible member **3345** is rotatably affixed to the proximal end portion **3223** of the elongated channel **3222** to enable the flexible member **3345** to rotate relative thereto to prevent the flexible member **3229** from "winding up" relative to the channel **3222**. Although not shown, the cutting element may be driven in one of the above described manners by a knife bar that can also accommodate articulation of the elongated shaft assembly. FIG. **56** depicts a surgical end effector **3212"** that is substantially identical to the surgical end effector **3212** described above, except that the threaded closure rod **3342** is attached to a closure nut **3347** that is constrained to only move axially within the elongated shaft assembly **3208**. The flexible member **3345** is attached to the closure nut **3347**. Such arrangement also prevents the threaded closure rod **3342** from winding-up the flexible member **3345**. A flexible knife bar **3235'** may be employed to facilitate articulation of the surgical end effector **3212"**.

The surgical tools **3200**, **3200'**, and **3200"** described above may also employ anyone of the cutting instrument embodiments described herein. As described above, the anvil of each of the end effectors of these tools is closed by drawing the elongated channel into contact with the distal end of the elongated shaft assembly. Thus, once the target tissue has been located between the staple cartridge **3234** and the anvil **3224**, the robotic controller **1001** can start to draw the channel **3222** inward into the shaft assembly **3208**. In various embodiments, however, to prevent the end effector **3212**, **3212'**, **3212"** from moving the target tissue with the end effector during this closing process, the controller **1001** may simultaneously move the tool holder and ultimately the tool such to compensate for the movement of the elongated channel **3222** so that, in effect, the target tissue is clamped between the anvil and the elongated channel without being otherwise moved.

FIGS. **57-59** depict another surgical tool embodiment **3201** that is substantially identical to surgical tool **3200"** described above, except for the differences discussed below. In this embodiment, the threaded closure rod **3342'** has variable pitched grooves. More specifically, as can be seen in FIG. **58**, the closure rod **3342'** has a distal groove section **3380** and a proximal groove section **3382**. The distal and proximal groove sections **3380**, **3382** are configured for engagement with a lug **3390** supported within the hollow threaded end portion **3341'**. As can be seen in FIG. **58**, the distal groove section **3380** has a finer pitch than the groove section **3382**. Thus, such variable pitch arrangement permits the elongated channel **3222** to be drawn into the shaft **3208** at a first speed or rate by virtue of the engagement between the lug **3390** and the proximal groove segment **3382**. When the lug **3390** engages the distal groove segment, the channel **3222** will be drawn into the shaft **3208** at a second speed or rate. Because

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the proximal groove segment **3382** is coarser than the distal groove segment **3380**, the first speed will be greater than the second speed. Such arrangement serves to speed up the initial closing of the end effector for tissue manipulation and then after the tissue has been properly positioned therein, generate the amount of closure forces to properly clamp the tissue for cutting and sealing. Thus, the anvil **3234** initially closes fast with a lower force and then applies a higher closing force as the anvil closes more slowly.

The surgical end effector opening and closing motions are employed to enable the user to use the end effector to grasp and manipulate tissue prior to fully clamping it in the desired location for cutting and sealing. The user may, for example, open and close the surgical end effector numerous times during this process to orient the end effector in a proper position which enables the tissue to be held in a desired location. Thus, in at least some embodiments, to produce the high loading for firing, the fine thread may require as many as 5-10 full rotations to generate the necessary load. In some cases, for example, this action could take as long as 2-5 seconds. If it also took an equally long time to open and close the end effector each time during the positioning/tissue manipulation process, just positioning the end effector may take an undesirably long time. If that happens, it is possible that a user may abandon such use of the end effector for use of a conventional grasper device. Use of graspers, etc. may undesirably increase the costs associated with completing the surgical procedure.

The above-described embodiments employ a battery or batteries to power the motors used to drive the end effector components. Activation of the motors is controlled by the robotic system **1000**. In alternative embodiments, the power supply may comprise alternating current "AC" that is supplied to the motors by the robotic system **1000**. That is, the AC power would be supplied from the system powering the robotic system **1000** through the tool holder and adapter. In still other embodiments, a power cord or tether may be attached to the tool mounting portion **3300** to supply the requisite power from a separate source of alternating or direct current.

In use, the controller **1001** may apply an initial rotary motion to the closure shaft **3340** (FIG. **54**) to draw the elongated channel **3222** axially inwardly into the elongated shaft assembly **3208** and move the anvil from a first position to an intermediate position at a first rate that corresponds with the point wherein the distal groove section **3380** transitions to the proximal groove section **3382**. Further application of rotary motion to the closure shaft **3340** will cause the anvil to move from the intermediate position to the closed position relative to the surgical staple cartridge. When in the closed position, the tissue to be cut and stapled is properly clamped between the anvil and the surgical staple cartridge.

FIGS. **60-64** illustrate another surgical tool embodiment **3400** of the present invention. This embodiment includes an elongated shaft assembly **3408** that extends from a tool mounting portion **3500**. The elongated shaft assembly **3408** includes a rotatable proximal closure tube segment **3410** that is rotatably journaled on a proximal spine member **3420** that is rigidly coupled to a tool mounting plate **3502** of the tool mounting portion **3500**. The proximal spine member **3420** has a distal end **3422** that is coupled to an elongated channel portion **3522** of a surgical end effector **3412**. For example, in at least one embodiment, the elongated channel portion **3522** has a distal end portion **3523** that "hookingly engages" the distal end **3422** of the spine member **3420**. The elongated channel **3522** is configured to support a surgical staple cartridge **3534** therein. This embodiment may employ one of the

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various cutting instrument embodiments disclosed herein to sever tissue that is clamped in the surgical end effector **3412** and fire the staples in the staple cartridge **3534** into the severed tissue.

Surgical end effector **3412** has an anvil **3524** that is pivotally coupled to the elongated channel **3522** by a pair of trunnions **3525** that are received in corresponding openings **3529** in the elongated channel **3522**. The anvil **3524** is moved between the open (FIG. **60**) and closed positions (FIGS. **61-63**) by a distal closure tube segment **3430**. A distal end portion **3432** of the distal closure tube segment **3430** includes an opening **3445** into which a tab **3527** on the anvil **3524** is inserted in order to open and close the anvil **3524** as the distal closure tube segment **3430** moves axially relative thereto. In various embodiments, the opening **3445** is shaped such that as the closure tube segment **3430** is moved in the proximal direction, the closure tube segment **3430** causes the anvil **3524** to pivot to an open position. In addition or in the alternative, a spring (not shown) may be employed to bias the anvil **3524** to the open position.

As can be seen in FIGS. **60-63**, the distal closure tube segment **3430** includes a lug **3442** that extends from its distal end **3440** into threaded engagement with a variable pitch groove/thread **3414** formed in the distal end **3412** of the rotatable proximal closure tube segment **3410**. The variable pitch groove/thread **3414** has a distal section **3416** and a proximal section **3418**. The pitch of the distal groove/thread section **3416** is finer than the pitch of the proximal groove/thread section **3418**. As can also be seen in FIGS. **60-63**, the distal closure tube segment **3430** is constrained for axial movement relative to the spine member **3420** by an axial retainer pin **3450** that is received in an axial slot **3424** in the distal end of the spine member **3420**.

As indicated above, the anvil **3524** is open and closed by rotating the proximal closure tube segment **3410**. The variable pitch thread arrangement permits the distal closure tube segment **3430** to be driven in the distal direction "DD" at a first speed or rate by virtue of the engagement between the lug **3442** and the proximal groove/thread section **3418**. When the lug **3442** engages the distal groove/thread section **3416**, the distal closure tube segment **3430** will be driven in the distal direction at a second speed or rate. Because the proximal groove/thread section **3418** is coarser than the distal groove/thread segment **3416**, the first speed will be greater than the second speed.

In at least one embodiment, the tool mounting portion **3500** is configured to receive a corresponding first rotary motion from the robotic controller **1001** and convert that first rotary motion to a primary rotary motion for rotating the rotatable proximal closure tube segment **3410** about a longitudinal tool axis LT-LT. As can be seen in FIG. **64**, a proximal end **3460** of the proximal closure tube segment **3410** is rotatably supported within a cradle arrangement **3504** attached to a tool mounting plate **3502** of the tool mounting portion **3500**. A rotation gear **3462** is formed on or attached to the proximal end **3460** of the closure tube segment **3410** for meshing engagement with a rotation drive assembly **3470** that is operably supported on the tool mounting plate **3502**. In at least one embodiment, a rotation drive gear **3472** is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **3502** when the tool mounting portion **3500** is coupled to the tool holder **1270**. See FIGS. **22** and **64**. The rotation drive assembly **3470** further comprises a rotary driven gear **3474** that is rotatably supported on the tool mounting plate **3502** in meshing engagement with the rotation gear **3462** and the rotation drive gear **3472**. Application of a first rotary control motion from the

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robotic controller **1001** through the tool holder **1270** and the adapter **1240** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **3472** by virtue of being operably coupled thereto. Rotation of the rotation drive gear **3472** ultimately results in the rotation of the closure tube segment **3410** to open and close the anvil **3524** as described above.

As indicated above, the surgical end effector **3412** employs a cutting instrument of the type and constructions described above. FIG. **64** illustrates one form of knife drive assembly **3480** for axially advancing a knife bar **3492** that is attached to such cutting instrument. One form of the knife drive assembly **3480** comprises a rotary drive gear **3482** that is coupled to a corresponding third one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **3502** when the tool drive portion **3500** is coupled to the tool holder **1270**. See FIGS. **22** and **64**. The knife drive assembly **3480** further comprises a first rotary driven gear assembly **3484** that is rotatably supported on the tool mounting plate **5200**. The first rotary driven gear assembly **3484** is in meshing engagement with a third rotary driven gear assembly **3486** that is rotatably supported on the tool mounting plate **3502** and which is in meshing engagement with a fourth rotary driven gear assembly **3488** that is in meshing engagement with a threaded portion **3494** of drive shaft assembly **3490** that is coupled to the knife bar **3492**. Rotation of the rotary drive gear **3482** in a second rotary direction will result in the axial advancement of the drive shaft assembly **3490** and knife bar **3492** in the distal direction "DD". Conversely, rotation of the rotary drive gear **3482** in a secondary rotary direction (opposite to the second rotary direction) will cause the drive shaft assembly **3490** and the knife bar **3492** to move in the proximal direction.

FIGS. **65-74** illustrate another surgical tool **3600** embodiment of the present invention that may be employed in connection with a robotic system **1000**. As can be seen in FIG. **65**, the tool **3600** includes an end effector in the form of a disposable loading unit **3612**. Various forms of disposable loading units that may be employed in connection with tool **3600** are disclosed, for example, in U.S. Patent Application Publication No. US 2009/0206131 A1, entitled END EFFECTOR ARRANGEMENTS FOR A SURGICAL CUTTING AND STAPLING INSTRUMENT, which published on Aug. 20, 2009, the disclosure of which is herein incorporated by reference in its entirety.

In at least one form, the disposable loading unit **3612** includes an anvil assembly **3620** that is supported for pivotal travel relative to a carrier **3630** that operably supports a staple cartridge **3640** therein. A mounting assembly **3650** is pivotally coupled to the cartridge carrier **3630** to enable the carrier **3630** to pivot about an articulation axis AA-AA relative to a longitudinal tool axis LT-LT. Referring to FIG. **70**, mounting assembly **3650** includes upper and lower mounting portions **3652** and **3654**. Each mounting portion includes a threaded bore **3656** on each side thereof dimensioned to receive threaded bolts (not shown) for securing the proximal end of carrier **3630** thereto. A pair of centrally located pivot members **3658** extends between upper and lower mounting portions via a pair of coupling members **3660** which engage a distal end of a housing portion **3662**. Coupling members **3660** each include an interlocking proximal portion **3664** configured to be received in grooves **3666** formed in the proximal end of housing portion **3662** to retain mounting assembly **3650** and housing portion **3662** in a longitudinally fixed position in relation thereto.

In various forms, housing portion **3662** of disposable loading unit **3614** includes an upper housing half **3670** and a lower housing half **3672** contained within an outer casing **3674**. The

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proximal end of housing half **3670** includes engagement nubs **3676** for releasably engaging an elongated shaft **3700** and an insertion tip **3678**. Nubs **3676** form a bayonet-type coupling with the distal end of the elongated shaft **3700** which will be discussed in further detail below. Housing halves **3670**, **3672** define a channel **3674** for slidably receiving axial drive assembly **3680**. A second articulation link **3690** is dimensioned to be slidably positioned within a slot **3679** formed between housing halves **3670**, **3672**. A pair of blow out plates **3691** are positioned adjacent the distal end of housing portion **3662** adjacent the distal end of axial drive assembly **3680** to prevent outward bulging of drive assembly **3680** during articulation of carrier **3630**.

In various embodiments, the second articulation link **3690** includes at least one elongated metallic plate. Preferably, two or more metallic plates are stacked to form link **3690**. The proximal end of articulation link **3690** includes a hook portion **3692** configured to engage first articulation link **3710** extending through the elongated shaft **3700**. The distal end of the second articulation link **3690** includes a loop **3694** dimensioned to engage a projection formed on mounting assembly **3650**. The projection is laterally offset from pivot pin **3658** such that linear movement of second articulation link **3690** causes mounting assembly **3650** to pivot about pivot pins **3658** to articulate the carrier **3630**.

In various forms, axial drive assembly **3680** includes an elongated drive beam **3682** including a distal working head **3684** and a proximal engagement section **3685**. Drive beam **3682** may be constructed from a single sheet of material or, preferably, multiple stacked sheets. Engagement section **3685** includes a pair of engagement fingers which are dimensioned and configured to mountingly engage a pair of corresponding retention slots formed in drive member **3686**. Drive member **3686** includes a proximal porthole **3687** configured to receive the distal end **3722** of control rod **2720** (See FIG. **74**) when the proximal end of disposable loading unit **3614** is engaged with elongated shaft **3700** of surgical tool **3600**.

Referring to FIGS. **65** and **72-74**, to use the surgical tool **3600**, a disposable loading unit **3612** is first secured to the distal end of elongated shaft **3700**. It will be appreciated that the surgical tool **3600** may include an articulating or a non-articulating disposable loading unit. To secure the disposable loading unit **3612** to the elongated shaft **3700**, the distal end **3722** of control rod **3720** is inserted into insertion tip **3678** of disposable loading unit **3612**, and insertion tip **3678** is slid longitudinally into the distal end of the elongated shaft **3700** in the direction indicated by arrow "A" in FIG. **72** such that hook portion **3692** of second articulation link **3690** slides within a channel **3702** in the elongated shaft **3700**. Nubs **3676** will each be aligned in a respective channel (not shown) in elongated shaft **3700**. When hook portion **3692** engages the proximal wall **3704** of channel **3702**, disposable loading unit **3612** is rotated in the direction indicated by arrow "B" in FIGS. **71** and **74** to move hook portion **3692** of second articulation link **3690** into engagement with finger **3712** of first articulation link **3710**. Nubs **3676** also form a "bayonet-type" coupling within annular channel **3703** in the elongated shaft **3700**. During rotation of loading unit **3612**, nubs **3676** engage cam surface **3732** (FIG. **72**) of block plate **3730** to initially move plate **3730** in the direction indicated by arrow "C" in FIG. **72** to lock engagement member **3734** in recess **3721** of control rod **3720** to prevent longitudinal movement of control rod **3720** during attachment of disposable loading unit **3612**. During the final degree of rotation, nubs **3676** disengage from cam surface **3732** to allow blocking plate **3730** to move in the direction indicated by arrow "D" in FIGS. **71** and **74** from behind engagement member **3734** to once again permit lon-

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gitudinal movement of control rod **3720**. While the above-described attachment method reflects that the disposable loading unit **3612** is manipulated relative to the elongated shaft **3700**, the person of ordinary skill in the art will appreciate that the disposable loading unit **3612** may be supported in a stationary position and the robotic system **1000** may manipulate the elongated shaft portion **3700** relative to the disposable loading unit **3612** to accomplish the above-described coupling procedure.

FIG. **75** illustrates another disposable loading unit **3612'** that is attachable in a bayonet-type arrangement with the elongated shaft **3700'** that is substantially identical to shaft **3700** except for the differences discussed below. As can be seen in FIG. **75**, the elongated shaft **3700'** has slots **3705** that extend for at least a portion thereof and which are configured to receive nubs **3676** therein. In various embodiments, the disposable loading unit **3612'** includes arms **3677** extending therefrom which, prior to the rotation of disposable loading unit **3612'**, can be aligned, or at least substantially aligned, with nubs **3676** extending from housing portion **3662**. In at least one embodiment, arms **3677** and nubs **3676** can be inserted into slots **3705** in elongated shaft **3700'**, for example, when disposable loading unit **3612'** is inserted into elongated shaft **3700'**. When disposable loading unit **3612'** is rotated, arms **3677** can be sufficiently confined within slots **3705** such that slots **3705** can hold them in position, whereas nubs **3676** can be positioned such that they are not confined within slots **3705** and can be rotated relative to arms **3677**. When rotated, the hook portion **3692** of the articulation link **3690** is engaged with the first articulation link **3710** extending through the elongated shaft **3700'**.

Other methods of coupling the disposable loading units to the end of the elongated shaft may be employed. For example, as shown in FIGS. **76** and **77**, disposable loading unit **3612"** can include connector portion **3613** which can be configured to be engaged with connector portion **3740** of the elongated shaft **3700"**. In at least one embodiment, connector portion **3613** can include at least one projection and/or groove which can be mated with at least one projection and/or groove of connector portion **3740**. In at least one such embodiment, the connector portions can include co-operating dovetail portions. In various embodiments, the connector portions can be configured to interlock with one another and prevent, or at least inhibit, distal and/or proximal movement of disposable loading unit **3612"** along axis **3741**. In at least one embodiment, the distal end of the axial drive assembly **3680'** can include aperture **3681** which can be configured to receive projection **3721** extending from control rod **3720'**. In various embodiments, such an arrangement can allow disposable loading unit **3612"** to be assembled to elongated shaft **3700** in a direction which is not collinear with or parallel to axis **3741**. Although not illustrated, axial drive assembly **3680'** and control rod **3720** can include any other suitable arrangement of projections and apertures to operably connect them to each other. Also in this embodiment, the first articulation link **3710** which can be operably engaged with second articulation link **3690**.

As can be seen in FIGS. **65** and **78**, the surgical tool **3600** includes a tool mounting portion **3750**. The tool mounting portion **3750** includes a tool mounting plate **3751** that is configured for attachment to the tool drive assembly **1010**. The tool mounting portion operably supported a transmission arrangement **3752** thereon. In use, it may be desirable to rotate the disposable loading unit **3612** about the longitudinal tool axis defined by the elongated shaft **3700**. In at least one embodiment, the transmission arrangement **3752** includes a rotational transmission assembly **3753** that is configured to

receive a corresponding rotary output motion from the tool drive assembly 1010 of the robotic system 1000 and convert that rotary output motion to a rotary control motion for rotating the elongated shaft 3700 (and the disposable loading unit 3612) about the longitudinal tool axis LT-LT. As can be seen in FIG. 78, a proximal end 3701 of the elongated shaft 3700 is rotatably supported within a cradle arrangement 3754 that is attached to the tool mounting plate 3751 of the tool mounting portion 3750. A rotation gear 3755 is formed on or attached to the proximal end 3701 of the elongated shaft 3700 for meshing engagement with a rotation gear assembly 3756 operably supported on the tool mounting plate 3751. In at least one embodiment, a rotation drive gear 3757 drivingly coupled to a corresponding first one of the driven discs or elements 1304 on the adapter side of the tool mounting plate 3751 when the tool mounting portion 3750 is coupled to the tool drive assembly 1010. The rotation transmission assembly 3753 further comprises a rotary driven gear 3758 that is rotatably supported on the tool mounting plate 3751 in meshing engagement with the rotation gear 3755 and the rotation drive gear 3757. Application of a first rotary output motion from the robotic system 1000 through the tool drive assembly 1010 to the corresponding driven element 1304 will thereby cause rotation of the rotation drive gear 3757 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 3757 ultimately results in the rotation of the elongated shaft 3700 (and the disposable loading unit 3612) about the longitudinal tool axis LT-LT (primary rotary motion).

As can be seen in FIG. 78, a drive shaft assembly 3760 is coupled to a proximal end of the control rod 2720. In various embodiments, the control rod 2720 is axially advanced in the distal and proximal directions by a knife/closure drive transmission 3762. One form of the knife/closure drive assembly 3762 comprises a rotary drive gear 3763 that is coupled to a corresponding second one of the driven rotatable body portions, discs or elements 1304 on the adapter side of the tool mounting plate 3751 when the tool mounting portion 3750 is coupled to the tool holder 1270. The rotary driven gear 3763 is in meshing driving engagement with a gear train, generally depicted as 3764. In at least one form, the gear train 3764 further comprises a first rotary driven gear assembly 3765 that is rotatably supported on the tool mounting plate 3751. The first rotary driven gear assembly 3765 is in meshing engagement with a second rotary driven gear assembly 3766 that is rotatably supported on the tool mounting plate 3751 and which is in meshing engagement with a third rotary driven gear assembly 3767 that is in meshing engagement with a threaded portion 3768 of the drive shaft assembly 3760. Rotation of the rotary drive gear 3763 in a second rotary direction will result in the axial advancement of the drive shaft assembly 3760 and control rod 2720 in the distal direction "DD". Conversely, rotation of the rotary drive gear 3763 in a secondary rotary direction which is opposite to the second rotary direction will cause the drive shaft assembly 3760 and the control rod 2720 to move in the proximal direction. When the control rod 2720 moves in the distal direction, it drives the drive beam 3682 and the working head 3684 thereof distally through the surgical staple cartridge 3640. As the working head 3684 is driven distally, it operably engages the anvil 3620 to pivot it to a closed position.

The cartridge carrier 3630 may be selectively articulated about articulation axis AA-AA by applying axial articulation control motions to the first and second articulation links 3710 and 3690. In various embodiments, the transmission arrangement 3752 further includes an articulation drive 3770 that is operably supported on the tool mounting plate 3751. More specifically and with reference to FIG. 78, it can be seen that

a proximal end portion 3772 of an articulation drive shaft 3771 configured to operably engage with the first articulation link 3710 extends through the rotation gear 3755 and is rotatably coupled to a shifter rack gear 3774 that is slidably affixed to the tool mounting plate 3751 through slots 3775. The articulation drive 3770 further comprises a shifter drive gear 3776 that is coupled to a corresponding third one of the driven discs or elements 1304 on the adapter side of the tool mounting plate 3751 when the tool mounting portion 3750 is coupled to the tool holder 1270. The articulation drive assembly 3770 further comprises a shifter driven gear 3778 that is rotatably supported on the tool mounting plate 3751 in meshing engagement with the shifter drive gear 3776 and the shifter rack gear 3774. Application of a third rotary output motion from the robotic system 1000 through the tool drive assembly 1010 to the corresponding driven element 1304 will thereby cause rotation of the shifter drive gear 3776 by virtue of being operably coupled thereto. Rotation of the shifter drive gear 3776 ultimately results in the axial movement of the shifter gear rack 3774 and the articulation drive shaft 3771. The direction of axial travel of the articulation drive shaft 3771 depends upon the direction in which the shifter drive gear 3776 is rotated by the robotic system 1000. Thus, rotation of the shifter drive gear 3776 in a first rotary direction will result in the axial movement of the articulation drive shaft 3771 in the proximal direction "PD" and cause the cartridge carrier 3630 to pivot in a first direction about articulation axis AA-AA. Conversely, rotation of the shifter drive gear 3776 in a second rotary direction (opposite to the first rotary direction) will result in the axial movement of the articulation drive shaft 3771 in the distal direction "DD" to thereby cause the cartridge carrier 3630 to pivot about articulation axis AA-AA in an opposite direction.

FIG. 79 illustrates yet another surgical tool 3800 embodiment of the present invention that may be employed with a robotic system 1000. As can be seen in FIG. 79, the surgical tool 3800 includes a surgical end effector 3812 in the form of an endocutter 3814 that employs various cable-driven components. Various forms of cable driven endocutters are disclosed, for example, in U.S. Pat. No. 7,726,537, entitled SURGICAL STAPLER WITH UNIVERSAL ARTICULATION AND TISSUE PRE-CLAMP, which issued on Jun. 1, 2010, and U.S. Patent Application Publication No. US 2008/0308603A1, entitled CABLE DRIVEN SURGICAL STAPLING AND CUTTING INSTRUMENT WITH IMPROVED CABLE ATTACHMENT ARRANGEMENTS, which published on Dec. 18, 2008, the disclosures of each are herein incorporated by reference in their respective entireties. Such endocutters 3814 may be referred to as a "disposable loading unit" because they are designed to be disposed of after a single use. However, the various unique and novel arrangements of various embodiments of the present invention may also be employed in connection with cable driven end effectors that are reusable.

As can be seen in FIG. 79, in at least one form, the endocutter 3814 includes an elongated channel 3822 that operably supports a surgical staple cartridge 3834 therein. An anvil 3824 is pivotally supported for movement relative to the surgical staple cartridge 3834. The anvil 3824 has a cam surface 3825 that is configured for interaction with a pre-clamping collar 3840 that is supported for axial movement relative thereto. The end effector 3814 is coupled to an elongated shaft assembly 3808 that is attached to a tool mounting portion 3900. In various embodiments, a closure cable 3850 is employed to move pre-clamping collar 3840 distally onto and over cam surface 3825 to close the anvil 3824 relative to the surgical staple cartridge 3834 and compress the tissue there-

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ebetween. Preferably, closure cable **3850** attaches to the pre-clamping collar **3840** at or near point **3841** and is fed through a passageway in anvil **3824** (or under a proximal portion of anvil **3824**) and fed proximally through shaft **3808**. Actuation of closure cable **3850** in the proximal direction "PD" forces pre-clamping collar **3840** distally against cam surface **3825** to close anvil **3824** relative to staple cartridge assembly **3834**. A return mechanism, e.g., a spring, cable system or the like, may be employed to return pre-clamping collar **3840** to a pre-clamping orientation which re-opens the anvil **3824**.

The elongated shaft assembly **3808** may be cylindrical in shape and define a channel **3811** which may be dimensioned to receive a tube adapter **3870**. See FIG. **80**. In various embodiments, the tube adapter **3870** may be slidably received in friction-fit engagement with the internal channel of elongated shaft **3808**. The outer surface of the tube adapter **3870** may further include at least one mechanical interface, e.g., a cutout or notch **3871**, oriented to mate with a corresponding mechanical interface, e.g., a radially inwardly extending protrusion or detent (not shown), disposed on the inner periphery of internal channel **3811** to lock the tube adapter **3870** to the elongated shaft **3808**. In various embodiments, the distal end of tube adapter **3870** may include a pair of opposing flanges **3872a** and **3872b** which define a cavity for pivotably receiving a pivot block **3873** therein. Each flange **3872a** and **3872b** may include an aperture **3874a** and **3874b** that is oriented to receive a pivot pin **3875** that extends through an aperture in pivot block **3873** to allow pivotable movement of pivot block **3873** about an axis that is perpendicular to longitudinal tool axis "LT-LT". The channel **3822** may be formed with two upwardly extending flanges **3823a**, **3823b** that have apertures therein, which are dimensioned to receive a pivot pin **3827**. In turn, pivot pin **3875** mounts through apertures in pivot block **3873** to permit rotation of the surgical end effector **3814** about the "Y" axis as needed during a given surgical procedure. Rotation of pivot block **3873** about pin **3875** along "Z" axis rotates the surgical end effector **3814** about the "Z" axis. See FIG. **80**. Other methods of fastening the elongated channel **3822** to the pivot block **3873** may be effectively employed without departing from the spirit and scope of the present invention.

The surgical staple cartridge **3834** can be assembled and mounted within the elongated channel **3822** during the manufacturing or assembly process and sold as part of the surgical end effector **3812**, or the surgical staple cartridge **3834** may be designed for selective mounting within the elongated channel **3822** as needed and sold separately, e.g., as a single use replacement, replaceable or disposable staple cartridge assembly. It is within the scope of this disclosure that the surgical end effector **3812** may be pivotally, operatively, or integrally attached, for example, to distal end **3809** of the elongated shaft assembly **3808** of a disposable surgical stapler. As is known, a used or spent disposable loading unit **3814** can be removed from the elongated shaft assembly **3808** and replaced with an unused disposable unit. The endocutter **3814** may also preferably include an actuator, preferably a dynamic clamping member **3860**, a sled **3862**, as well as staple pushers (not shown) and staples (not shown) once an unspent or unused cartridge **3834** is mounted in the elongated channel **3822**. See FIG. **80**.

In various embodiments, the dynamic clamping member **3860** is associated with, e.g., mounted on and rides on, or with or is connected to or integral with and/or rides behind sled **3862**. It is envisioned that dynamic clamping member **3860** can have cam wedges or cam surfaces attached or integrally formed or be pushed by a leading distal surface thereof. In various embodiments, dynamic clamping member **3860** may

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include an upper portion **3863** having a transverse aperture **3864** with a pin **3865** mountable or mounted therein, a central support or upward extension **3866** and substantially T-shaped bottom flange **3867** which cooperate to slidably retain dynamic clamping member **3860** along an ideal cutting path during longitudinal, distal movement of sled **3862**. The leading cutting edge **3868**, here, knife blade **3869**, is dimensioned to ride within slot **3835** of staple cartridge assembly **3834** and separate tissue once stapled. As used herein, the term "knife assembly" may include the aforementioned dynamic clamping member **3860**, knife **3869**, and sled **3862** or other knife/beam/sled drive arrangements and cutting instrument arrangements. In addition, the various embodiments of the present invention may be employed with knife assembly/cutting instrument arrangements that may be entirely supported in the staple cartridge **3834** or partially supported in the staple cartridge **3834** and elongated channel **3822** or entirely supported within the elongated channel **3822**.

In various embodiments, the dynamic clamping member **3860** may be driven in the proximal and distal directions by a cable drive assembly **3870**. In one non-limiting form, the cable drive assembly comprises a pair of advance cables **3880**, **3882** and a firing cable **3884**. FIGS. **81** and **82** illustrate the cables **3880**, **3882**, **3884** in diagrammatic form. As can be seen in those Figures, a first advance cable **3880** is operably supported on a first distal cable transition support **3885** which may comprise, for example, a pulley, rod, capstan, etc. that is attached to the distal end of the elongated channel **3822** and a first proximal cable transition support **3886** which may comprise, for example, a pulley, rod, capstan, etc. that is operably supported by the elongated channel **3822**. A distal end **3881** of the first advance cable **3880** is affixed to the dynamic clamping assembly **3860**. The second advance cable **3882** is operably supported on a second distal cable transition support **3887** which may, for example, comprise a pulley, rod, capstan etc. that is mounted to the distal end of the elongated channel **3822** and a second proximal cable transition support **3888** which may, for example, comprise a pulley, rod, capstan, etc. mounted to the proximal end of the elongated channel **3822**. The proximal end **3883** of the second advance cable **3882** may be attached to the dynamic clamping assembly **3860**. Also in these embodiments, an endless firing cable **3884** is employed and journaled on a support **3889** that may comprise a pulley, rod, capstan, etc. mounted within the elongated shaft **3808**. In one embodiment, the retract cable **3884** may be formed in a loop and coupled to a connector **3889'** that is fixedly attached to the first and second advance cables **3880**, **3882**.

Various non-limiting embodiments of the present invention include a cable drive transmission **3920** that is operably supported on a tool mounting plate **3902** of the tool mounting portion **3900**. The tool mounting portion **3900** has an array of electrical connecting pins **3904** which are configured to interface with the slots **1258** (FIG. **21**) in the adapter **1240'**. Such arrangement permits the robotic system **1000** to provide control signals to a control circuit **3910** of the tool **3800**. While the interface is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

Control circuit **3910** is shown in schematic form in FIG. **79**. In one form or embodiment, the control circuit **3910** includes a power supply in the form of a battery **3912** that is coupled to an on-off solenoid powered switch **3914**. In other embodiments, however, the power supply may comprise a source of alternating current. Control circuit **3910** further includes an on/off solenoid **3916** that is coupled to a double pole switch

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3918 for controlling motor rotation direction. Thus, when the robotic system 1000 supplies an appropriate control signal, switch 3914 will permit battery 3912 to supply power to the double pole switch 3918. The robotic system 1000 will also supply an appropriate signal to the double pole switch 3918 to supply power to a shifter motor 3922.

Turning to FIGS. 83-88, at least one embodiment of the cable drive transmission 3920 comprises a drive pulley 3930 that is operably mounted to a drive shaft 3932 that is attached to a driven element 1304 of the type and construction described above that is designed to interface with a corresponding drive element 1250 of the adapter 1240. See FIGS. 18 and 84. Thus, when the tool mounting portion 3900 is operably coupled to the tool holder 1270, the robot system 1000 can apply rotary motion to the drive pulley 3930 in a desired direction. A first drive member or belt 3934 drivingly engages the drive pulley 3930 and a second drive shaft 3936 that is rotatably supported on a shifter yoke 3940. The shifter yoke 3940 is operably coupled to the shifter motor 3922 such that rotation of the shaft 3923 of the shifter motor 3922 in a first direction will shift the shifter yoke in a first direction “FD” and rotation of the shifter motor shaft 3923 in a second direction will shift the shifter yoke 3940 in a second direction “SD”. Other embodiments of the present invention may employ a shifter solenoid arrangement for shifting the shifter yoke in said first and second directions.

As can be seen in FIGS. 83-86, a closure drive gear 3950 mounted to a second drive shaft 3936 and is configured to selectively mesh with a closure drive assembly, generally designated as 3951. Likewise a firing drive gear 3960 is also mounted to the second drive shaft 3936 and is configured to selectively mesh with a firing drive assembly generally designated as 3961. Rotation of the second drive shaft 3936 causes the closure drive gear 3950 and the firing drive gear 3960 to rotate. In one non-limiting embodiment, the closure drive assembly 3951 comprises a closure driven gear 3952 that is coupled to a first closure pulley 3954 that is rotatably supported on a third drive shaft 3956. The closure cable 3850 is drivingly received on the first closure pulley 3954 such that rotation of the closure driven gear 3952 will drive the closure cable 3850. Likewise, the firing drive assembly 3961 comprises a firing driven gear 3962 that is coupled to a first firing pulley 3964 that is rotatably supported on the third drive shaft 3956. The first and second driving pulleys 3954 and 3964 are independently rotatable on the third drive shaft 3956. The firing cable 3884 is drivingly received on the first firing pulley 3964 such that rotation of the firing driven gear 3962 will drive the firing cable 3884.

Also in various embodiments, the cable drive transmission 3920 further includes a braking assembly 3970. In at least one embodiment, for example, the braking assembly 3970 includes a closure brake 3972 that comprises a spring arm 3973 that is attached to a portion of the transmission housing 3971. The closure brake 3972 has a gear lug 3974 that is sized to engage the teeth of the closure driven gear 3952 as will be discussed in further detail below. The braking assembly 3970 further includes a firing brake 3976 that comprises a spring arm 3977 that is attached to another portion of the transmission housing 3971. The firing brake 3976 has a gear lug 3978 that is sized to engage the teeth of the firing driven gear 3962.

At least one embodiment of the surgical tool 3800 may be used as follows. The tool mounting portion 3900 is operably coupled to the interface 1240 of the robotic system 1000. The controller or control unit of the robotic system is operated to locate the tissue to be cut and stapled between the open anvil 3824 and the staple cartridge 3834. When in that initial position, the braking assembly 3970 has locked the closure driven

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gear 3952 and the firing driven gear 3962 such that they cannot rotate. That is, as shown in FIG. 84, the gear lug 3974 is in locking engagement with the closure driven gear 3952 and the gear lug 3978 is in locking engagement with the firing driven gear 3962. Once the surgical end effector 3814 has been properly located, the controller 1001 of the robotic system 1000 will provide a control signal to the shifter motor 3922 (or shifter solenoid) to move the shifter yoke 3940 in the first direction. As the shifter yoke 3940 is moved in the first direction, the closure drive gear 3950 moves the gear lug 3974 out of engagement with the closure driven gear 3952 as it moves into meshing engagement with the closure driven gear 3952. As can be seen in FIG. 83, when in that position, the gear lug 3978 remains in locking engagement with the firing driven gear 3962 to prevent actuation of the firing system. Thereafter, the robotic controller 1001 provides a first rotary actuation motion to the drive pulley 3930 through the interface between the driven element 1304 and the corresponding components of the tool holder 1240. As the drive pulley 3930 is rotated in the first direction, the closure cable 3850 is rotated to drive the preclamping collar 3840 into closing engagement with the cam surface 3825 of the anvil 3824 to move it to the closed position thereby clamping the target tissue between the anvil 3824 and the staple cartridge 3834. See FIG. 79. Once the anvil 3824 has been moved to the closed position, the robotic controller 1001 stops the application of the first rotary motion to the drive pulley 3930. Thereafter, the robotic controller 1001 may commence the firing process by sending another control signal to the shifter motor 3922 (or shifter solenoid) to cause the shifter yoke to move in the second direction “SD” as shown in FIG. 94. As the shifter yoke 3940 is moved in the second direction, the firing drive gear 3960 moves the gear lug 3978 out of engagement with the firing driven gear 3962 as it moves into meshing engagement with the firing driven gear 3962. As can be seen in FIG. 85, when in that position, the gear lug 3974 remains in locking engagement with the closure driven gear 3952 to prevent actuation of the closure system. Thereafter, the robotic controller 1001 is activated to provide the first rotary actuation motion to the drive pulley 3930 through the interface between the driven element 1304 and the corresponding components of the tool holder 1240. As the drive pulley 3930 is rotated in the first direction, the firing cable 3884 is rotated to drive the dynamic clamping member 3860 in the distal direction “DD” thereby firing the staples and cutting the tissue clamped in the end effector 3814. Once the robotic system 1000 determines that the dynamic clamping member 3860 has reached its distal most position—either through sensors or through monitoring the amount of rotary input applied to the drive pulley 3930, the controller 1001 may then apply a second rotary motion to the drive pulley 3930 to rotate the closure cable 3850 in an opposite direction to cause the dynamic clamping member 3860 to be retracted in the proximal direction “PD”. Once the dynamic clamping member has been retracted to the starting position, the application of the second rotary motion to the drive pulley 3930 is discontinued. Thereafter, the shifter motor 3922 (or shifter solenoid) is powered to move the shifter yoke 3940 to the closure position (FIG. 83). Once the closure drive gear 3950 is in meshing engagement with the closure driven gear 3952, the robotic controller 1001 may once again apply the second rotary motion to the drive pulley 3930. Rotation of the drive pulley 3930 in the second direction causes the closure cable 3850 to retract the preclamping collar 3840 out of engagement with the cam surface 3825 of the anvil 3824 to permit the anvil

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3824 to move to an open position (by a spring or other means) to release the stapled tissue from the surgical end effector 3814.

FIG. 89 illustrates a surgical tool 4000 that employs a gear driven firing bar 4092 as shown in FIGS. 90-92. This embodiment includes an elongated shaft assembly 4008 that extends from a tool mounting portion 4100. The tool mounting portion 4100 includes a tool mounting plate 4102 that operable supports a transmission arrangement 4103 thereon. The elongated shaft assembly 4008 includes a rotatable proximal closure tube 4010 that is rotatably journaled on a proximal spine member 4020 that is rigidly coupled to the tool mounting plate 4102. The proximal spine member 4020 has a distal end that is coupled to an elongated channel portion 4022 of a surgical end effector 4012. The surgical end effector 4012 may be substantially similar to surgical end effector 3412 described above. In addition, the anvil 4024 of the surgical end effector 4012 may be opened and closed by a distal closure tube 4030 that operably interfaces with the proximal closure tube 4010. Distal closure tube 4030 is identical to distal closure tube 3430 described above. Similarly, proximal closure tube 4010 is identical to proximal closure tube segment 3410 described above.

Anvil 4024 is opened and closed by rotating the proximal closure tube 4010 in manner described above with respect to distal closure tube 3410. In at least one embodiment, the transmission arrangement comprises a closure transmission, generally designated as 4011. As will be further discussed below, the closure transmission 4011 is configured to receive a corresponding first rotary motion from the robotic system 1000 and convert that first rotary motion to a primary rotary motion for rotating the rotatable proximal closure tube 4010 about the longitudinal tool axis LT-LT. As can be seen in FIG. 92, a proximal end 4060 of the proximal closure tube 4010 is rotatably supported within a cradle arrangement 4104 that is attached to a tool mounting plate 4102 of the tool mounting portion 4100. A rotation gear 4062 is formed on or attached to the proximal end 4060 of the closure tube segment 4010 for meshing engagement with a rotation drive assembly 4070 that is operably supported on the tool mounting plate 4102. In at least one embodiment, a rotation drive gear 4072 is coupled to a corresponding first one of the driven discs or elements 1304 on the adapter side of the tool mounting plate 4102 when the tool mounting portion 4100 is coupled to the tool holder 1270. See FIGS. 22 and 92. The rotation drive assembly 4070 further comprises a rotary driven gear 4074 that is rotatably supported on the tool mounting plate 4102 in meshing engagement with the rotation gear 4062 and the rotation drive gear 4072. Application of a first rotary control motion from the robotic system 1000 through the tool holder 1270 and the adapter 1240 to the corresponding driven element 1304 will thereby cause rotation of the rotation drive gear 4072 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 4072 ultimately results in the rotation of the closure tube segment 4010 to open and close the anvil 4024 as described above.

As indicated above, the end effector 4012 employs a cutting element 3860 as shown in FIGS. 90 and 91. In at least one non-limiting embodiment, the transmission arrangement 4103 further comprises a knife drive transmission that includes a knife drive assembly 4080. FIG. 92 illustrates one form of knife drive assembly 4080 for axially advancing the knife bar 4092 that is attached to such cutting element using cables as described above with respect to surgical tool 3800. In particular, the knife bar 4092 replaces the firing cable 3884 employed in an embodiment of surgical tool 3800. One form of the knife drive assembly 4080 comprises a rotary drive gear

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4082 that is coupled to a corresponding second one of the driven discs or elements 1304 on the adapter side of the tool mounting plate 4102 when the tool mounting portion 4100 is coupled to the tool holder 1270. See FIGS. 22 and 92. The knife drive assembly 4080 further comprises a first rotary driven gear assembly 4084 that is rotatably supported on the tool mounting plate 4102. The first rotary driven gear assembly 4084 is in meshing engagement with a third rotary driven gear assembly 4086 that is rotatably supported on the tool mounting plate 4102 and which is in meshing engagement with a fourth rotary driven gear assembly 4088 that is in meshing engagement with a threaded portion 4094 of drive shaft assembly 4090 that is coupled to the knife bar 4092. Rotation of the rotary drive gear 4082 in a second rotary direction will result in the axial advancement of the drive shaft assembly 4090 and knife bar 4092 in the distal direction "DD". Conversely, rotation of the rotary drive gear 4082 in a secondary rotary direction (opposite to the second rotary direction) will cause the drive shaft assembly 4090 and the knife bar 4092 to move in the proximal direction. Movement of the firing bar 4092 in the proximal direction "PD" will drive the cutting element 3860 in the distal direction "DD". Conversely, movement of the firing bar 4092 in the distal direction "DD" will result in the movement of the cutting element 3860 in the proximal direction "PD".

FIGS. 93-99 illustrate yet another surgical tool 5000 that may be effectively employed in connection with a robotic system 1000. In various forms, the surgical tool 5000 includes a surgical end effector 5012 in the form of a surgical stapling instrument that includes an elongated channel 5020 and a pivotally translatable clamping member, such as an anvil 5070, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 5012. As can be seen in FIG. 95, the elongated channel 5020 may be substantially U-shaped in cross-section and be fabricated from, for example, titanium, 203 stainless steel, 304 stainless steel, 416 stainless steel, 17-4 stainless steel, 17-7 stainless steel, 6061 or 7075 aluminum, chromium steel, ceramic, etc. A substantially U-shaped metal channel pan 5022 may be supported in the bottom of the elongated channel 5020 as shown.

Various embodiments include an actuation member in the form of a sled assembly 5030 that is operably supported within the surgical end effector 5012 and axially movable therein between a starting position and an ending position in response to control motions applied thereto. In some forms, the metal channel pan 5022 has a centrally-disposed slot 5024 therein to movably accommodate a base portion 5032 of the sled assembly 5030. The base portion 5032 includes a foot portion 5034 that is sized to be slidably received in a slot 5021 in the elongated channel 5020. See FIG. 95. As can be seen in FIGS. 94, 95, 98, and 99, the base portion 5032 of sled assembly 5030 includes an axially extending threaded bore 5036 that is configured to be threadedly received on a threaded drive shaft 5130 as will be discussed in further detail below. In addition, the sled assembly 5030 includes an upstanding support portion 5038 that supports a tissue cutting blade or tissue cutting instrument 5040. The upstanding support portion 5038 terminates in a top portion 5042 that has a pair of laterally extending retaining fins 5044 protruding therefrom. As shown in FIG. 95, the fins 5044 are positioned to be received within corresponding slots 5072 in anvil 5070. The fins 5044 and the foot 5034 serve to retain the anvil 5070 in a desired spaced closed position as the sled assembly 5030 is driven distally through the tissue clamped within the surgical end effector 5014. As can also be seen in FIGS. 97 and 99, the sled assembly 5030 further includes a reciprocatably

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or sequentially activatable drive assembly **5050** for driving staple pushers toward the closed anvil **5070**.

More specifically and with reference to FIGS. **95** and **96**, the elongated channel **5020** is configured to operably support a surgical staple cartridge **5080** therein. In at least one form, the surgical staple cartridge **5080** comprises a body portion **5082** that may be fabricated from, for example, Vectra, Nylon (6/6 or 6/12) and include a centrally disposed slot **5084** for accommodating the upstanding support portion **5038** of the sled assembly **5030**. See FIG. **95**. These materials could also be filled with glass, carbon, or mineral fill of 10%-40%. The surgical staple cartridge **5080** further includes a plurality of cavities **5086** for movably supporting lines or rows of staple-supporting pushers **5088** therein. The cavities **5086** may be arranged in spaced longitudinally extending lines or rows **5090**, **5092**, **5094**, **5096**. For example, the rows **5090** may be referred to herein as first outboard rows. The rows **5092** may be referred to herein as first inboard rows. The rows **5094** may be referred to as second inboard rows and the rows **5096** may be referred to as second outboard rows. The first inboard row **5090** and the first outboard row **5092** are located on a first lateral side of the longitudinal slot **5084** and the second inboard row **5094** and the second outboard row **5096** are located on a second lateral side of the longitudinal slot **5084**. The first staple pushers **5088** in the first inboard row **5092** are staggered in relationship to the first staple pushers **5088** in the first outboard row **5090**. Similarly, the second staple pushers **5088** in the second outboard row **5096** are staggered in relationship to the second pushers **5088** in the second inboard row **5094**. Each pusher **5088** operably supports a surgical staple **5098** thereon.

In various embodiments, the sequentially-activatable or reciprocatably-activatable drive assembly **5050** includes a pair of outboard drivers **5052** and a pair of inboard drivers **5054** that are each attached to a common shaft **5056** that is rotatably mounted within the base **5032** of the sled assembly **5030**. The outboard drivers **5052** are oriented to sequentially or reciprocatingly engage a corresponding plurality of outboard activation cavities **5026** provided in the channel pan **5022**. Likewise, the inboard drivers **5054** are oriented to sequentially or reciprocatingly engage a corresponding plurality of inboard activation cavities **5028** provided in the channel pan **5022**. The inboard activation cavities **5028** are arranged in a staggered relationship relative to the adjacent outboard activation cavities **5026**. See FIG. **96**. As can also be seen in FIGS. **96** and **98**, in at least one embodiment, the sled assembly **5030** further includes distal wedge segments **5060** and intermediate wedge segments **5062** located on each side of the bore **5036** to engage the pushers **5088** as the sled assembly **5030** is driven distally in the distal direction "DD". As indicated above, the sled assembly **5030** is threadedly received on a threaded portion **5132** of a drive shaft **5130** that is rotatably supported within the end effector **5012**. In various embodiments, for example, the drive shaft **5130** has a distal end **5134** that is supported in a distal bearing **5136** mounted in the surgical end effector **5012**. See FIGS. **95** and **96**.

In various embodiments, the surgical end effector **5012** is coupled to a tool mounting portion **5200** by an elongated shaft assembly **5108**. In at least one embodiment, the tool mounting portion **5200** operably supports a transmission arrangement generally designated as **5204** that is configured to receive rotary output motions from the robotic system. The elongated shaft assembly **5108** includes an outer closure tube **5110** that is rotatable and axially movable on a spine member **5120** that is rigidly coupled to a tool mounting plate **5201** of the tool mounting portion **5200**. The spine member **5120** also

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has a distal end **5122** that is coupled to the elongated channel portion **5020** of the surgical end effector **5012**.

In use, it may be desirable to rotate the surgical end effector **5012** about a longitudinal tool axis LT-LT defined by the elongated shaft assembly **5008**. In various embodiments, the outer closure tube **5110** has a proximal end **5112** that is rotatably supported on the tool mounting plate **5201** of the tool drive portion **5200** by a forward support cradle **5203**. The proximal end **5112** of the outer closure tube **5110** is configured to operably interface with a rotation transmission portion **5206** of the transmission arrangement **5204**. In various embodiments, the proximal end **5112** of the outer closure tube **5110** is also supported on a closure sled **5140** that is also movably supported on the tool mounting plate **5201**. A closure tube gear segment **5114** is formed on the proximal end **5112** of the outer closure tube **5110** for meshing engagement with a rotation drive assembly **5150** of the rotation transmission **5206**. As can be seen in FIG. **93**, the rotation drive assembly **5150**, in at least one embodiment, comprises a rotation drive gear **5152** that is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **5201** when the tool drive portion **5200** is coupled to the tool holder **1270**. The rotation drive assembly **5150** further comprises a rotary driven gear **5154** that is rotatably supported on the tool mounting plate **5201** in meshing engagement with the closure tube gear segment **5114** and the rotation drive gear **5152**. Application of a first rotary control motion from the robotic system **1000** through the tool holder **1270** and the adapter **1240** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **5152**. Rotation of the rotation drive gear **5152** ultimately results in the rotation of the elongated shaft assembly **5108** (and the end effector **5012**) about the longitudinal tool axis LT-LT (represented by arrow "R" in FIG. **93**).

Closure of the anvil **5070** relative to the surgical staple cartridge **5080** is accomplished by axially moving the outer closure tube **5110** in the distal direction "DD". Such axial movement of the outer closure tube **5110** may be accomplished by a closure transmission portion **5144** of the transmission arrangement **5204**. As indicated above, in various embodiments, the proximal end **5112** of the outer closure tube **5110** is supported by the closure sled **5140** which enables the proximal end **5112** to rotate relative thereto, yet travel axially with the closure sled **5140**. In particular, as can be seen in FIG. **93**, the closure sled **5140** has an upstanding tab **5141** that extends into a radial groove **5115** in the proximal end portion **5112** of the outer closure tube **5110**. In addition, as was described above, the closure sled **5140** is slidably mounted to the tool mounting plate **5201**. In various embodiments, the closure sled **5140** has an upstanding portion **5142** that has a closure rack gear **5143** formed thereon. The closure rack gear **5143** is configured for driving engagement with the closure transmission **5144**.

In various forms, the closure transmission **5144** includes a closure spur gear **5145** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **5201**. Thus, application of a second rotary control motion from the robotic system **1000** through the tool holder **1270** and the adapter **1240** to the corresponding second driven element **1304** will cause rotation of the closure spur gear **5145** when the interface **1230** is coupled to the tool mounting portion **5200**. The closure transmission **5144** further includes a driven closure gear set **5146** that is supported in meshing engagement with the closure spur gear **5145** and the closure rack gear **5143**. Thus, application of a second rotary control motion from the robotic

system 1000 through the tool holder 1270 and the adapter 1240 to the corresponding second driven element 1304 will cause rotation of the closure spur gear 5145 and ultimately drive the closure sled 5140 and the outer closure tube 5110 axially. The axial direction in which the closure tube 5110 moves ultimately depends upon the direction in which the second driven element 1304 is rotated. For example, in response to one rotary closure motion received from the robotic system 1000, the closure sled 5140 will be driven in the distal direction "DD" and ultimately the outer closure tube 5110 will be driven in the distal direction as well. The outer closure tube 5110 has an opening 5117 in the distal end 5116 that is configured for engagement with a tab 5071 on the anvil 5070 in the manners described above. As the outer closure tube 5110 is driven distally, the proximal end 5116 of the closure tube 5110 will contact the anvil 5070 and pivot it closed. Upon application of an "opening" rotary motion from the robotic system 1000, the closure sled 5140 and outer closure tube 5110 will be driven in the proximal direction "PD" and pivot the anvil 5070 to the open position in the manners described above.

In at least one embodiment, the drive shaft 5130 has a proximal end 5137 that has a proximal shaft gear 5138 attached thereto. The proximal shaft gear 5138 is supported in meshing engagement with a distal drive gear 5162 attached to a rotary drive bar 5160 that is rotatably supported with spine member 5120. Rotation of the rotary drive bar 5160 and ultimately rotary drive shaft 5130 is controlled by a rotary knife transmission 5207 which comprises a portion of the transmission arrangement 5204 supported on the tool mounting plate 5210. In various embodiments, the rotary knife transmission 5207 comprises a rotary knife drive system 5170 that is operably supported on the tool mounting plate 5201. In various embodiments, the knife drive system 5170 includes a rotary drive gear 5172 that is coupled to a corresponding third one of the driven discs or elements 1304 on the adapter side of the tool mounting plate 5201 when the tool drive portion 5200 is coupled to the tool holder 1270. The knife drive system 5170 further comprises a first rotary driven gear 5174 that is rotatably supported on the tool mounting plate 5201 in meshing engagement with a second rotary driven gear 5176 and the rotary drive gear 5172. The second rotary driven gear 5176 is coupled to a proximal end portion 5164 of the rotary drive bar 5160.

Rotation of the rotary drive gear 5172 in a first rotary direction will result in the rotation of the rotary drive bar 5160 and rotary drive shaft 5130 in a first direction. Conversely, rotation of the rotary drive gear 5172 in a second rotary direction (opposite to the first rotary direction) will cause the rotary drive bar 5160 and rotary drive shaft 5130 to rotate in a second direction. 2400. Thus, rotation of the drive shaft 2440 results in rotation of the drive sleeve 2400.

One method of operating the surgical tool 5000 will now be described. The tool drive 5200 is operably coupled to the interface 1240 of the robotic system 1000. The controller 1001 of the robotic system 1000 is operated to locate the tissue to be cut and stapled between the open anvil 5070 and the surgical staple cartridge 5080. Once the surgical end effector 5012 has been positioned by the robot system 1000 such that the target tissue is located between the anvil 5070 and the surgical staple cartridge 5080, the controller 1001 of the robotic system 1000 may be activated to apply the second rotary output motion to the second driven element 1304 coupled to the closure spur gear 5145 to drive the closure sled 5140 and the outer closure tube 5110 axially in the distal direction to pivot the anvil 5070 closed in the manner described above. Once the robotic controller 1001 determines

that the anvil 5070 has been closed by, for example, sensors in the surgical end effector 5012 and/or the tool drive portion 5200, the robotic controller 1001 system may provide the surgeon with an indication that signifies the closure of the anvil. Such indication may be, for example, in the form of a light and/or audible sound, tactile feedback on the control members, etc. Then the surgeon may initiate the firing process. In alternative embodiments, however, the robotic controller 1001 may automatically commence the firing process.

To commence the firing process, the robotic controller applies a third rotary output motion to the third driven disc or element 1304 coupled to the rotary drive gear 5172. Rotation of the rotary drive gear 5172 results in the rotation of the rotary drive bar 5160 and rotary drive shaft 5130 in the manner described above. Firing and formation of the surgical staples 5098 can be best understood from reference to FIGS. 94, 96, and 97. As the sled assembly 5030 is driven in the distal direction "DD" through the surgical staple cartridge 5080, the distal wedge segments 5060 first contact the staple pushers 5088 and start to move them toward the closed anvil 5070. As the sled assembly 5030 continues to move distally, the outboard drivers 5052 will drop into the corresponding activation cavity 5026 in the channel pan 5022. The opposite end of each outboard driver 5052 will then contact the corresponding outboard pusher 5088 that has moved up the distal and intermediate wedge segments 5060, 5062. Further distal movement of the sled assembly 5030 causes the outboard drivers 5052 to rotate and drive the corresponding pushers 5088 toward the anvil 5070 to cause the staples 5098 supported thereon to be formed as they are driven into the anvil 5070. It will be understood that as the sled assembly 5030 moves distally, the knife blade 5040 cuts through the tissue that is clamped between the anvil and the staple cartridge. Because the inboard drivers 5054 and outboard drivers 5052 are attached to the same shaft 5056 and the inboard drivers 5054 are radially offset from the outboard drivers 5052 on the shaft 5056, as the outboard drivers 5052 are driving their corresponding pushers 5088 toward the anvil 5070, the inboard drivers 5054 drop into their next corresponding activation cavity 5028 to cause them to rotatably or reciprocatingly drive the corresponding inboard pushers 5088 towards the closed anvil 5070 in the same manner. Thus, the laterally corresponding outboard staples 5098 on each side of the centrally disposed slot 5084 are simultaneously formed together and the laterally corresponding inboard staples 5098 on each side of the slot 5084 are simultaneously formed together as the sled assembly 5030 is driven distally. Once the robotic controller 1001 determines that the sled assembly 5030 has reached its distal most position—either through sensors or through monitoring the amount of rotary input applied to the drive shaft 5130 and/or the rotary drive bar 5160, the controller 1001 may then apply a third rotary output motion to the drive shaft 5130 to rotate the drive shaft 5130 in an opposite direction to retract the sled assembly 5030 back to its starting position. Once the sled assembly 5030 has been retracted to the starting position (as signaled by sensors in the end effector 5012 and/or the tool drive portion 5200), the application of the second rotary motion to the drive shaft 5130 is discontinued. Thereafter, the surgeon may manually activate the anvil opening process or it may be automatically commenced by the robotic controller 1001. To open the anvil 5070, the second rotary output motion is applied to the closure spur gear 5145 to drive the closure sled 5140 and the outer closure tube 5110 axially in the proximal direction. As the closure tube 5110 moves proximally, the opening 5117 in the distal end 5116 of the closure tube 5110 contacts the tab 5071 on the anvil 5070 to pivot the anvil 5070 to the open

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position. A spring may also be employed to bias the anvil 5070 to the open position when the closure tube 5116 has been returned to the starting position. Again, sensors in the surgical end effector 5012 and/or the tool mounting portion 5200 may provide the robotic controller 1001 with a signal indicating that the anvil 5070 is now open. Thereafter, the surgical end effector 5012 may be withdrawn from the surgical site.

FIGS. 100-105 diagrammatically depict the sequential firing of staples in a surgical tool assembly 5000' that is substantially similar to the surgical tool assembly 5000 described above. In this embodiment, the inboard and outboard drivers 5052', 5054' have a cam-like shape with a cam surface 5053 and an actuator protrusion 5055 as shown in FIGS. 100-106. The drivers 5052', 5054' are journaled on the same shaft 5056' that is rotatably supported by the sled assembly 5030'. In this embodiment, the sled assembly 5030' has distal wedge segments 5060' for engaging the pushers 5088. FIG. 100 illustrates an initial position of two inboard or outboard drivers 5052', 5054' as the sled assembly 5030' is driven in the distal direction "DD". As can be seen in that Figure, the pusher 5088a has advanced up the wedge segment 5060' and has contacted the driver 5052', 5054'. Further travel of the sled assembly 5030' in the distal direction causes the driver 5052', 5054' to pivot in the "P" direction (FIG. 101) until the actuator portion 5055 contacts the end wall 5029a of the activation cavity 5026, 5028 as shown in FIG. 102. Continued advancement of the sled assembly 5030' in the distal direction "DD" causes the driver 5052', 5054' to rotate in the "D" direction as shown in FIG. 103. As the driver 5052', 5054' rotates, the pusher 5088a rides up the cam surface 5053 to the final vertical position shown in FIG. 104. When the pusher 5088a reaches the final vertical position shown in FIGS. 104 and 105, the staple (not shown) supported thereon has been driven into the staple forming surface of the anvil to form the staple.

FIGS. 107-112 illustrate a surgical end effector 5312 that may be employed for example, in connection with the tool mounting portion 1300 and shaft 2008 described in detail above. In various forms, the surgical end effector 5312 includes an elongated channel 5322 that is constructed as described above for supporting a surgical staple cartridge 5330 therein. The surgical staple cartridge 5330 comprises a body portion 5332 that includes a centrally disposed slot 5334 for accommodating an upstanding support portion 5386 of a sled assembly 5380. See FIGS. 107-109. The surgical staple cartridge body portion 5332 further includes a plurality of cavities 5336 for movably supporting staple-supporting pushers 5350 therein. The cavities 5336 may be arranged in spaced longitudinally extending rows 5340, 5342, 5344, 5346. The rows 5340, 5342 are located on one lateral side of the longitudinal slot 5334 and the rows 5344, 5346 are located on the other side of longitudinal slot 5334. In at least one embodiment, the pushers 5350 are configured to support two surgical staples 5352 thereon. In particular, each pusher 5350 located on one side of the elongated slot 5334 supports one staple 5352 in row 5340 and one staple 5352 in row 5342 in a staggered orientation. Likewise, each pusher 5350 located on the other side of the elongated slot 5334 supports one surgical staple 5352 in row 5344 and another surgical staple 5352 in row 5346 in a staggered orientation. Thus, every pusher 5350 supports two surgical staples 5352.

As can be further seen in FIGS. 107, 108, the surgical staple cartridge 5330 includes a plurality of rotary drivers 5360. More particularly, the rotary drivers 5360 on one side of the elongated slot 5334 are arranged in a single line 5370 and correspond to the pushers 5350 in lines 5340, 5342. In addition, the rotary drivers 5360 on the other side of the elongated

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slot 5334 are arranged in a single line 5372 and correspond to the pushers 5350 in lines 5344, 5346. As can be seen in FIG. 107, each rotary driver 5360 is rotatably supported within the staple cartridge body 5332. More particularly, each rotary driver 5360 is rotatably received on a corresponding driver shaft 5362. Each driver 5360 has an arcuate ramp portion 5364 formed thereon that is configured to engage an arcuate lower surface 5354 formed on each pusher 5350. See FIG. 112. In addition, each driver 5360 has a lower support portion 5366 extend therefrom to slidably support the pusher 5360 on the channel 5322. Each driver 5360 has a downwardly extending actuation rod 5368 that is configured for engagement with a sled assembly 5380.

As can be seen in FIG. 109, in at least one embodiment, the sled assembly 5380 includes a base portion 5382 that has a foot portion 5384 that is sized to be slidably received in a slot 5333 in the channel 5322. See FIG. 107. The sled assembly 5380 includes an upstanding support portion 5386 that supports a tissue cutting blade or tissue cutting instrument 5388. The upstanding support portion 5386 terminates in a top portion 5390 that has a pair of laterally extending retaining fins 5392 protruding therefrom. The fins 5392 are positioned to be received within corresponding slots (not shown) in the anvil (not shown). As with the above-described embodiments, the fins 5392 and the foot portion 5384 serve to retain the anvil (not shown) in a desired spaced closed position as the sled assembly 5380 is driven distally through the tissue clamped within the surgical end effector 5312. The upstanding support portion 5386 is configured for attachment to a knife bar 2200 (FIG. 28). The sled assembly 5380 further has a horizontally-extending actuator plate 5394 that is shaped for actuating engagement with each of the actuation rods 5368 on the pushers 5360.

Operation of the surgical end effector 5312 will now be explained with reference to FIGS. 107 and 108. As the sled assembly 5380 is driven in the distal direction "DD" through the staple cartridge 5330, the actuator plate 5394 sequentially contacts the actuation rods 5368 on the pushers 5360. As the sled assembly 5380 continues to move distally, the actuator plate 5394 sequentially contacts the actuator rods 5368 of the drivers 5360 on each side of the elongated slot 5334. Such action causes the drivers 5360 to rotate from a first unactuated position to an actuated position wherein the pushers 5350 are driven towards the closed anvil. As the pushers 5350 are driven toward the anvil, the surgical staples 5352 thereon are driven into forming contact with the underside of the anvil. Once the robotic system 1000 determines that the sled assembly 5080 has reached its distal most position through sensors or other means, the control system of the robotic system 1000 may then retract the knife bar and sled assembly 5380 back to the starting position. Thereafter, the robotic control system may then activate the procedure for returning the anvil to the open position to release the stapled tissue.

FIGS. 113-117 depict one form of an automated reloading system embodiment of the present invention, generally designated as 5500. In one form, the automated reloading system 5500 is configured to replace a "spent" surgical end effector component in a manipulatable surgical tool portion of a robotic surgical system with a "new" surgical end effector component. As used herein, the term "surgical end effector component" may comprise, for example, a surgical staple cartridge, a disposable loading unit or other end effector components that, when used, are spent and must be replaced with a new component. Furthermore, the term "spent" means that the end effector component has been activated and is no longer useable for its intended purpose in its present state. For example, in the context of a surgical staple cartridge or dis-

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posable loading unit, the term “spent” means that at least some of the unformed staples that were previously supported therein have been “fired” therefrom. As used herein, the term “new” surgical end effector component refers to an end effector component that is in condition for its intended use. In the context of a surgical staple cartridge or disposable loading unit, for example, the term “new” refers to such a component that has unformed staples therein and which is otherwise ready for use.

In various embodiments, the automated reloading system **5500** includes a base portion **5502** that may be strategically located within a work envelope **1109** of a robotic arm cart **1100** (FIG. **14**) of a robotic system **1000**. As used herein, the term “manipulatable surgical tool portion” collectively refers to a surgical tool of the various types disclosed herein and other forms of surgical robotically-actuated tools that are operably attached to, for example, a robotic arm cart **1100** or similar device that is configured to automatically manipulate and actuate the surgical tool. The term “work envelope” as used herein refers to the range of movement of the manipulatable surgical tool portion of the robotic system. FIG. **14** generally depicts an area that may comprise a work envelope of the robotic arm cart **1100**. Those of ordinary skill in the art will understand that the shape and size of the work envelope depicted therein is merely illustrative. The ultimate size, shape and location of a work envelope will ultimately depend upon the construction, range of travel limitations, and location of the manipulatable surgical tool portion. Thus, the term “work envelope” as used herein is intended to cover a variety of different sizes and shapes of work envelopes and should not be limited to the specific size and shape of the sample work envelope depicted in FIG. **14**.

As can be seen in FIG. **113**, the base portion **5502** includes a new component support section or arrangement **5510** that is configured to operably support at least one new surgical end effector component in a “loading orientation”. As used herein, the term “loading orientation” means that the new end effector component is supported in such away so as to permit the corresponding component support portion of the manipulatable surgical tool portion to be brought into loading engagement with (i.e., operably seated or operably attached to) the new end effector component (or the new end effector component to be brought into loading engagement with the corresponding component support portion of the manipulatable surgical tool portion) without human intervention beyond that which may be necessary to actuate the robotic system. As will be further appreciated as the present Detailed Description proceeds, in at least one embodiment, the preparation nurse will load the new component support section before the surgery with the appropriate length and color cartridges (some surgical staple cartridges may support certain sizes of staples the size of which may be indicated by the color of the cartridge body) required for completing the surgical procedure. However, no direct human interaction is necessary during the surgery to reload the robotic endocutter. In one form, the surgical end effector component comprises a staple cartridge **2034** that is configured to be operably seated within a component support portion (elongated channel) of any of the various other end effector arrangements described above. For explanation purposes, new (unused) cartridges will be designated as “**2034a**” and spent cartridges will be designated as “**2034b**”. The Figures depict cartridges **2034a**, **2034b** designed for use with a surgical end effector **2012** that includes a channel **2022** and an anvil **2024**, the construction and operation of which were discussed in detail above. Cartridges **2034a**, **2034b** are identical to cartridges **2034** described above. In various embodiments, the cartridges

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2034a, **2034b** are configured to be snappingly retained (i.e., loading engagement) within the channel **2022** of a surgical end effector **2012**. As the present Detailed Description proceeds, however, those of ordinary skill in the art will appreciate that the unique and novel features of the automated cartridge reloading system **5500** may be effectively employed in connection with the automated removal and installation of other cartridge arrangements without departing from the spirit and scope of the present invention.

In the depicted embodiment, the term “loading orientation” means that the distal tip portion **2035a** of the new surgical staple cartridge **2034a** is inserted into a corresponding support cavity **5512** in the new cartridge support section **5510** such that the proximal end portion **2037a** of the new surgical staple cartridge **2034a** is located in a convenient orientation for enabling the arm cart **1100** to manipulate the surgical end effector **2012** into a position wherein the new cartridge **2034a** may be automatically loaded into the channel **2022** of the surgical end effector **2012**. In various embodiments, the base **5502** includes at least one sensor **5504** which communicates with the control system **1003** of the robotic controller **1001** to provide the control system **1003** with the location of the base **5502** and/or the reload length and color of each staged or new cartridge **2034a**.

As can also be seen in the Figures, the base **5502** further includes a collection receptacle **5520** that is configured to collect spent cartridges **2034b** that have been removed or disengaged from the surgical end effector **2012** that is operably attached to the robotic system **1000**. In addition, in one form, the automated reloading system **5500** includes an extraction system **5530** for automatically removing the spent end effector component from the corresponding support portion of the end effector or manipulatable surgical tool portion without specific human intervention beyond that which may be necessary to activate the robotic system. In various embodiments, the extraction system **5530** includes an extraction hook member **5532**. In one form, for example, the extraction hook member **5532** is rigidly supported on the base portion **5502**. In one embodiment, the extraction hook member has at least one hook **5534** formed thereon that is configured to hookingly engage the distal end **2035** of a spent cartridge **2034b** when it is supported in the elongated channel **2022** of the surgical end effector **2012**. In various forms, the extraction hook member **5532** is conveniently located within a portion of the collection receptacle **5520** such that when the spent end effector component (cartridge **2034b**) is brought into extractive engagement with the extraction hook member **5532**, the spent end effector component (cartridge **2034b**) is dislodged from the corresponding component support portion (elongated channel **2022**), and falls into the collection receptacle **5520**. Thus, to use this embodiment, the manipulatable surgical tool portion manipulates the end effector attached thereto to bring the distal end **2035** of the spent cartridge **2034b** therein into hooking engagement with the hook **5534** and then moves the end effector in such a way to dislodge the spent cartridge **2034b** from the elongated channel **2022**.

In other arrangements, the extraction hook member **5532** comprises a rotatable wheel configuration that has a pair of diametrically-opposed hooks **5534** protruding therefrom. See FIGS. **113** and **116**. The extraction hook member **5532** is rotatably supported within the collection receptacle **5520** and is coupled to an extraction motor **5540** that is controlled by the controller **1001** of the robotic system. This form of the automated reloading system **5500** may be used as follows. FIG. **115** illustrates the introduction of the surgical end effector **2012** that is operably attached to the manipulatable surgi-

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cal tool portion **1200**. As can be seen in that Figure, the arm cart **1100** of the robotic system **1000** locates the surgical end effector **2012** in the shown position wherein the hook end **5534** of the extraction member **5532** hookingly engages the distal end **2035** of the spent cartridge **2034b** in the surgical end effector **2012**. The anvil **2024** of the surgical end effector **2012** is in the open position. After the distal end **2035** of the spent cartridge **2034b** is engaged with the hook end **5532**, the extraction motor **5540** is actuated to rotate the extraction wheel **5532** to disengage the spent cartridge **2034b** from the channel **2022**. To assist with the disengagement of the spent cartridge **2034b** from the channel **2022** (or if the extraction member **5530** is stationary), the robotic system **1000** may move the surgical end effector **2012** in an upward direction (arrow "U" in FIG. **116**). As the spent cartridge **2034b** is dislodged from the channel **2022**, the spent cartridge **2034b** falls into the collection receptacle **5520**. Once the spent cartridge **2034b** has been removed from the surgical end effector **2012**, the robotic system **1000** moves the surgical end effector **2012** to the position shown in FIG. **117**.

In various embodiments, a sensor arrangement **5533** is located adjacent to the extraction member **5532** that is in communication with the controller **1001** of the robotic system **1000**. The sensor arrangement **5533** may comprise a sensor that is configured to sense the presence of the surgical end effector **2012** and, more particularly the tip **2035b** of the spent surgical staple cartridge **2034b** thereof as the distal tip portion **2035b** is brought into engagement with the extraction member **5532**. In some embodiments, the sensor arrangement **5533** may comprise, for example, a light curtain arrangement. However, other forms of proximity sensors may be employed. In such arrangement, when the surgical end effector **2012** with the spent surgical staple cartridge **2034b** is brought into extractive engagement with the extraction member **5532**, the sensor senses the distal tip **2035b** of the surgical staple cartridge **2034b** (e.g., the light curtain is broken). When the extraction member **5532** spins and pops the surgical staple cartridge **2034b** loose and it falls into the collection receptacle **5520**, the light curtain is again unbroken. Because the surgical end effector **2012** was not moved during this procedure, the robotic controller **1001** is assured that the spent surgical staple cartridge **2034b** has been removed therefrom. Other sensor arrangements may also be successfully employed to provide the robotic controller **1001** with an indication that the spent surgical staple cartridge **2034b** has been removed from the surgical end effector **2012**.

As can be seen in FIG. **117**, the surgical end effector **2012** is positioned to grasp a new surgical staple cartridge **2034a** between the channel **2022** and the anvil **2024**. More specifically, as shown in FIGS. **114** and **117**, each cavity **5512** has a corresponding upstanding pressure pad **5514** associated with it. The surgical end effector **2012** is located such that the pressure pad **5514** is located between the new cartridge **2034a** and the anvil **2024**. Once in that position, the robotic system **1000** closes the anvil **2024** onto the pressure pad **5514** which serves to push the new cartridge **2034a** into snapping engagement with the channel **2022** of the surgical end effector **2012**. Once the new cartridge **2034a** has been snapped into position within the elongated channel **2022**, the robotic system **1000** then withdraws the surgical end effector **2012** from the automated cartridge reloading system **5500** for use in connection with performing another surgical procedure.

FIGS. **118-122** depict another automated reloading system **5600** that may be used to remove a spent disposable loading unit **3612** from a manipulatable surgical tool arrangement **3600** (FIGS. **65-78**) that is operably attached to an arm cart **1100** or other portion of a robotic system **1000** and reload a

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new disposable loading unit **3612** therein. As can be seen in FIGS. **118** and **119**, one form of the automated reloading system **5600** includes a housing **5610** that has a movable support assembly in the form of a rotary carousel top plate **5620** supported thereon which cooperates with the housing **5610** to form a hollow enclosed area **5612**. The automated reloading system **5600** is configured to be operably supported within the work envelop of the manipulatable surgical tool portion of a robotic system as was described above. In various embodiments, the rotary carousel plate **5620** has a plurality of holes **5622** for supporting a plurality of orientation tubes **5660** therein. As can be seen in FIGS. **119** and **120**, the rotary carousel plate **5620** is affixed to a spindle shaft **5624**. The spindle shaft **5624** is centrally disposed within the enclosed area **5612** and has a spindle gear **5626** attached thereto. The spindle gear **5626** is in meshing engagement with a carousel drive gear **5628** that is coupled to a carousel drive motor **5630** that is in operative communication with the robotic controller **1001** of the robotic system **1000**.

Various embodiments of the automated reloading system **5600** may also include a carousel locking assembly, generally designated as **5640**. In various forms, the carousel locking assembly **5640** includes a cam disc **5642** that is affixed to the spindle shaft **5624**. The spindle gear **5626** may be attached to the underside of the cam disc **5642** and the cam disc **5642** may be keyed onto the spindle shaft **5624**. In alternative arrangements, the spindle gear **5626** and the cam disc **5642** may be independently non-rotatably affixed to the spindle shaft **5624**. As can be seen in FIGS. **119** and **120**, a plurality of notches **5644** are spaced around the perimeter of the cam disc **5642**. A locking arm **5648** is pivotally mounted within the housing **5610** and is biased into engagement with the perimeter of the cam disc **5642** by a locking spring **5649**. As can be seen in FIG. **118**, the outer perimeter of the cam disc **5642** is rounded to facilitate rotation of the cam disc **5642** relative to the locking arm **5648**. The edges of each notch **5644** are also rounded such that when the cam disc **5642** is rotated, the locking arm **5648** is cammed out of engagement with the notches **5644** by the perimeter of the cam disc **5642**.

Various forms of the automated reloading system **5600** are configured to support a portable/replaceable tray assembly **5650** that is configured to support a plurality of disposable loading units **3612** in individual orientation tubes **5660**. More specifically and with reference to FIGS. **119** and **120**, the replaceable tray assembly **5650** comprises a tray **5652** that has a centrally-disposed locator spindle **5654** protruding from the underside thereof. The locator spindle **5654** is sized to be received within a hollow end **5625** of spindle shaft **5624**. The tray **5652** has a plurality of holes **5656** therein that are configured to support an orientation tube **5660** therein. Each orientation tube **5660** is oriented within a corresponding hole **5656** in the replaceable tray assembly **5650** in a desired orientation by a locating fin **5666** on the orientation tube **5660** that is designed to be received within a corresponding locating slot **5658** in the tray assembly **5650**. In at least one embodiment, the locating fin **5666** has a substantially V-shaped cross-sectional shape that is sized to fit within a V-shaped locating slot **5658**. Such arrangement serves to orient the orientation tube **5660** in a desired starting position while enabling it to rotate within the hole **5656** when a rotary motion is applied thereto. That is, when a rotary motion is applied to the orientation tube **5660** the V-shaped locating fin **5666** will pop out of its corresponding locating slot enabling the tube **5660** to rotate relative to the tray **5652** as will be discussed in further detail below. As can also be seen in FIGS. **118-120**, the replaceable tray **5652** may be provided with one

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or more handle portions **5653** to facilitate transport of the tray assembly **5652** when loaded with orientation tubes **5660**.

As can be seen in FIG. **122**, each orientation tube **5660** comprises a body portion **5662** that has a flanged open end **5664**. The body portion **5662** defines a cavity **5668** that is sized to receive a portion of a disposable loading unit **3612** therein. To properly orient the disposable loading unit **3612** within the orientation tube **5660**, the cavity **5668** has a flat locating surface **5670** formed therein. As can be seen in FIG. **122**, the flat locating surface **5670** is configured to facilitate the insertion of the disposable loading unit into the cavity **5668** in a desired or predetermined non-rotatable orientation. In addition, the end **5669** of the cavity **5668** may include a foam or cushion material **5672** that is designed to cushion the distal end of the disposable loading unit **3612** within the cavity **5668**. Also, the length of the locating surface may cooperate with a sliding support member **3689** of the axial drive assembly **3680** of the disposable loading unit **3612** to further locate the disposable loading unit **3612** at a desired position within the orientation tube **5660**.

The orientation tubes **5660** may be fabricated from Nylon, polycarbonate, polyethylene, liquid crystal polymer, 6061 or 7075 aluminum, titanium, 300 or 400 series stainless steel, coated or painted steel, plated steel, etc. and, when loaded in the replaceable tray **5662** and the locator spindle **5654** is inserted into the hollow end **5625** of spindle shaft **5624**, the orientation tubes **5660** extend through corresponding holes **5662** in the carousel top plate **5620**. Each replaceable tray **5662** is equipped with a location sensor **5663** that communicates with the control system **1003** of the controller **1001** of the robotic system **1000**. The sensor **5663** serves to identify the location of the reload system, and the number, length, color and fired status of each reload housed in the tray. In addition, an optical sensor or sensors **5665** that communicate with the robotic controller **1001** may be employed to sense the type/size/length of disposable loading units that are loaded within the tray **5662**.

Various embodiments of the automated reloading system **5600** further include a drive assembly **5680** for applying a rotary motion to the orientation tube **5660** holding the disposable loading unit **3612** to be attached to the shaft **3700** of the surgical tool **3600** (collectively the “manipulatable surgical tool portion”) that is operably coupled to the robotic system. The drive assembly **5680** includes a support yoke **5682** that is attached to the locking arm **5648**. Thus, the support yoke **5682** pivots with the locking arm **5648**. The support yoke **5682** rotatably supports a tube idler wheel **5684** and a tube drive wheel **5686** that is driven by a tube motor **5688** attached thereto. Tube motor **5688** communicates with the control system **1003** and is controlled thereby. The tube idler wheel **5684** and tube drive wheel **5686** are fabricated from, for example, natural rubber, sanoprene, isoplast, etc. such that the outer surfaces thereof create sufficient amount of friction to result in the rotation of an orientation tube **5660** in contact therewith upon activation of the tube motor **5688**. The idler wheel **5684** and tube drive wheel **5686** are oriented relative to each other to create a cradle area **5687** therebetween for receiving an orientation tube **5660** in driving engagement therein.

In use, one or more of the orientation tubes **5660** loaded in the automated reloading system **5600** are left empty, while the other orientation tubes **5660** may operably support a corresponding new disposable loading unit **3612** therein. As will be discussed in further detail below, the empty orientation tubes **5660** are employed to receive a spent disposable loading unit **3612** therein.

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The automated reloading system **5600** may be employed as follows after the system **5600** is located within the work envelope of the manipulatable surgical tool portion of a robotic system. If the manipulatable surgical tool portion has a spent disposable loading unit **3612** operably coupled thereto, one of the orientation tubes **5660** that are supported on the replaceable tray **5662** is left empty to receive the spent disposable loading unit **3612** therein. If, however, the manipulatable surgical tool portion does not have a disposable loading unit **3612** operably coupled thereto, each of the orientation tubes **5660** may be provided with a properly oriented new disposable loading unit **3612**.

As described hereinabove, the disposable loading unit **3612** employs a rotary “bayonet-type” coupling arrangement for operably coupling the disposable loading unit **3612** to a corresponding portion of the manipulatable surgical tool portion. That is, to attach a disposable loading unit **3612** to the corresponding portion of the manipulatable surgical tool portion (**3700**—see FIG. **71**, **72**), a rotary installation motion must be applied to the disposable loading unit **3612** and/or the corresponding portion of the manipulatable surgical tool portion when those components have been moved into loading engagement with each other. Such installation motions are collectively referred to herein as “loading motions”. Likewise, to decouple a spent disposable loading unit **3612** from the corresponding portion of the manipulatable surgical tool, a rotary decoupling motion must be applied to the spent disposable loading unit **3612** and/or the corresponding portion of the manipulatable surgical tool portion while simultaneously moving the spent disposable loading unit and the corresponding portion of the manipulatable surgical tool away from each other. Such decoupling motions are collectively referred to herein as “extraction motions”.

To commence the loading process, the robotic system **1000** is activated to manipulate the manipulatable surgical tool portion and/or the automated reloading system **5600** to bring the manipulatable surgical tool portion into loading engagement with the new disposable loading unit **3612** that is supported in the orientation tube **5660** that is in driving engagement with the drive assembly **5680**. Once the robotic controller **1001** (FIG. **13**) of the robotic control system **1000** has located the manipulatable surgical tool portion in loading engagement with the new disposable loading unit **3612**, the robotic controller **1001** activates the drive assembly **5680** to apply a rotary loading motion to the orientation tube **5660** in which the new disposable loading unit **3612** is supported and/or applies another rotary loading motion to the corresponding portion of the manipulatable surgical tool portion. Upon application of such rotary loading motions(s), the robotic controller **1001** also causes the corresponding portion of the manipulatable surgical tool portion to be moved towards the new disposable loading unit **3612** into loading engagement therewith. Once the disposable loading unit **3612** is in loading engagement with the corresponding portion of the manipulatable tool portion, the loading motions are discontinued and the manipulatable surgical tool portion may be moved away from the automated reloading system **5600** carrying with it the new disposable loading unit **3612** that has been operably coupled thereto.

To decouple a spent disposable loading unit **3612** from a corresponding manipulatable surgical tool portion, the robotic controller **1001** of the robotic system manipulates the manipulatable surgical tool portion so as to insert the distal end of the spent disposable loading unit **3612** into the empty orientation tube **5660** that remains in driving engagement with the drive assembly **5680**. Thereafter, the robotic controller **1001** activates the drive assembly **5680** to apply a rotary

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extraction motion to the orientation tube **5660** in which the spent disposable loading unit **3612** is supported and/or applies a rotary extraction motion to the corresponding portion of the manipulatable surgical tool portion. The robotic controller **1001** also causes the manipulatable surgical tool portion to withdraw away from the spent rotary disposable loading unit **3612**. Thereafter the rotary extraction motion(s) are discontinued.

After the spent disposable loading unit **3612** has been removed from the manipulatable surgical tool portion, the robotic controller **1001** may activate the carousel drive motor **5630** to index the carousel top plate **5620** to bring another orientation tube **5660** that supports a new disposable loading unit **3612** therein into driving engagement with the drive assembly **5680**. Thereafter, the loading process may be repeated to attach the new disposable loading unit **3612** therein to the portion of the manipulatable surgical tool portion. The robotic controller **1001** may record the number of disposable loading units that have been used from a particular replaceable tray **5652**. Once the controller **1001** determines that all of the new disposable loading units **3612** have been used from that tray, the controller **1001** may provide the surgeon with a signal (visual and/or audible) indicating that the tray **5652** supporting all of the spent disposable loading units **3612** must be replaced with a new tray **5652** containing new disposable loading units **3612**.

FIGS. **123-128** depict another non-limiting embodiment of a surgical tool **6000** of the present invention that is well-adapted for use with a robotic system **1000** that has a tool drive assembly **1010** (FIG. **18**) that is operatively coupled to a master controller **1001** that is operable by inputs from an operator (i.e., a surgeon). As can be seen in FIG. **123**, the surgical tool **6000** includes a surgical end effector **6012** that comprises an endocutter. In at least one form, the surgical tool **6000** generally includes an elongated shaft assembly **6008** that has a proximal closure tube **6040** and a distal closure tube **6042** that are coupled together by an articulation joint **6100**. The surgical tool **6000** is operably coupled to the manipulator by a tool mounting portion, generally designated as **6200**. The surgical tool **6000** further includes an interface **6030** which may mechanically and electrically couple the tool mounting portion **6200** to the manipulator in the various manners described in detail above.

In at least one embodiment, the surgical tool **6000** includes a surgical end effector **6012** that comprises, among other things, at least one component **6024** that is selectively movable between first and second positions relative to at least one other component **6022** in response to various control motions applied to component **6024** as will be discussed in further detail below to perform a surgical procedure. In various embodiments, component **6022** comprises an elongated channel **6022** configured to operably support a surgical staple cartridge **6034** therein and component **6024** comprises a pivotally translatable clamping member, such as an anvil **6024**. Various embodiments of the surgical end effector **6012** are configured to maintain the anvil **6024** and elongated channel **6022** at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector **6012**. Unless otherwise stated, the end effector **6012** is similar to the surgical end effector **2012** described above and includes a cutting instrument (not shown) and a sled (not shown). The anvil **6024** may include a tab **6027** at its proximal end that interacts with a component of the mechanical closure system (described further below) to facilitate the opening of the anvil **6024**. The elongated channel **6022** and the anvil **6024** may be made of an electrically conductive material (such as metal) so that they may serve as part of an antenna that communicates

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with sensor(s) in the end effector, as described above. The surgical staple cartridge **6034** could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge **6034**, as was also described above.

As can be seen in FIG. **123**, the surgical end effector **6012** is attached to the tool mounting portion **6200** by the elongated shaft assembly **6008** according to various embodiments. As shown in the illustrated embodiment, the elongated shaft assembly **6008** includes an articulation joint generally designated as **6100** that enables the surgical end effector **6012** to be selectively articulated about a first tool articulation axis AA1-AA1 that is substantially transverse to a longitudinal tool axis LT-LT and a second tool articulation axis AA2-AA2 that is substantially transverse to the longitudinal tool axis LT-LT as well as the first articulation axis AA1-AA1. See FIG. **124**. In various embodiments, the elongated shaft assembly **6008** includes a closure tube assembly **6009** that comprises a proximal closure tube **6040** and a distal closure tube **6042** that are pivotally linked by a pivot links **6044** and **6046**. The closure tube assembly **6009** is movably supported on a spine assembly generally designated as **6102**.

As can be seen in FIG. **125**, the proximal closure tube **6040** is pivotally linked to an intermediate closure tube joint **6043** by an upper pivot link **6044U** and a lower pivot link **6044L** such that the intermediate closure tube joint **6043** is pivotable relative to the proximal closure tube **6040** about a first closure axis CA1-CA1 and a second closure axis CA2-CA2. In various embodiments, the first closure axis CA1-CA1 is substantially parallel to the second closure axis CA2-CA2 and both closure axes CA1-CA1, CA2-CA2 are substantially transverse to the longitudinal tool axis LT-LT. As can be further seen in FIG. **134**, the intermediate closure tube joint **6043** is pivotally linked to the distal closure tube **6042** by a left pivot link **6046L** and a right pivot link **6046R** such that the intermediate closure tube joint **6043** is pivotable relative to the distal closure tube **6042** about a third closure axis CA3-CA3 and a fourth closure axis CA4-CA4. In various embodiments, the third closure axis CA3-CA3 is substantially parallel to the fourth closure axis CA4-CA4 and both closure axes CA3-CA3, CA4-CA4 are substantially transverse to the first and second closure axes CA1-CA1, CA2-CA2 as well as to longitudinal tool axis LT-LT.

The closure tube assembly **6009** is configured to axially slide on the spine assembly **6102** in response to actuation motions applied thereto. The distal closure tube **6042** includes an opening **6045** which interfaces with the tab **6027** on the anvil **6024** to facilitate opening of the anvil **6024** as the distal closure tube **6042** is moved axially in the proximal direction "PD". The closure tubes **6040**, **6042** may be made of electrically conductive material (such as metal) so that they may serve as part of the antenna, as described above. Components of the spine assembly **6102** may be made of a non-conductive material (such as plastic).

As indicated above, the surgical tool **6000** includes a tool mounting portion **6200** that is configured for operable attachment to the tool mounting assembly **1010** of the robotic system **1000** in the various manners described in detail above. As can be seen in FIG. **127**, the tool mounting portion **6200** comprises a tool mounting plate **6202** that operably supports a transmission arrangement **6204** thereon. In various embodiments, the transmission arrangement **6204** includes an articulation transmission **6142** that comprises a portion of an articulation system **6140** for articulating the surgical end effector **6012** about a first tool articulation axis TA1-TA1 and a second tool articulation axis TA2-TA2. The first tool articulation axis TA1-TA1 is substantially transverse to the second tool articu-

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lation axis TA2-TA2 and both of the first and second tool articulation axes are substantially transverse to the longitudinal tool axis LT-LT. See FIG. 124.

To facilitate selective articulation of the surgical end effector 6012 about the first and second tool articulation axes TA1-TA1, TA2-TA2, the spine assembly 6102 comprises a proximal spine portion 6110 that is pivotally coupled to a distal spine portion 6120 by pivot pins 6122 for selective pivotal travel about TA1-TA1. Similarly, the distal spine portion 6120 is pivotally attached to the elongated channel 6022 of the surgical end effector 6012 by pivot pins 6124 to enable the surgical end effector 6012 to selectively pivot about the second tool axis TA2-TA2 relative to the distal spine portion 6120.

In various embodiments, the articulation system 6140 further includes a plurality of articulation elements that operably interface with the surgical end effector 6012 and an articulation control arrangement 6160 that is operably supported in the tool mounting member 6200 as will be described in further detail below. In at least one embodiment, the articulation elements comprise a first pair of first articulation cables 6144 and 6146. The first articulation cables are located on a first or right side of the longitudinal tool axis. Thus, the first articulation cables are referred to herein as a right upper cable 6144 and a right lower cable 6146. The right upper cable 6144 and the right lower cable 6146 extend through corresponding passages 6147, 6148, respectively along the right side of the proximal spine portion 6110. See FIG. 128. The articulation system 6140 further includes a second pair of second articulation cables 6150, 6152. The second articulation cables are located on a second or left side of the longitudinal tool axis. Thus, the second articulation cables are referred to herein as a left upper articulation cable 6150 and a left articulation cable 6152. The left upper articulation cable 6150 and the left lower articulation cable 6152 extend through passages 6153, 6154, respectively in the proximal spine portion 6110.

As can be seen in FIG. 124, the right upper cable 6144 extends around an upper pivot joint 6123 and is attached to a left upper side of the elongated channel 6022 at a left pivot joint 6125. The right lower cable 6146 extends around a lower pivot joint 6126 and is attached to a left lower side of the elongated channel 6022 at left pivot joint 6125. The left upper cable 6150 extends around the upper pivot joint 6123 and is attached to a right upper side of the elongated channel 6022 at a right pivot joint 6127. The left lower cable 6152 extends around the lower pivot joint 6126 and is attached to a right lower side of the elongated channel 6022 at right pivot joint 6127. Thus, to pivot the surgical end effector 6012 about the first tool articulation axis TA1-TA1 to the left (arrow "L"), the right upper cable 6144 and the right lower cable 6146 must be pulled in the proximal direction "PD". To articulate the surgical end effector 6012 to the right (arrow "R") about the first tool articulation axis TA1-TA1, the left upper cable 6150 and the left lower cable 6152 must be pulled in the proximal direction "PD". To articulate the surgical end effector 6012 about the second tool articulation axis TA2-TA2, in an upward direction (arrow "U"), the right upper cable 6144 and the left upper cable 6150 must be pulled in the proximal direction "PD". To articulate the surgical end effector 6012 in the downward direction (arrow "DW") about the second tool articulation axis TA2-TA2, the right lower cable 6146 and the left lower cable 6152 must be pulled in the proximal direction "PD".

The proximal ends of the articulation cables 6144, 6146, 6150, 6152 are coupled to the articulation control arrangement 6160 which comprises a ball joint assembly that is a part of the articulation transmission 6142. More specifically and

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with reference to FIG. 128, the ball joint assembly 6160 includes a ball-shaped member 6162 that is formed on a proximal portion of the proximal spine 6110. Movably supported on the ball-shaped member 6162 is an articulation control ring 6164. As can be further seen in FIG. 128, the proximal ends of the articulation cables 6144, 6146, 6150, 6152 are coupled to the articulation control ring 6164 by corresponding ball joint arrangements 6166. The articulation control ring 6164 is controlled by an articulation drive assembly 6170. As can be most particularly seen in FIG. 128, the proximal ends of the first articulation cables 6144, 6146 are attached to the articulation control ring 6164 at corresponding spaced first points 6149, 6151 that are located on plane 6159. Likewise, the proximal ends of the second articulation cables 6150, 6152 are attached to the articulation control ring 6164 at corresponding spaced second points 6153, 6155 that are also located along plane 6159. As the present Detailed Description proceeds, those of ordinary skill in the art will appreciate that such cable attachment configuration on the articulation control ring 6164 facilitates the desired range of articulation motions as the articulation control ring 6164 is manipulated by the articulation drive assembly 6170.

In various forms, the articulation drive assembly 6170 comprises a horizontal articulation assembly generally designated as 6171. In at least one form, the horizontal articulation assembly 6171 comprises a horizontal push cable 6172 that is attached to a horizontal gear arrangement 6180. The articulation drive assembly 6170 further comprises a vertical articulation assembly generally designated as 6173. In at least one form, the vertical articulation assembly 6173 comprises a vertical push cable 6174 that is attached to a vertical gear arrangement 6190. As can be seen in FIGS. 127 and 128, the horizontal push cable 6172 extends through a support plate 6167 that is attached to the proximal spine portion 6110. The distal end of the horizontal push cable 6174 is attached to the articulation control ring 6164 by a corresponding ball/pivot joint 6168. The vertical push cable 6174 extends through the support plate 6167 and the distal end thereof is attached to the articulation control ring 6164 by a corresponding ball/pivot joint 6169.

The horizontal gear arrangement 6180 includes a horizontal driven gear 6182 that is pivotally mounted on a horizontal shaft 6181 that is attached to a proximal portion of the proximal spine portion 6110. The proximal end of the horizontal push cable 6172 is pivotally attached to the horizontal driven gear 6182 such that, as the horizontal driven gear 6172 is rotated about horizontal pivot axis HA, the horizontal push cable 6172 applies a first pivot motion to the articulation control ring 6164. Likewise, the vertical gear arrangement 6190 includes a vertical driven gear 6192 that is pivotally supported on a vertical shaft 6191 attached to the proximal portion of the proximal spine portion 6110 for pivotal travel about a vertical pivot axis VA. The proximal end of the vertical push cable 6174 is pivotally attached to the vertical driven gear 6192 such that as the vertical driven gear 6192 is rotated about vertical pivot axis VA, the vertical push cable 6174 applies a second pivot motion to the articulation control ring 6164.

The horizontal driven gear 6182 and the vertical driven gear 6192 are driven by an articulation gear train 6300 that operably interfaces with an articulation shifter assembly 6320. In at least one form, the articulation shifter assembly comprises an articulation drive gear 6322 that is coupled to a corresponding one of the driven discs or elements 1304 on the adapter side 1307 of the tool mounting plate 6202. See FIG. 22. Thus, application of a rotary input motion from the robotic system 1000 through the tool drive assembly 1010 to the

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corresponding driven element **1304** will cause rotation of the articulation drive gear **6322** when the interface **1230** is coupled to the tool holder **1270**. An articulation driven gear **6324** is attached to a splined shifter shaft **6330** that is rotatably supported on the tool mounting plate **6202**. The articulation driven gear **6324** is in meshing engagement with the articulation drive gear **6322** as shown. Thus, rotation of the articulation drive gear **6322** will result in the rotation of the shaft **6330**. In various forms, a shifter driven gear assembly **6340** is movably supported on the splined portion **6332** of the shifter shaft **6330**.

In various embodiments, the shifter driven gear assembly **6340** includes a driven shifter gear **6342** that is attached to a shifter plate **6344**. The shifter plate **6344** operably interfaces with a shifter solenoid assembly **6350**. The shifter solenoid assembly **6350** is coupled to corresponding pins **6352** by conductors **6352**. See FIG. **127**. Pins **6352** are oriented to electrically communicate with slots **1258** (FIG. **21**) on the tool side **1244** of the adaptor **1240**. Such arrangement serves to electrically couple the shifter solenoid assembly **6350** to the robotic controller **1001**. Thus, activation of the shifter solenoid **6350** will shift the shifter driven gear assembly **6340** on the splined portion **6332** of the shifter shaft **6330** as represented by arrow “S” in FIGS. **136** and **137**. Various embodiments of the articulation gear train **6300** further include a horizontal gear assembly **6360** that includes a first horizontal drive gear **6362** that is mounted on a shaft **6361** that is rotatably attached to the tool mounting plate **6202**. The first horizontal drive gear **6362** is supported in meshing engagement with a second horizontal drive gear **6364**. As can be seen in FIG. **128**, the horizontal driven gear **6182** is in meshing engagement with the distal face portion **6365** of the second horizontal driven gear **6364**.

Various embodiments of the articulation gear train **6300** further include a vertical gear assembly **6370** that includes a first vertical drive gear **6372** that is mounted on a shaft **6371** that is rotatably supported on the tool mounting plate **6202**. The first vertical drive gear **6372** is supported in meshing engagement with a second vertical drive gear **6374** that is concentrically supported with the second horizontal drive gear **6364**. The second vertical drive gear **6374** is rotatably supported on the proximal spine portion **6110** for travel therearound. The second horizontal drive gear **6364** is rotatably supported on a portion of said second vertical drive gear **6374** for independent rotatable travel thereon. As can be seen in FIG. **128**, the vertical driven gear **6192** is in meshing engagement with the distal face portion **6375** of the second vertical driven gear **6374**.

In various forms, the first horizontal drive gear **6362** has a first diameter and the first vertical drive gear **6372** has a second diameter. As can be seen in FIGS. **127** and **128**, the shaft **6361** is not on a common axis with shaft **6371**. That is, the first horizontal driven gear **6362** and the first vertical driven gear **6372** do not rotate about a common axis. Thus, when the shifter gear **6342** is positioned in a center “locking” position such that the shifter gear **6342** is in meshing engagement with both the first horizontal driven gear **6362** and the first vertical drive gear **6372**, the components of the articulation system **6140** are locked in position. Thus, the shiftable shifter gear **6342** and the arrangement of first horizontal and vertical drive gears **6362**, **6372** as well as the articulation shifter assembly **6320** collectively may be referred to as an articulation locking system, generally designated as **6380**.

In use, the robotic controller **1001** of the robotic system **1000** may control the articulation system **6140** as follows. To articulate the end effector **6012** to the left about the first tool articulation axis TA1-TA1, the robotic controller **1001** acti-

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vates the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first horizontal drive gear **6362**. Thereafter, the controller **1001** causes a first rotary output motion to be applied to the articulation drive gear **6322** to drive the shifter gear in a first direction to ultimately drive the horizontal driven gear **6182** in another first direction. The horizontal driven gear **6182** is driven to pivot the articulation ring **6164** on the ball-shaped portion **6162** to thereby pull right upper cable **6144** and the right lower cable **6146** in the proximal direction “PD”. To articulate the end effector **6012** to the right about the first tool articulation axis TA1-TA1, the robotic controller **1001** activates the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first horizontal drive gear **6362**. Thereafter, the controller **1001** causes the first rotary output motion in an opposite direction to be applied to the articulation drive gear **6322** to drive the shifter gear **6342** in a second direction to ultimately drive the horizontal driven gear **6182** in another second direction. Such actions result in the articulation control ring **6164** moving in such a manner as to pull the left upper cable **6150** and the left lower cable **6152** in the proximal direction “PD”. In various embodiments the gear ratios and frictional forces generated between the gears of the vertical gear assembly **6370** serve to prevent rotation of the vertical driven gear **6192** as the horizontal gear assembly **6360** is actuated.

To articulate the end effector **6012** in the upper direction about the second tool articulation axis TA2-TA2, the robotic controller **1001** activates the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first vertical drive gear **6372**. Thereafter, the controller **1001** causes the first rotary output motion to be applied to the articulation drive gear **6322** to drive the shifter gear **6342** in a first direction to ultimately drive the vertical driven gear **6192** in another first direction. The vertical driven gear **6192** is driven to pivot the articulation ring **6164** on the ball-shaped portion **6162** of the proximal spine portion **6110** to thereby pull right upper cable **6144** and the left upper cable **6150** in the proximal direction “PD”. To articulate the end effector **6012** in the downward direction about the second tool articulation axis TA2-TA2, the robotic controller **1001** activates the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first vertical drive gear **6372**. Thereafter, the controller **1001** causes the first rotary output motion to be applied in an opposite direction to the articulation drive gear **6322** to drive the shifter gear **6342** in a second direction to ultimately drive the vertical driven gear **6192** in another second direction. Such actions thereby cause the articulation control ring **6164** to pull the right lower cable **6146** and the left lower cable **6152** in the proximal direction “PD”. In various embodiments, the gear ratios and frictional forces generated between the gears of the horizontal gear assembly **6360** serve to prevent rotation of the horizontal driven gear **6182** as the vertical gear assembly **6370** is actuated.

In various embodiments, a variety of sensors may communicate with the robotic controller **1001** to determine the articulated position of the end effector **6012**. Such sensors may interface with, for example, the articulation joint **6100** or be located within the tool mounting portion **6200**. For example, sensors may be employed to detect the position of the articulation control ring **6164** on the ball-shaped portion **6162** of the proximal spine portion **6110**. Such feedback from the sensors to the controller **1001** permits the controller **1001** to adjust the amount of rotation and the direction of the rotary output to the articulation drive gear **6322**. Further, as indicated above, when the shifter drive gear **6342** is centrally

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positioned in meshing engagement with the first horizontal drive gear **6362** and the first vertical drive gear **6372**, the end effector **6012** is locked in the articulated position. Thus, after the desired amount of articulation has been attained, the controller **1001** may activate the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first horizontal drive gear **6362** and the first vertical drive gear **6372**. In alternative embodiments, the shifter solenoid assembly **6350** may be spring activated to the central locked position.

In use, it may be desirable to rotate the surgical end effector **6012** about the longitudinal tool axis LT-LT. In at least one embodiment, the transmission arrangement **6204** on the tool mounting portion includes a rotational transmission assembly **6400** that is configured to receive a corresponding rotary output motion from the tool drive assembly **1010** of the robotic system **1000** and convert that rotary output motion to a rotary control motion for rotating the elongated shaft assembly **6008** (and surgical end effector **6012**) about the longitudinal tool axis LT-LT. In various embodiments, for example, a proximal end portion **6041** of the proximal closure tube **6040** is rotatably supported on the tool mounting plate **6202** of the tool mounting portion **6200** by a forward support cradle **6205** and a closure sled **6510** that is also movably supported on the tool mounting plate **6202**. In at least one form, the rotational transmission assembly **6400** includes a tube gear segment **6402** that is formed on (or attached to) the proximal end **6041** of the proximal closure tube **6040** for operable engagement by a rotational gear assembly **6410** that is operably supported on the tool mounting plate **6202**. As can be seen in FIG. **136**, the rotational gear assembly **6410**, in at least one embodiment, comprises a rotation drive gear **6412** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **6202** when the tool mounting portion **6200** is coupled to the tool drive assembly **1010**. See FIG. **22**. The rotational gear assembly **6410** further comprises a first rotary driven gear **6414** that is rotatably supported on the tool mounting plate **6202** in meshing engagement with the rotation drive gear **6412**. The first rotary driven gear **6414** is attached to a drive shaft **6416** that is rotatably supported on the tool mounting plate **6202**. A second rotary driven gear **6418** is attached to the drive shaft **6416** and is in meshing engagement with tube gear segment **6402** on the proximal closure tube **6040**. Application of a second rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **6412**. Rotation of the rotation drive gear **6412** ultimately results in the rotation of the elongated shaft assembly **6008** (and the surgical end effector **6012**) about the longitudinal tool axis LT-LT. It will be appreciated that the application of a rotary output motion from the tool drive assembly **1010** in one direction will result in the rotation of the elongated shaft assembly **6008** and surgical end effector **6012** about the longitudinal tool axis LT-LT in a first direction and an application of the rotary output motion in an opposite direction will result in the rotation of the elongated shaft assembly **6008** and surgical end effector **6012** in a second direction that is opposite to the first direction.

In at least one embodiment, the closure of the anvil **2024** relative to the staple cartridge **2034** is accomplished by axially moving a closure portion of the elongated shaft assembly **2008** in the distal direction "DD" on the spine assembly **2049**. As indicated above, in various embodiments, the proximal end portion **6041** of the proximal closure tube **6040** is supported by the closure sled **6510** which comprises a portion of a closure transmission, generally depicted as **6512**. As can be

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seen in FIG. **127**, the proximal end portion **6041** of the proximal closure tube portion **6040** has a collar **6048** formed thereon. The closure sled **6510** is coupled to the collar **6048** by a yoke **6514** that engages an annular groove **6049** in the collar **6048**. Such arrangement serves to enable the collar **6048** to rotate about the longitudinal tool axis LT-LT while still being coupled to the closure transmission **6512**. In various embodiments, the closure sled **6510** has an upstanding portion **6516** that has a closure rack gear **6518** formed thereon. The closure rack gear **6518** is configured for driving engagement with a closure gear assembly **6520**. See FIG. **127**.

In various forms, the closure gear assembly **6520** includes a closure spur gear **6522** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **6202**. See FIG. **22**. Thus, application of a third rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding second driven element **1304** will cause rotation of the closure spur gear **6522** when the tool mounting portion **6202** is coupled to the tool drive assembly **1010**. The closure gear assembly **6520** further includes a closure reduction gear set **6524** that is supported in meshing engagement with the closure spur gear **6522** and the closure rack gear **2106**. Thus, application of a third rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding second driven element **1304** will cause rotation of the closure spur gear **6522** and the closure transmission **6512** and ultimately drive the closure sled **6510** and the proximal closure tube **6040** axially on the proximal spine portion **6110**. The axial direction in which the proximal closure tube **6040** moves ultimately depends upon the direction in which the third driven element **1304** is rotated. For example, in response to one rotary output motion received from the tool drive assembly **1010** of the robotic system **1000**, the closure sled **6510** will be driven in the distal direction "DD" and ultimately drive the proximal closure tube **6040** in the distal direction "DD". As the proximal closure tube **6040** is driven distally, the distal closure tube **6042** is also driven distally by virtue of its connection with the proximal closure tube **6040**. As the distal closure tube **6042** is driven distally, the end of the closure tube **6042** will engage a portion of the anvil **6024** and cause the anvil **6024** to pivot to a closed position. Upon application of an "opening" output motion from the tool drive assembly **1010** of the robotic system **1000**, the closure sled **6510** and the proximal closure tube **6040** will be driven in the proximal direction "PD" on the proximal spine portion **6110**. As the proximal closure tube **6040** is driven in the proximal direction "PD", the distal closure tube **6042** will also be driven in the proximal direction "PD". As the distal closure tube **6042** is driven in the proximal direction "PD", the opening **6045** therein interacts with the tab **6027** on the anvil **6024** to facilitate the opening thereof. In various embodiments, a spring (not shown) may be employed to bias the anvil **6024** to the open position when the distal closure tube **6042** has been moved to its starting position. In various embodiments, the various gears of the closure gear assembly **6520** are sized to generate the necessary closure forces needed to satisfactorily close the anvil **6024** onto the tissue to be cut and stapled by the surgical end effector **6012**. For example, the gears of the closure transmission **6520** may be sized to generate approximately 70-120 pounds of closure forces.

In various embodiments, the cutting instrument is driven through the surgical end effector **6012** by a knife bar **6530**. See FIG. **127**. In at least one form, the knife bar **6530** is fabricated with a joint arrangement (not shown) and/or is fabricated from material that can accommodate the articula-

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tion of the surgical end effector **6102** about the first and second tool articulation axes while remaining sufficiently rigid so as to push the cutting instrument through tissue clamped in the surgical end effector **6012**. The knife bar **6530** extends through a hollow passage **6532** in the proximal spine portion **6110**.

In various embodiments, a proximal end **6534** of the knife bar **6530** is rotatably affixed to a knife rack gear **6540** such that the knife bar **6530** is free to rotate relative to the knife rack gear **6540**. The distal end of the knife bar **6530** is attached to the cutting instrument in the various manners described above. As can be seen in FIG. **127**, the knife rack gear **6540** is slidably supported within a rack housing **6542** that is attached to the tool mounting plate **6202** such that the knife rack gear **6540** is retained in meshing engagement with a knife drive transmission portion **6550** of the transmission arrangement **6204**. In various embodiments, the knife drive transmission portion **6550** comprises a knife gear assembly **6560**. More specifically and with reference to FIG. **127**, in at least one embodiment, the knife gear assembly **6560** includes a knife spur gear **6562** that is coupled to a corresponding fourth one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **6202**. See FIG. **22**. Thus, application of another rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding fourth driven element **1304** will cause rotation of the knife spur gear **6562**. The knife gear assembly **6560** further includes a knife gear reduction set **6564** that includes a first knife driven gear **6566** and a second knife drive gear **6568**. The knife gear reduction set **6564** is rotatably mounted to the tool mounting plate **6202** such that the first knife driven gear **6566** is in meshing engagement with the knife spur gear **6562**. Likewise, the second knife drive gear **6568** is in meshing engagement with a third knife drive gear assembly **6570**. As shown in FIG. **127**, the second knife driven gear **6568** is in meshing engagement with a fourth knife driven gear **6572** of the third knife drive gear assembly **6570**. The fourth knife driven gear **6572** is in meshing engagement with a fifth knife driven gear assembly **6574** that is in meshing engagement with the knife rack gear **6540**. In various embodiments, the gears of the knife gear assembly **6560** are sized to generate the forces needed to drive the cutting instrument through the tissue clamped in the surgical end effector **6012** and actuate the staples therein. For example, the gears of the knife gear assembly **6560** may be sized to generate approximately 40 to 100 pounds of driving force. It will be appreciated that the application of a rotary output motion from the tool drive assembly **1010** in one direction will result in the axial movement of the cutting instrument in a distal direction and application of the rotary output motion in an opposite direction will result in the axial travel of the cutting instrument in a proximal direction.

As can be appreciated from the foregoing description, the surgical tool **6000** represents a vast improvement over prior robotic tool arrangements. The unique and novel transmission arrangement employed by the surgical tool **6000** enables the tool to be operably coupled to a tool holder portion **1010** of a robotic system that only has four rotary output bodies, yet obtain the rotary output motions therefrom to: (i) articulate the end effector about two different articulation axes that are substantially transverse to each other as well as the longitudinal tool axis; (ii) rotate the end effector **6012** about the longitudinal tool axis; (iii) close the anvil **6024** relative to the surgical staple cartridge **6034** to varying degrees to enable the end effector **6012** to be used to manipulate tissue and then clamp it into position for cutting and stapling; and (iv) firing the cutting instrument to cut through the tissue clamped

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within the end effector **6012**. The unique and novel shifter arrangements of various embodiments of the present invention described above enable two different articulation actions to be powered from a single rotatable body portion of the robotic system.

The various embodiments of the present invention have been described above in connection with cutting-type surgical instruments. It should be noted, however, that in other embodiments, the inventive surgical instrument disclosed herein need not be a cutting-type surgical instrument, but rather could be used in any type of surgical instrument including remote sensor transponders. For example, it could be a non-cutting endoscopic instrument, a grasper, a stapler, a clip applicator, an access device, a drug/gene therapy delivery device, an energy device using ultrasound, RF, laser, etc. In addition, the present invention may be in laparoscopic instruments, for example. The present invention also has application in conventional endoscopic and open surgical instrumentation as well as robotic-assisted surgery.

FIG. **129** depicts use of various aspects of certain embodiments of the present invention in connection with a surgical tool **7000** that has an ultrasonically powered end effector **7012**. The end effector **7012** is operably attached to a tool mounting portion **7100** by an elongated shaft assembly **7008**. The tool mounting portion **7100** may be substantially similar to the various tool mounting portions described hereinabove. In one embodiment, the end effector **7012** includes an ultrasonically powered jaw portion **7014** that is powered by alternating current or direct current in a known manner. Such ultrasonically-powered devices are disclosed, for example, in U.S. Pat. No. 6,783,524, entitled ROBOTIC SURGICAL TOOL WITH ULTRASOUND CAUTERIZING AND CUTTING INSTRUMENT, which issued on Aug. 31, 2004, the entire disclosure of which is herein incorporated by reference. In the illustrated embodiment, a separate power cord **7020** is shown. It will be understood, however, that the power may be supplied thereto from the robotic controller **1001** through the tool mounting portion **7100**. The surgical end effector **7012** further includes a movable jaw **7016** that may be used to clamp tissue onto the ultrasonic jaw portion **7014**. The movable jaw portion **7016** may be selectively actuated by the robotic controller **1001** through the tool mounting portion **7100** in any one of the various manners herein described.

FIG. **130** illustrates use of various aspects of certain embodiments of the present invention in connection with a surgical tool **8000** that has an end effector **8012** that comprises a linear stapling device. The end effector **8012** is operably attached to a tool mounting portion **8100** by an elongated shaft assembly **3700** of the type and construction described above. However, the end effector **8012** may be attached to the tool mounting portion **8100** by a variety of other elongated shaft assemblies described herein. In one embodiment, the tool mounting portion **8100** may be substantially similar to tool mounting portion **3750**. However, various other tool mounting portions and their respective transmission arrangements describe in detail herein may also be employed. Such linear stapling head portions are also disclosed, for example, in U.S. Pat. No. 7,673,781, entitled SURGICAL STAPLING DEVICE WITH STAPLE DRIVER THAT SUPPORTS MULTIPLE WIRE DIAMETER STAPLES, which issued on Mar. 9, 2010, the entire disclosure of which is herein incorporated by reference.

Various sensor embodiments described in U.S. Patent Publication No. 2011/0062212 A1, entitled SURGICAL INSTRUMENT HAVING RECORDING CAPABILITIES, now U.S. Pat. No. 8,167,185, which issued on May 1, 2012, the disclosure of which is herein incorporated by reference in

its entirety, may be employed with many of the surgical tool embodiments disclosed herein. As was indicated above, the master controller **1001** generally includes master controllers (generally represented by **1003**) which are grasped by the surgeon and manipulated in space while the surgeon views the procedure via a stereo display **1002**. See FIG. 13. The master controllers **1001** are manual input devices which preferably move with multiple degrees of freedom, and which often further have an actuatable handle for actuating the surgical tools. Some of the surgical tool embodiments disclosed herein employ a motor or motors in their tool drive portion to supply various control motions to the tool's end effector. Such embodiments may also obtain additional control motion(s) from the motor arrangement employed in the robotic system components. Other embodiments disclosed herein obtain all of the control motions from motor arrangements within the robotic system.

Such motor powered arrangements may employ various sensor arrangements that are disclosed in the published US patent application cited above to provide the surgeon with a variety of forms of feedback without departing from the spirit and scope of the present invention. For example, those master controller arrangements **1003** that employ a manually actuatable firing trigger can employ run motor sensor(s) to provide the surgeon with feedback relating to the amount of force applied to or being experienced by the cutting member. The run motor sensor(s) may be configured for communication with the firing trigger portion to detect when the firing trigger portion has been actuated to commence the cutting/stapling operation by the end effector. The run motor sensor may be a proportional sensor such as, for example, a rheostat or variable resistor. When the firing trigger is drawn in, the sensor detects the movement, and sends an electrical signal indicative of the voltage (or power) to be supplied to the corresponding motor. When the sensor is a variable resistor or the like, the rotation of the motor may be generally proportional to the amount of movement of the firing trigger. That is, if the operator only draws or closes the firing trigger in a small amount, the rotation of the motor is relatively low. When the firing trigger is fully drawn in (or in the fully closed position), the rotation of the motor is at its maximum. In other words, the harder the surgeon pulls on the firing trigger, the more voltage is applied to the motor causing greater rates of rotation. Other arrangements may provide the surgeon with a feedback meter **1005** that may be viewed through the display **1002** and provide the surgeon with a visual indication of the amount of force being applied to the cutting instrument or dynamic clamping member. Other sensor arrangements may be employed to provide the master controller **1001** with an indication as to whether a staple cartridge has been loaded into the end effector, whether the anvil has been moved to a closed position prior to firing, etc.

In alternative embodiments, a motor-controlled interface may be employed in connection with the controller **1001** that limit the maximum trigger pull based on the amount of loading (e.g., clamping force, cutting force, etc.) experienced by the surgical end effector. For example, the harder it is to drive the cutting instrument through the tissue clamped within the end effector, the harder it would be to pull/actuate the activation trigger. In still other embodiments, the trigger on the controller **1001** is arranged such that the trigger pull location is proportionate to the end effector-location/condition. For example, the trigger is only fully depressed when the end effector is fully fired.

The devices disclosed herein can be designed to be disposed of after a single use, or they can be designed to be used multiple times. In either case, however, the device can be

reconditioned for reuse after at least one use. Reconditioning can include any combination of the steps of disassembly of the device, followed by cleaning or replacement of particular pieces, and subsequent reassembly. In particular, the device can be disassembled, and any number of the particular pieces or parts of the device can be selectively replaced or removed in any combination. Upon cleaning and/or replacement of particular parts, the device can be reassembled for subsequent use either at a reconditioning facility, or by a surgical team immediately prior to a surgical procedure. Those skilled in the art will appreciate that reconditioning of a device can utilize a variety of techniques for disassembly, cleaning/replacement, and reassembly. Use of such techniques, and the resulting reconditioned device, are all within the scope of the present application.

Although the present invention has been described herein in connection with certain disclosed embodiments, many modifications and variations to those embodiments may be implemented. For example, different types of end effectors may be employed. Also, where materials are disclosed for certain components, other materials may be used. The foregoing description and following claims are intended to cover all such modification and variations.

Any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated materials does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

What is claimed is:

1. A disposable loading unit configured to be operably attached to a surgical instrument which is configured to selectively generate at least one control motion for the operation of said disposable loading unit, said disposable loading unit comprising:

- a carrier operably supporting a cartridge assembly therein; an anvil supported relative to said carrier and being movable from an open position to closed positions upon application of at least one control motion thereto;
- a housing coupled to said carrier, said housing including means for removably attaching said housing to the surgical instrument;
- a rotary drive at least partially supported within said housing;
- a motor supported within said housing and operably interfacing with said rotary drive to selectively apply a rotary motion thereto, wherein said motor is configured to receive power from a power source such that said motor can only selectively receive power from said power source when said means for removably attaching said housing to the surgical instrument is operably coupled to the surgical instrument; and
- a linear member coupled with said rotary drive which moves axially upon the application of a rotary motion thereto from said motor.

2. The disposable loading unit of claim 1, wherein said cartridge assembly comprises a plurality of staples removably stored therein.

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3. The disposable loading unit of claim 2, wherein said linear member comprises a sled movable between a start position and an end position to eject said staples from said cartridge assembly.

4. The disposable loading unit of claim 3, wherein said linear member further comprises a knife configured to incise tissue captured between said anvil and said cartridge assembly.

5. The disposable loading unit of claim 1, wherein said cartridge assembly is configured to be removed from said carrier and replaced with a different cartridge assembly.

6. A stapling sub-system configured to be operably engaged with a surgical instrument system, said stapling sub-system comprising:

- a staple cartridge carrier;
- a staple cartridge assembly supported by said staple cartridge carrier;
- an anvil supported relative to said staple cartridge carrier and movable from an open position to a closed position;
- a housing, wherein said staple cartridge carrier extends from said housing, and wherein said housing comprises a housing connector removably attachable to the surgical instrument system; and
- a rotary drive system, comprising
 - a rotary shaft;
 - a translatable drive member operably engaged with said rotary shaft, wherein said translatable drive member is selectively translatable through said staple cartridge assembly from a start position to an end position when a rotary motion is applied to said rotary shaft; and
 - an electric motor operably interfacing with said rotary shaft to selectively apply said rotary motion to said rotary shaft, wherein said electric motor is operably disconnected from a power source when said housing is not attached to the surgical instrument system, and wherein said electric motor is operably connected to the power source when said housing is attached to the surgical instrument system.

7. The stapling sub-system of claim 6, wherein said staple cartridge assembly comprises a plurality of staples removably stored therein.

8. The stapling sub-system of claim 7, wherein said translatable drive member comprises a sled movable between said start position and said end position to eject said staples from said staple cartridge assembly.

9. The stapling sub-system of claim 8, wherein said translatable drive member further comprises a knife configured to incise tissue captured between said anvil and said staple cartridge assembly.

10. The stapling sub-system of claim 6, wherein said staple cartridge assembly is configured to be removed from said staple cartridge carrier and replaced with a different staple cartridge assembly.

11. A stapling attachment configured to be operably attached to a surgical instrument system, said stapling attachment comprising:

- a staple cartridge carrier;
- a staple cartridge body supported by said staple cartridge carrier, wherein said staple cartridge body comprises a proximal end and a distal end;
- a plurality of staples removably stored in said staple cartridge body;
- an anvil supported relative to said staple cartridge carrier and movable from an open position to a closed position;

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a housing, wherein said staple cartridge carrier extends from said housing, and wherein said housing is removably attachable to the surgical instrument system;

an electric motor configured to produce rotational motion, wherein said electric motor selectively receives power from a power source only when said housing is coupled to said surgical instrument system; and

drive means for converting the rotational motion produced by said electric motor to translational motion to eject said staples from said staple cartridge body.

12. The stapling attachment of claim 11, wherein said drive means comprises a sled movable between a proximal position and a distal position to eject said staples from said staple cartridge body.

13. The stapling attachment of claim 12, wherein said drive means further comprises a knife configured to incise tissue captured between said anvil and said staple cartridge body.

14. The stapling attachment of claim 11, wherein said staple cartridge body is configured to be removed from said staple cartridge carrier and replaced with a different staple cartridge body.

15. The stapling attachment of claim 11, wherein the translational motion is directed toward said distal end.

16. A loading unit configured to be operably attached to a surgical instrument which is configured to selectively generate at least one control motion for the operation of said loading unit, said loading unit comprising:

- an end effector;
- a housing including means for removably attaching said housing to the surgical instrument;
- a rotary drive at least partially supported within said housing;
- a motor supported within said housing and operably interfacing with said rotary drive to selectively apply a rotary motion thereto, wherein said motor is configured to receive power from a power source such that said motor can only selectively receive power from said power source when said means for removably attaching said housing to the surgical instrument is operably coupled to the surgical instrument; and
- a linear member coupled with said rotary drive which moves axially upon the application of a rotary motion thereto from said motor.

17. A stapling sub-system configured to be operably engaged with a surgical instrument system, said stapling sub-system comprising:

- a stapling portion;
- a housing, wherein said stapling portion extends from said housing, and wherein said housing comprises a housing connector removably attachable to the surgical instrument system; and

a rotary drive system, comprising

- a rotary shaft;

- a translatable drive member operably engaged with said rotary shaft, wherein said translatable drive member is selectively translatable through said stapling portion from a start position to an end position when a rotary motion is applied to said rotary shaft; and

- an electric motor operably interfacing with said rotary shaft to selectively apply said rotary motion to said rotary shaft, wherein said electric motor is operably disconnected from a power source when said housing is not attached to the surgical instrument system, and wherein said electric motor is operably connected to the power source when said housing is attached to the surgical instrument system.

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18. A stapling attachment configured to be operably attached to a surgical instrument system, said stapling attachment comprising:

a staple cartridge body comprising a proximal end and a distal end;

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a plurality of staples removably stored in said staple cartridge body;

an anvil supported relative to said staple cartridge body;

a housing removably attachable to the surgical instrument system;

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an electric motor configured to produce rotational motion, wherein said electric motor selectively receives power from a power source only when said housing is coupled to said surgical instrument system; and

drive means for converting the rotational motion produced by said electric motor to translational motion to eject said staples from said staple cartridge body.

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