



US008479969B2

(12) **United States Patent**
Shelton, IV

(10) **Patent No.:** **US 8,479,969 B2**
(45) **Date of Patent:** **Jul. 9, 2013**

(54) **DRIVE INTERFACE FOR OPERABLY
COUPLING A MANIPULATABLE SURGICAL
TOOL TO A ROBOT**

(75) Inventor: **Frederick E. Shelton, IV**, Hillsboro,
OH (US)

(73) Assignee: **Ethicon Endo-Surgery, Inc.**, Cincinnati,
OH (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/369,609**

(22) Filed: **Feb. 9, 2012**

(65) **Prior Publication Data**

US 2012/0211546 A1 Aug. 23, 2012

Related U.S. Application Data

(63) Continuation of application No. 13/118,259, filed on
May 27, 2011, which is a continuation-in-part of
application No. 11/651,807, filed on Jan. 10, 2007.

(51) **Int. Cl.**
A61B 17/068 (2006.01)

(52) **U.S. Cl.**
USPC **227/180.1**; 227/19; 227/175.1; 227/177.1

(58) **Field of Classification Search**
USPC 227/175.1, 177.1, 180.1, 19
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

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

951,393 A	3/1910	Hahn
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
3,032,769 A	5/1962	Palmer
3,075,062 A	1/1963	Iaccarino
3,078,465 A	2/1963	Bobrov
3,166,072 A	1/1965	Sullivan, Jr.
3,266,494 A	8/1966	Brownrigg et al.
3,269,630 A	8/1966	Fleischer

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2458946 A1	3/2003
CA	2512960 A1	1/2006

(Continued)

OTHER PUBLICATIONS

European Examination Report, Application No. 08250100.8, dated
Feb. 19, 2009 (4 pages).

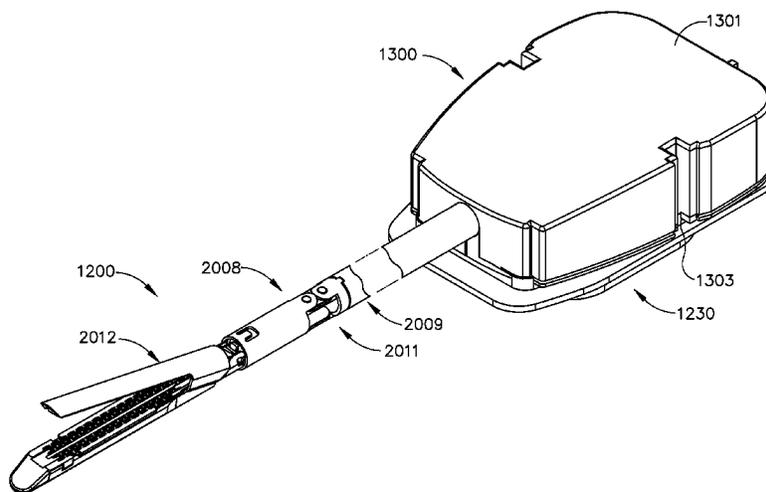
(Continued)

Primary Examiner — Brian D Nash

(57) **ABSTRACT**

A surgical instrument for use with a robotic system that has a control unit and a shaft portion that includes an electrically conductive elongated member that is attached to a portion of the robotic system. The elongated member is configured to transmit control motions from the robotic system to an end effector.

28 Claims, 109 Drawing Sheets



U.S. PATENT DOCUMENTS							
3,357,296	A	12/1967	Lefever	4,619,262	A	10/1986	Taylor
3,490,675	A	1/1970	Green et al.	4,629,107	A	12/1986	Fedotov et al.
3,551,987	A	1/1971	Wilkinson	4,632,290	A	12/1986	Green et al.
3,598,943	A	8/1971	Barrett	4,633,874	A	1/1987	Chow et al.
3,643,851	A	2/1972	Green et al.	4,641,076	A	2/1987	Linden
3,662,939	A	5/1972	Bryan	4,646,722	A	3/1987	Silverstein et al.
3,717,294	A	2/1973	Green	4,655,222	A	4/1987	Florez et al.
3,734,207	A	5/1973	Fishbein	4,663,874	A	5/1987	Sano et al.
3,740,994	A	6/1973	DeCarlo, Jr.	4,664,305	A	5/1987	Blake, III et al.
3,744,495	A	7/1973	Johnson	4,665,916	A	5/1987	Green
3,746,002	A	7/1973	Haller	4,667,674	A	5/1987	Korthoff et al.
3,751,902	A	8/1973	Kingsbury et al.	4,671,445	A	6/1987	Barker et al.
3,819,100	A	6/1974	Noiles et al.	4,676,245	A	6/1987	Fukuda
3,821,919	A	7/1974	Knohl	4,693,248	A	9/1987	Failla
3,885,491	A	5/1975	Curtis	4,709,120	A	11/1987	Pearson
3,892,228	A	7/1975	Mitsui	4,715,520	A	12/1987	Roehr, Jr. et al.
3,894,174	A	7/1975	Cartun	4,719,917	A	1/1988	Barrows et al.
3,940,844	A	3/1976	Colby et al.	4,728,020	A	3/1988	Green et al.
RE28,932	E	8/1976	Noiles et al.	4,728,876	A	3/1988	Mongeon et al.
4,060,089	A	11/1977	Noiles	4,729,260	A	3/1988	Dudden
4,129,059	A	12/1978	Van Eck	4,741,336	A	5/1988	Failla et al.
4,213,562	A	7/1980	Garrett et al.	4,752,024	A	6/1988	Green et al.
4,250,436	A	2/1981	Weissman	4,754,909	A	7/1988	Barker et al.
4,261,244	A	4/1981	Becht et al.	4,767,044	A	8/1988	Green
4,272,662	A	6/1981	Simpson	4,777,780	A	10/1988	Holzwarth
4,275,813	A	6/1981	Noiles	4,787,387	A	11/1988	Burbank, III et al.
4,289,133	A	9/1981	Rothfuss	4,790,225	A	12/1988	Moody et al.
4,305,539	A	12/1981	Korolkov et al.	4,805,617	A	2/1989	Bedi et al.
4,317,451	A	3/1982	Cerwin et al.	4,805,823	A	2/1989	Rothfuss
4,321,002	A	3/1982	Froehlich	4,809,695	A	3/1989	Gwathmey et al.
4,331,277	A	5/1982	Green	4,817,847	A	4/1989	Redtenbacher et al.
4,340,331	A	7/1982	Savino	4,819,853	A	4/1989	Green
4,347,450	A	8/1982	Colligan	4,821,939	A	4/1989	Green
4,349,028	A	9/1982	Green	4,827,911	A	5/1989	Broadwin et al.
4,353,371	A	10/1982	Cosman	4,844,068	A	7/1989	Arata et al.
4,379,457	A	4/1983	Gravener et al.	4,869,414	A	9/1989	Green et al.
4,380,312	A	4/1983	Landrus	4,869,415	A	9/1989	Fox
4,383,634	A	5/1983	Green	4,880,015	A	11/1989	Nierman
4,396,139	A	8/1983	Hall et al.	4,890,613	A	1/1990	Golden et al.
4,402,445	A	9/1983	Green	4,892,244	A	1/1990	Fox et al.
4,408,692	A	10/1983	Siegel et al.	4,915,100	A	4/1990	Green
4,415,112	A	11/1983	Green	4,930,503	A	6/1990	Pruitt
4,428,376	A	1/1984	Mericle	4,932,960	A	6/1990	Green et al.
4,429,695	A	2/1984	Green	4,938,408	A	7/1990	Bedi et al.
4,434,796	A	3/1984	Karapetian et al.	4,941,623	A	7/1990	Pruitt
4,442,964	A	4/1984	Becht	4,944,443	A	7/1990	Odds et al.
4,451,743	A	5/1984	Suzuki et al.	4,955,959	A	9/1990	Tompkins et al.
4,454,887	A	6/1984	Krüger	4,978,049	A	12/1990	Green
4,467,805	A	8/1984	Fukuda	4,986,808	A	1/1991	Broadwin et al.
4,475,679	A	10/1984	Fleury, Jr.	4,988,334	A	1/1991	Hornlein et al.
4,485,816	A	12/1984	Krumme	5,002,553	A	3/1991	Shiber
4,489,875	A	12/1984	Crawford et al.	5,009,661	A	4/1991	Michelson
4,500,024	A	2/1985	DiGiovanni et al.	5,014,899	A	5/1991	Presty et al.
4,505,273	A	3/1985	Braun et al.	5,015,227	A	5/1991	Broadwin et al.
4,505,414	A	3/1985	Filipi	5,027,834	A	7/1991	Pruitt
4,506,671	A	3/1985	Green	5,031,814	A	7/1991	Tompkins et al.
4,520,817	A	6/1985	Green	5,040,715	A	8/1991	Green et al.
4,522,327	A	6/1985	Korthoff et al.	5,042,707	A	8/1991	Taheri
4,526,174	A	7/1985	Froehlich	5,061,269	A	10/1991	Muller
4,527,724	A	7/1985	Chow et al.	5,062,563	A	11/1991	Green et al.
4,530,453	A	7/1985	Green	5,065,929	A	11/1991	Schulze et al.
4,548,202	A	10/1985	Duncan	5,071,052	A	12/1991	Rodak et al.
4,565,189	A	1/1986	Mabuchi	5,071,430	A	12/1991	de Salis et al.
4,566,620	A	1/1986	Green et al.	5,074,454	A	12/1991	Peters
4,573,469	A	3/1986	Golden et al.	5,080,556	A	1/1992	Carreno
4,573,622	A	3/1986	Green et al.	5,083,695	A	1/1992	Foslien et al.
4,576,167	A	3/1986	Noiles et al.	5,084,057	A	1/1992	Green et al.
4,580,712	A	4/1986	Green	5,088,979	A	2/1992	Filipi et al.
4,589,416	A	5/1986	Green	5,088,997	A	2/1992	Delahuerga et al.
4,591,085	A	5/1986	Di Giovanni	5,094,247	A	3/1992	Hernandez et al.
4,604,786	A	8/1986	Howie, Jr.	5,100,420	A	3/1992	Green et al.
4,605,001	A	8/1986	Rothfuss et al.	5,104,025	A	4/1992	Main et al.
4,605,004	A	8/1986	Di Giovanni et al.	5,106,008	A	4/1992	Tompkins et al.
4,606,343	A	8/1986	Conta et al.	5,111,987	A	5/1992	Moeinzadeh et al.
4,607,638	A	8/1986	Crainich	5,116,349	A	5/1992	Aranyi
4,608,981	A	9/1986	Rothfuss et al.	5,129,570	A	7/1992	Schulze et al.
4,610,250	A	9/1986	Green	5,137,198	A	8/1992	Nobis et al.
4,610,383	A	9/1986	Rothfuss et al.	5,139,513	A	8/1992	Segato
				5,141,144	A	8/1992	Foslien et al.

US 8,479,969 B2

Page 3

5,156,315	A	10/1992	Green et al.	5,366,134	A	11/1994	Green et al.
5,156,614	A	10/1992	Green et al.	5,366,479	A	11/1994	McGarry et al.
5,158,567	A	10/1992	Green	5,368,015	A	11/1994	Wilk
D330,699	S	11/1992	Gill	5,370,645	A	12/1994	Klicek et al.
5,163,598	A	11/1992	Peters et al.	5,372,596	A	12/1994	Klicek et al.
5,171,247	A	12/1992	Hughett et al.	5,372,602	A	12/1994	Burke
5,171,249	A	12/1992	Stefanchik et al.	5,374,277	A	12/1994	Hassler
5,188,111	A	2/1993	Yates et al.	5,379,933	A	1/1995	Green et al.
5,190,517	A	3/1993	Zieve et al.	5,381,782	A	1/1995	DeLaRama et al.
5,195,968	A	3/1993	Lundquist et al.	5,382,247	A	1/1995	Cimino et al.
5,197,648	A	3/1993	Gingold	5,383,880	A	1/1995	Hooven
5,200,280	A	4/1993	Karasa	5,383,881	A	1/1995	Green et al.
5,205,459	A	4/1993	Brinkerhoff et al.	5,383,888	A	1/1995	Zvenyatsky et al.
5,207,697	A	5/1993	Carusillo et al.	5,383,895	A	1/1995	Holmes et al.
5,209,747	A	5/1993	Knoepfler	5,389,098	A	2/1995	Tsuruta et al.
5,211,649	A	5/1993	Kohler et al.	5,391,180	A	2/1995	Tovey et al.
5,217,457	A	6/1993	Delahuerga et al.	5,392,979	A	2/1995	Green et al.
5,217,478	A	6/1993	Rexroth	5,395,030	A	3/1995	Kuramoto et al.
5,219,111	A	6/1993	Bilotti et al.	5,395,033	A	3/1995	Byrne et al.
5,221,036	A	6/1993	Takase	5,395,312	A	3/1995	Desai
5,221,281	A	6/1993	Klicek	5,397,046	A	3/1995	Savage et al.
5,222,963	A	6/1993	Brinkerhoff et al.	5,397,324	A	3/1995	Carroll et al.
5,222,975	A	6/1993	Crainich	5,403,312	A	4/1995	Yates et al.
5,222,976	A	6/1993	Yoon	5,405,072	A	4/1995	Zlock et al.
5,223,675	A	6/1993	Taft	5,405,344	A	4/1995	Williamson et al.
5,234,447	A	8/1993	Kaster et al.	5,407,293	A	4/1995	Crainich
5,236,440	A	8/1993	Hlavacek	5,409,498	A	4/1995	Braddock et al.
5,239,981	A	8/1993	Anapliotis	5,411,508	A	5/1995	Bessler et al.
5,240,163	A	8/1993	Stein et al.	5,413,267	A	5/1995	Solyntjes et al.
5,242,457	A	9/1993	Akopov et al.	5,413,268	A	5/1995	Green et al.
5,244,462	A	9/1993	Delahuerga et al.	5,413,272	A	5/1995	Green et al.
5,246,156	A	9/1993	Rothfuss et al.	5,415,334	A	5/1995	Williamson, IV et al.
5,246,443	A	9/1993	Mai	5,415,335	A	5/1995	Knodell, Jr.
5,253,793	A	10/1993	Green et al.	5,417,361	A	5/1995	Williamson, IV
5,258,009	A	11/1993	Connors	5,421,829	A	6/1995	Olichney et al.
5,258,012	A	11/1993	Luscombe et al.	5,422,567	A	6/1995	Matsunaga
5,259,366	A	11/1993	Reydel et al.	5,423,809	A	6/1995	Klicek
5,260,637	A	11/1993	Pizzi	5,425,745	A	6/1995	Green et al.
5,263,629	A	11/1993	Trumbull et al.	5,431,322	A	7/1995	Green et al.
5,263,973	A	11/1993	Cook	5,431,668	A	7/1995	Burbank, III et al.
5,268,622	A	12/1993	Philipp	5,433,721	A	7/1995	Hooven et al.
5,271,543	A	12/1993	Grant et al.	5,438,302	A	8/1995	Goble
5,271,544	A	12/1993	Fox et al.	5,439,479	A	8/1995	Shichman et al.
RE34,519	E	1/1994	Fox et al.	5,441,193	A	8/1995	Gravener
5,275,323	A	1/1994	Schulze et al.	5,441,494	A	8/1995	Ortiz
5,275,608	A	1/1994	Forman et al.	5,445,304	A	8/1995	Plyley et al.
5,281,216	A	1/1994	Klicek	5,445,644	A	8/1995	Pietrafitta et al.
5,282,806	A	2/1994	Haber et al.	5,447,417	A	9/1995	Kuhl et al.
5,282,829	A	2/1994	Hermes	5,447,513	A	9/1995	Davison et al.
5,297,714	A	3/1994	Kramer	5,449,355	A	9/1995	Rhum et al.
5,304,204	A	4/1994	Bregen	5,449,365	A	9/1995	Green et al.
5,307,976	A	5/1994	Olson et al.	5,452,836	A	9/1995	Huitema et al.
5,309,927	A	5/1994	Welch	5,452,837	A	9/1995	Williamson, IV et al.
5,312,023	A	5/1994	Green et al.	5,454,827	A	10/1995	Aust et al.
5,312,329	A	5/1994	Beaty et al.	5,456,401	A	10/1995	Green et al.
5,314,424	A	5/1994	Nicholas	5,458,579	A	10/1995	Chodorow et al.
5,318,221	A	6/1994	Green et al.	5,462,215	A	10/1995	Viola et al.
5,330,502	A	7/1994	Hassler et al.	5,464,300	A	11/1995	Crainich
5,332,142	A	7/1994	Robinson et al.	5,465,894	A	11/1995	Clark et al.
5,333,422	A	8/1994	Warren et al.	5,465,895	A	11/1995	Knodel et al.
5,333,772	A	8/1994	Rothfuss et al.	5,465,896	A	11/1995	Allen et al.
5,334,183	A	8/1994	Wuchinich	5,466,020	A	11/1995	Page et al.
5,336,232	A	8/1994	Green et al.	5,467,911	A	11/1995	Tsuruta et al.
5,339,799	A	8/1994	Kami et al.	5,470,006	A	11/1995	Rodak
5,341,724	A	8/1994	Vatel	5,470,007	A	11/1995	Plyley et al.
5,341,810	A	8/1994	Dardel	5,470,009	A	11/1995	Rodak
5,342,395	A	8/1994	Jarrett et al.	5,472,132	A	12/1995	Savage et al.
5,342,396	A	8/1994	Cook	5,472,442	A	12/1995	Klicek
5,344,060	A	9/1994	Gravener et al.	5,473,204	A	12/1995	Temple
5,350,400	A	9/1994	Esposito et al.	5,474,057	A	12/1995	Makower et al.
5,352,235	A	10/1994	Koros et al.	5,474,566	A	12/1995	Alesi et al.
5,352,238	A	10/1994	Green et al.	5,476,206	A	12/1995	Green et al.
5,354,303	A	10/1994	Spaeth et al.	5,476,479	A	12/1995	Green et al.
5,356,006	A	10/1994	Alpern et al.	5,478,003	A	12/1995	Green et al.
5,358,510	A	10/1994	Luscombe et al.	5,478,354	A	12/1995	Tovey et al.
5,359,231	A	10/1994	Flowers et al.	5,480,089	A	1/1996	Blewett
D352,780	S	11/1994	Glaeser et al.	5,480,409	A	1/1996	Riza
5,360,428	A	11/1994	Hutchinson, Jr.	5,482,197	A	1/1996	Green et al.
5,364,003	A	11/1994	Williamson, IV	5,484,095	A	1/1996	Green et al.

US 8,479,969 B2

5,484,398 A	1/1996	Stoddard	5,591,187 A	1/1997	Dekel
5,484,451 A	1/1996	Akopov et al.	5,597,107 A	1/1997	Knodel et al.
5,485,947 A	1/1996	Olson et al.	5,599,151 A	2/1997	Daum et al.
5,485,952 A	1/1996	Fontayne	5,599,344 A	2/1997	Paterson
5,487,499 A	1/1996	Sorrentino et al.	5,599,350 A	2/1997	Schulze et al.
5,487,500 A	1/1996	Knodel et al.	5,601,224 A	2/1997	Bishop et al.
5,489,058 A	2/1996	Plyley et al.	5,603,443 A	2/1997	Clark et al.
5,489,256 A	2/1996	Adair	5,605,272 A	2/1997	Witt et al.
5,496,312 A	3/1996	Klicek	5,605,273 A	2/1997	Hamblin et al.
5,496,317 A	3/1996	Goble et al.	5,607,094 A	3/1997	Clark et al.
5,497,933 A	3/1996	DeFonzo et al.	5,607,095 A	3/1997	Smith et al.
5,503,320 A	4/1996	Webster et al.	5,607,450 A	3/1997	Zvenyatsky et al.
5,503,635 A	4/1996	Sauer et al.	5,609,285 A	3/1997	Grant et al.
5,503,638 A	4/1996	Cooper et al.	5,611,709 A	3/1997	McAnulty
5,505,363 A	4/1996	Green et al.	5,613,966 A	3/1997	Makower et al.
5,507,426 A	4/1996	Young et al.	5,618,294 A	4/1997	Aust et al.
5,509,596 A	4/1996	Green et al.	5,618,303 A	4/1997	Marlow et al.
5,509,916 A	4/1996	Taylor	5,618,307 A	4/1997	Donlon et al.
5,511,564 A	4/1996	Wilk	5,620,289 A	4/1997	Curry
5,514,129 A	5/1996	Smith	5,620,452 A	4/1997	Yoon
5,514,157 A	5/1996	Nicholas et al.	5,624,452 A	4/1997	Yates
5,518,163 A	5/1996	Hooven	5,626,587 A	5/1997	Bishop et al.
5,518,164 A	5/1996	Hooven	5,628,446 A	5/1997	Geiste et al.
5,520,678 A	5/1996	Heckele et al.	5,628,743 A	5/1997	Cimino
5,520,700 A	5/1996	Beyar et al.	5,630,539 A	5/1997	Plyley et al.
5,522,817 A	6/1996	Sander et al.	5,630,540 A	5/1997	Blewett
5,527,320 A	6/1996	Carruthers et al.	5,630,782 A	5/1997	Adair
5,529,235 A	6/1996	Boiarski et al.	5,632,432 A	5/1997	Schulze et al.
D372,086 S	7/1996	Grasso et al.	5,632,433 A	5/1997	Grant et al.
5,531,744 A	7/1996	Nardella et al.	5,634,584 A	6/1997	Okorochoa et al.
5,533,521 A	7/1996	Granger	5,636,779 A	6/1997	Palmer
5,533,581 A	7/1996	Barth et al.	5,636,780 A	6/1997	Green et al.
5,533,661 A	7/1996	Main et al.	5,639,008 A	6/1997	Gallagher et al.
5,535,934 A	7/1996	Boiarski et al.	5,643,291 A	7/1997	Pier et al.
5,535,935 A	7/1996	Vidal et al.	5,645,209 A	7/1997	Green et al.
5,535,937 A	7/1996	Boiarski et al.	5,647,526 A	7/1997	Green et al.
5,540,375 A	7/1996	Bolanos et al.	5,647,869 A	7/1997	Goble et al.
5,541,376 A	7/1996	Ladtkow et al.	5,649,937 A	7/1997	Bito et al.
5,542,594 A	8/1996	McKean et al.	5,651,491 A	7/1997	Heaton et al.
5,543,119 A	8/1996	Sutter et al.	5,653,373 A	8/1997	Green et al.
5,547,117 A	8/1996	Hamblin et al.	5,653,374 A	8/1997	Young et al.
5,549,621 A	8/1996	Bessler et al.	5,653,677 A	8/1997	Okada et al.
5,549,628 A	8/1996	Cooper et al.	5,653,721 A	8/1997	Knodel et al.
5,549,637 A	8/1996	Crainich	5,655,698 A	8/1997	Yoon
5,553,675 A	9/1996	Pitzen et al.	5,657,921 A	8/1997	Young et al.
5,553,765 A	9/1996	Knodel et al.	5,658,281 A	8/1997	Heard
5,554,169 A	9/1996	Green et al.	5,658,300 A	8/1997	Bito et al.
5,556,416 A	9/1996	Clark et al.	5,662,258 A	9/1997	Knodel et al.
5,558,665 A	9/1996	Kieturakis	5,662,260 A	9/1997	Yoon
5,558,671 A	9/1996	Yates	5,662,662 A	9/1997	Bishop et al.
5,560,530 A	10/1996	Bolanos et al.	5,667,517 A	9/1997	Hooven
5,560,532 A	10/1996	DeFonzo et al.	5,667,526 A	9/1997	Levin
5,562,239 A	10/1996	Boiarski et al.	5,667,527 A	9/1997	Cook
5,562,241 A	10/1996	Knodel et al.	5,669,544 A	9/1997	Schulze et al.
5,562,682 A	10/1996	Oberlin et al.	5,669,904 A	9/1997	Platt, Jr. et al.
5,562,701 A	10/1996	Huitema et al.	5,669,907 A	9/1997	Platt, Jr. et al.
5,562,702 A	10/1996	Huitema et al.	5,669,918 A	9/1997	Balazs et al.
5,564,615 A	10/1996	Bishop et al.	5,673,840 A	10/1997	Schulze et al.
5,569,161 A	10/1996	Ebling et al.	5,673,841 A	10/1997	Schulze et al.
5,569,284 A	10/1996	Young et al.	5,673,842 A	10/1997	Bittner et al.
5,571,090 A	11/1996	Sherts	5,678,748 A	10/1997	Plyley et al.
5,571,100 A	11/1996	Goble et al.	5,680,981 A	10/1997	Mililli et al.
5,571,116 A	11/1996	Bolanos et al.	5,680,982 A	10/1997	Schulze et al.
5,573,543 A	11/1996	Akopov et al.	5,680,983 A	10/1997	Plyley et al.
5,574,431 A	11/1996	McKeown et al.	5,683,349 A	11/1997	Makower et al.
5,575,789 A	11/1996	Bell et al.	5,685,474 A	11/1997	Seeber
5,575,799 A	11/1996	Bolanos et al.	5,688,270 A	11/1997	Yates et al.
5,575,803 A	11/1996	Cooper et al.	5,690,269 A	11/1997	Bolanos et al.
5,577,654 A	11/1996	Bishop	5,692,668 A	12/1997	Schulze et al.
5,579,978 A	12/1996	Green et al.	5,693,042 A	12/1997	Boiarski et al.
5,580,067 A	12/1996	Hamblin et al.	5,693,051 A	12/1997	Schulze et al.
5,582,611 A	12/1996	Tsuruta et al.	5,695,494 A	12/1997	Becker
5,582,617 A	12/1996	Klieman et al.	5,695,504 A	12/1997	Gifford, III et al.
5,584,425 A	12/1996	Savage et al.	5,695,524 A	12/1997	Kelley et al.
5,586,711 A	12/1996	Plyley et al.	5,697,543 A	12/1997	Burdorff
5,588,579 A	12/1996	Schnut et al.	5,697,943 A	12/1997	Sauer et al.
5,588,580 A	12/1996	Paul et al.	5,700,270 A	12/1997	Peysen et al.
5,588,581 A	12/1996	Conlon et al.	5,702,387 A	12/1997	Arts et al.
5,591,170 A	1/1997	Spievack et al.	5,702,408 A	12/1997	Wales et al.

5,702,409	A	12/1997	Rayburn et al.	5,817,093	A	10/1998	Williamson, IV et al.
5,704,087	A	1/1998	Strub	5,817,109	A	10/1998	McGarry et al.
5,704,534	A	1/1998	Huitema et al.	5,817,119	A	10/1998	Klieman et al.
5,706,997	A	1/1998	Green et al.	5,820,009	A	10/1998	Melling et al.
5,706,998	A	1/1998	Plyley et al.	5,823,066	A	10/1998	Huitema et al.
5,707,392	A	1/1998	Kortenbach	5,826,776	A	10/1998	Schulze et al.
5,709,334	A	1/1998	Sorrentino et al.	5,827,271	A	10/1998	Buyse et al.
5,709,680	A	1/1998	Yates et al.	5,829,662	A	11/1998	Allen et al.
5,711,472	A	1/1998	Bryan	5,833,690	A	11/1998	Yates et al.
5,713,128	A	2/1998	Schrenk et al.	5,833,695	A	11/1998	Yoon
5,713,505	A	2/1998	Huitema	5,833,696	A	11/1998	Whitfield et al.
5,713,895	A	2/1998	Lontine et al.	5,836,503	A	11/1998	Ehrenfels et al.
5,713,896	A	2/1998	Nardella	5,836,960	A	11/1998	Kolesa et al.
5,715,987	A	2/1998	Kelley et al.	5,839,639	A	11/1998	Sauer et al.
5,715,988	A	2/1998	Palmer	5,843,132	A	12/1998	Ilvento
5,716,366	A	2/1998	Yates	5,846,254	A	12/1998	Schulze et al.
5,718,359	A	2/1998	Palmer et al.	5,849,011	A	12/1998	Jones et al.
5,718,360	A	2/1998	Green et al.	5,855,311	A	1/1999	Hamblin et al.
5,718,548	A	2/1998	Cotellessa	5,855,583	A	1/1999	Wang et al.
5,720,744	A	2/1998	Eggleston et al.	5,860,975	A	1/1999	Goble et al.
D393,067	S	3/1998	Geary et al.	5,865,361	A	2/1999	Milliman et al.
5,725,536	A	3/1998	Oberlin et al.	5,868,760	A	2/1999	McGuckin, Jr.
5,725,554	A	3/1998	Simon et al.	5,871,135	A	2/1999	Williamson IV et al.
5,728,121	A	3/1998	Bimbo et al.	5,873,885	A	2/1999	Weidenbenner
5,730,758	A	3/1998	Allgeyer	5,876,401	A	3/1999	Schulze et al.
5,732,871	A	3/1998	Clark et al.	5,878,193	A	3/1999	Wang et al.
5,732,872	A	3/1998	Bolduc et al.	5,878,937	A	3/1999	Green et al.
5,735,445	A	4/1998	Vidal et al.	5,878,938	A	3/1999	Bittner et al.
5,735,848	A	4/1998	Yates et al.	5,891,160	A	4/1999	Williamson, IV et al.
5,735,874	A	4/1998	Measamer et al.	5,893,506	A	4/1999	Powell
5,738,474	A	4/1998	Blewett	5,894,979	A	4/1999	Powell
5,738,648	A	4/1998	Lands et al.	5,897,562	A	4/1999	Bolanos et al.
5,743,456	A	4/1998	Jones et al.	5,899,914	A	5/1999	Zirps et al.
5,747,953	A	5/1998	Philipp	5,901,895	A	5/1999	Heaton et al.
5,749,889	A	5/1998	Bacich et al.	5,902,312	A	5/1999	Frater et al.
5,749,893	A	5/1998	Vidal et al.	5,904,693	A	5/1999	Dicesare et al.
5,752,644	A	5/1998	Bolanos et al.	5,906,625	A	5/1999	Bito et al.
5,752,965	A	5/1998	Francis et al.	5,908,402	A	6/1999	Blythe
5,755,717	A	5/1998	Yates et al.	5,908,427	A	6/1999	McKean et al.
5,758,814	A	6/1998	Gallagher et al.	5,911,353	A	6/1999	Bolanos et al.
5,762,255	A	6/1998	Chrisman et al.	5,915,616	A	6/1999	Viola et al.
5,762,256	A	6/1998	Mastri et al.	5,918,791	A	7/1999	Sorrentino et al.
5,766,188	A	6/1998	Igaki	5,919,198	A	7/1999	Graves, Jr. et al.
5,766,205	A	6/1998	Zvenyatsky et al.	5,928,256	A	7/1999	Riza
5,769,892	A	6/1998	Kingwell	5,931,847	A	8/1999	Bittner et al.
5,772,379	A	6/1998	Evensen	5,931,853	A	8/1999	McEwen et al.
5,772,578	A	6/1998	Heimberger et al.	5,937,951	A	8/1999	Izuchukwu et al.
5,772,659	A	6/1998	Becker et al.	5,938,667	A	8/1999	Peysen et al.
5,776,130	A	7/1998	Buyse et al.	5,941,442	A	8/1999	Geiste et al.
5,779,130	A	7/1998	Alesi et al.	5,944,172	A	8/1999	Hannula
5,779,131	A	7/1998	Knodel et al.	5,944,715	A	8/1999	Goble et al.
5,779,132	A	7/1998	Knodel et al.	5,948,030	A	9/1999	Miller et al.
5,782,396	A	7/1998	Mastri et al.	5,951,552	A	9/1999	Long et al.
5,782,397	A	7/1998	Koukline	5,951,574	A	9/1999	Stefanchik et al.
5,782,749	A	7/1998	Riza	5,954,259	A	9/1999	Viola et al.
5,782,859	A	7/1998	Nicholas et al.	5,964,774	A	10/1999	McKean et al.
5,784,934	A	7/1998	Izumisawa	5,971,916	A	10/1999	Koren
5,785,232	A	7/1998	Vidal et al.	5,988,479	A	11/1999	Palmer
5,787,897	A	8/1998	Kieturakis	6,003,517	A	12/1999	Sheffield et al.
5,792,135	A	8/1998	Madhani et al.	6,004,319	A	12/1999	Goble et al.
5,792,165	A	8/1998	Klieman et al.	6,010,054	A	1/2000	Johnson et al.
5,794,834	A	8/1998	Hamblin et al.	6,012,494	A	1/2000	Balazs
5,796,188	A	8/1998	Bays	6,013,076	A	1/2000	Goble et al.
5,797,536	A	8/1998	Smith et al.	6,015,406	A	1/2000	Goble et al.
5,797,537	A	8/1998	Oberlin et al.	6,017,322	A	1/2000	Snoke et al.
5,797,538	A	8/1998	Heaton et al.	6,017,356	A	1/2000	Frederick et al.
5,797,906	A	8/1998	Rhum et al.	6,022,352	A	2/2000	Vandewalle
5,797,959	A	8/1998	Castro et al.	6,024,741	A	2/2000	Williamson, IV et al.
5,799,857	A	9/1998	Robertson et al.	6,024,748	A	2/2000	Manzo et al.
5,807,376	A	9/1998	Viola et al.	6,027,501	A	2/2000	Goble et al.
5,807,378	A	9/1998	Jensen et al.	6,032,849	A	3/2000	Mastri et al.
5,807,393	A	9/1998	Williamson, IV et al.	6,033,378	A	3/2000	Lundquist et al.
5,809,441	A	9/1998	McKee	6,033,399	A	3/2000	Gines
5,810,811	A	9/1998	Yates et al.	6,033,427	A	3/2000	Lee
5,810,855	A	9/1998	Rayburn et al.	6,039,733	A	3/2000	Buyse et al.
5,813,813	A	9/1998	Daum et al.	6,039,734	A	3/2000	Goble
5,814,057	A	9/1998	Oi et al.	6,045,560	A	4/2000	McKean et al.
5,817,084	A	10/1998	Jensen	6,050,472	A	4/2000	Shibata
5,817,091	A	10/1998	Nardella et al.	6,053,390	A	4/2000	Green et al.

US 8,479,969 B2

6,056,746	A	5/2000	Goble et al.	6,338,737	B1	1/2002	Toledano
6,063,097	A	5/2000	Oi et al.	6,346,077	B1	2/2002	Taylor et al.
6,063,098	A	5/2000	Houser et al.	6,352,503	B1	3/2002	Matsui et al.
6,066,132	A	5/2000	Chen et al.	6,358,224	B1	3/2002	Tims et al.
6,068,627	A	5/2000	Orszulak et al.	6,364,877	B1	4/2002	Goble et al.
6,071,233	A	6/2000	Ishikawa et al.	6,364,888	B1	4/2002	Niemeyer et al.
6,074,386	A	6/2000	Goble et al.	6,373,152	B1	4/2002	Wang et al.
6,077,286	A	6/2000	Cuschieri et al.	6,387,113	B1	5/2002	Hawkins et al.
6,079,606	A	6/2000	Milliman et al.	6,387,114	B2	5/2002	Adams
6,082,577	A	7/2000	Coates et al.	6,391,038	B2	5/2002	Vargas et al.
6,083,234	A	7/2000	Nicholas et al.	6,398,781	B1	6/2002	Goble et al.
6,083,242	A	7/2000	Cook	6,398,797	B2	6/2002	Bombard et al.
6,086,600	A	7/2000	Kortenbach	6,406,440	B1	6/2002	Stefanchik
6,090,106	A	7/2000	Goble et al.	6,409,724	B1	6/2002	Penny et al.
6,093,186	A	7/2000	Goble	H2037	H	7/2002	Yates et al.
6,099,537	A	8/2000	Sugai et al.	6,416,486	B1	7/2002	Wampler
6,099,551	A	8/2000	Gabbay	6,416,509	B1	7/2002	Goble et al.
6,102,271	A	8/2000	Longo et al.	6,419,695	B1	7/2002	Gabbay
6,109,500	A	8/2000	Alli et al.	RE37,814	E	8/2002	Allgeyer
6,117,158	A	9/2000	Measamer et al.	6,436,097	B1	8/2002	Nardella
6,119,913	A	9/2000	Adams et al.	6,436,107	B1	8/2002	Wang et al.
6,120,433	A	9/2000	Mizuno et al.	6,436,122	B1	8/2002	Frank et al.
6,123,241	A	9/2000	Walter et al.	6,439,446	B1	8/2002	Perry et al.
H1904	H	10/2000	Yates et al.	6,440,146	B2	8/2002	Nicholas et al.
6,126,058	A	10/2000	Adams et al.	6,443,973	B1	9/2002	Whitman
6,126,670	A	10/2000	Walker et al.	6,450,391	B1	9/2002	Kayan et al.
6,131,789	A	10/2000	Schulze et al.	6,468,275	B1	10/2002	Wampler et al.
6,132,368	A	10/2000	Cooper	6,471,106	B1	10/2002	Reining
6,139,546	A	10/2000	Koenig et al.	6,482,200	B2	11/2002	Shippert
6,155,473	A	12/2000	Tompkins et al.	6,485,490	B2	11/2002	Wampler et al.
6,156,056	A	12/2000	Kearns et al.	6,488,196	B1	12/2002	Fenton, Jr.
6,159,146	A	12/2000	El Gazayerli	6,488,197	B1	12/2002	Whitman
6,159,200	A	12/2000	Verdura et al.	6,491,201	B1	12/2002	Whitman
6,162,208	A	12/2000	Hipps	6,491,690	B1	12/2002	Goble et al.
6,165,175	A	12/2000	Wampler et al.	6,491,701	B2*	12/2002	Tierney et al. 606/130
6,165,184	A	12/2000	Verdura et al.	6,492,785	B1	12/2002	Kasten et al.
6,168,605	B1	1/2001	Measamer et al.	6,494,896	B1	12/2002	D'Alessio et al.
6,171,316	B1	1/2001	Kovac et al.	6,503,257	B2	1/2003	Grant et al.
6,171,330	B1	1/2001	Benchetrit	6,503,259	B2	1/2003	Huxel et al.
6,174,308	B1	1/2001	Goble et al.	6,505,768	B2	1/2003	Whitman
6,174,309	B1	1/2001	Wrublewski et al.	6,510,854	B2	1/2003	Goble
6,179,776	B1	1/2001	Adams et al.	6,511,468	B1	1/2003	Cragg et al.
6,181,105	B1	1/2001	Cutolo et al.	6,517,535	B2	2/2003	Edwards
6,193,129	B1	2/2001	Bittner et al.	6,517,565	B1	2/2003	Whitman et al.
6,197,042	B1	3/2001	Ginn et al.	6,517,566	B1	2/2003	Hovland et al.
6,202,914	B1	3/2001	Geiste et al.	6,522,101	B2	2/2003	Malackowski
6,214,028	B1	4/2001	Yoon et al.	6,543,456	B1	4/2003	Freeman
6,220,368	B1	4/2001	Ark et al.	6,547,786	B1	4/2003	Goble
6,223,835	B1	5/2001	Habedank et al.	6,550,546	B2	4/2003	Thurler et al.
6,228,081	B1	5/2001	Goble	6,551,333	B2	4/2003	Kuhns et al.
6,228,084	B1	5/2001	Kirwan, Jr.	6,554,861	B2	4/2003	Knox et al.
6,231,565	B1	5/2001	Tovey et al.	6,558,379	B1	5/2003	Batchelor et al.
6,234,178	B1	5/2001	Goble et al.	6,565,560	B1	5/2003	Goble et al.
6,241,139	B1	6/2001	Milliman et al.	6,569,085	B2	5/2003	Kortenbach et al.
6,241,723	B1	6/2001	Heim et al.	6,569,171	B2	5/2003	DeGuillebon et al.
6,249,076	B1	6/2001	Madden et al.	6,578,751	B2	6/2003	Hartwick
6,250,532	B1	6/2001	Green et al.	6,582,427	B1	6/2003	Goble et al.
6,258,107	B1	7/2001	Balázs et al.	6,588,643	B2	7/2003	Bolduc et al.
6,261,286	B1	7/2001	Goble et al.	6,589,164	B1	7/2003	Flaherty
6,264,086	B1	7/2001	McGuckin, Jr.	6,592,597	B2	7/2003	Grant et al.
6,264,087	B1	7/2001	Whitman	6,596,432	B2	7/2003	Kawakami et al.
6,270,508	B1	8/2001	Klieman et al.	D478,665	S	8/2003	Isaacs et al.
6,273,897	B1	8/2001	Dalessandro et al.	D478,986	S	8/2003	Johnston et al.
6,277,114	B1	8/2001	Bullivant et al.	6,601,749	B2	8/2003	Sullivan et al.
6,293,942	B1	9/2001	Goble et al.	6,602,252	B2	8/2003	Mollenauer
6,296,640	B1	10/2001	Wampler et al.	6,605,078	B2	8/2003	Adams
6,302,311	B1	10/2001	Adams et al.	6,605,669	B2	8/2003	Awokola et al.
6,306,134	B1	10/2001	Goble et al.	6,616,686	B2	9/2003	Coleman et al.
6,309,403	B1	10/2001	Minor et al.	6,619,529	B2	9/2003	Green et al.
6,315,184	B1	11/2001	Whitman	6,620,166	B1	9/2003	Wenstrom, Jr. et al.
6,320,123	B1	11/2001	Reimers	6,629,630	B2	10/2003	Adams
6,324,339	B1	11/2001	Hudson et al.	6,629,974	B2	10/2003	Penny et al.
6,325,799	B1	12/2001	Goble	6,629,988	B2	10/2003	Weadock
6,325,810	B1	12/2001	Hamilton et al.	6,636,412	B2	10/2003	Smith
6,330,965	B1	12/2001	Milliman et al.	6,638,108	B2	10/2003	Tachi
6,331,181	B1*	12/2001	Tierney et al. 606/130	6,638,285	B2	10/2003	Gabbay
6,331,761	B1	12/2001	Kumar et al.	6,638,297	B1	10/2003	Huitema
6,334,860	B1	1/2002	Dorn	6,641,528	B2	11/2003	Torii
6,336,926	B1	1/2002	Goble	6,644,532	B2	11/2003	Green et al.

US 8,479,969 B2

6,648,816	B2	11/2003	Irion et al.	6,893,435	B2	5/2005	Goble
D484,243	S	12/2003	Ryan et al.	6,905,057	B2	6/2005	Swayze et al.
D484,595	S	12/2003	Ryan et al.	6,905,497	B2	6/2005	Truckai et al.
D484,596	S	12/2003	Ryan et al.	6,913,608	B2	7/2005	Liddicoat et al.
6,656,193	B2	12/2003	Grant et al.	6,913,613	B2	7/2005	Schwarz et al.
6,666,875	B1	12/2003	Sakurai et al.	6,923,803	B2	8/2005	Goble
6,669,073	B2	12/2003	Milliman et al.	6,929,641	B2	8/2005	Goble et al.
6,671,185	B2	12/2003	Duval	6,931,830	B2	8/2005	Liao
D484,977	S	1/2004	Ryan et al.	6,936,042	B2	8/2005	Wallace et al.
6,676,660	B2	1/2004	Wampler et al.	6,939,358	B2	9/2005	Palacios et al.
6,679,410	B2	1/2004	Würsch et al.	6,942,662	B2	9/2005	Goble et al.
6,681,978	B2	1/2004	Geiste et al.	6,945,444	B2	9/2005	Gresham et al.
6,681,979	B2	1/2004	Whitman	6,953,138	B1	10/2005	Dworak et al.
6,682,527	B2	1/2004	Strul	6,953,139	B2	10/2005	Milliman et al.
6,682,528	B2	1/2004	Frazier et al.	6,959,851	B2	11/2005	Heinrich
6,685,727	B2	2/2004	Fisher et al.	6,959,852	B2	11/2005	Shelton, IV et al.
6,692,507	B2	2/2004	Pugsley et al.	6,960,163	B2	11/2005	Ewers et al.
6,695,199	B2	2/2004	Whitman	6,960,220	B2	11/2005	Marino et al.
6,698,643	B2	3/2004	Whitman	6,964,363	B2	11/2005	Wales et al.
6,699,235	B2	3/2004	Wallace et al.	6,966,907	B2	11/2005	Goble
6,704,210	B1	3/2004	Myers	6,966,909	B2	11/2005	Marshall et al.
6,705,503	B1	3/2004	Pedicini et al.	6,972,199	B2	12/2005	Leboutitz et al.
6,712,773	B1	3/2004	Viola	6,974,462	B2	12/2005	Sater
6,716,223	B2	4/2004	Leopold et al.	6,978,921	B2	12/2005	Shelton, IV et al.
6,716,232	B1	4/2004	Vidal et al.	6,978,922	B2	12/2005	Bilotti et al.
6,716,233	B1	4/2004	Whitman	6,981,628	B2	1/2006	Wales
6,722,552	B2	4/2004	Fenton, Jr.	6,981,941	B2	1/2006	Whitman et al.
6,723,087	B2	4/2004	O'Neill et al.	6,981,978	B2	1/2006	Gannoe
6,723,091	B2	4/2004	Goble et al.	6,984,203	B2	1/2006	Tartaglia et al.
6,726,697	B2	4/2004	Nicholas et al.	6,984,231	B2	1/2006	Goble et al.
6,740,030	B2	5/2004	Martone et al.	6,986,451	B1	1/2006	Mastri et al.
6,747,121	B2	6/2004	Gogolewski	6,988,649	B2	1/2006	Shelton, IV et al.
6,749,560	B1	6/2004	Konstorum et al.	6,988,650	B2	1/2006	Schwemberger et al.
6,752,768	B2	6/2004	Burdorff et al.	6,990,796	B2	1/2006	Schnipke et al.
6,752,816	B2	6/2004	Culp et al.	6,994,708	B2	2/2006	Manzo
6,755,195	B1	6/2004	Lemke et al.	6,997,931	B2	2/2006	Sauer et al.
6,755,338	B2	6/2004	Hahnen et al.	7,000,818	B2	2/2006	Shelton, IV et al.
6,758,846	B2	7/2004	Goble et al.	7,000,819	B2	2/2006	Swayze et al.
6,761,685	B2	7/2004	Adams et al.	7,001,380	B2	2/2006	Goble
6,767,352	B2	7/2004	Field et al.	7,001,408	B2	2/2006	Knodel et al.
6,767,356	B2	7/2004	Kanner et al.	7,008,435	B2	3/2006	Cummins
6,769,594	B2	8/2004	Orban, III	7,018,390	B2	3/2006	Turovskiy et al.
6,773,438	B1	8/2004	Knodel et al.	7,025,743	B2	4/2006	Mann et al.
6,780,151	B2	8/2004	Grabover et al.	7,029,435	B2	4/2006	Nakao
6,780,180	B1	8/2004	Goble et al.	7,032,798	B2	4/2006	Whitman et al.
6,786,382	B1	9/2004	Hoffman	7,032,799	B2	4/2006	Viola et al.
6,786,864	B2	9/2004	Matsuura et al.	7,033,356	B2	4/2006	Latterell et al.
6,786,896	B1	9/2004	Madhani et al.	7,036,680	B1	5/2006	Flannery
6,790,173	B2	9/2004	Saadat et al.	7,037,344	B2	5/2006	Kagan et al.
6,793,652	B1	9/2004	Whitman et al.	7,044,352	B2	5/2006	Shelton, IV et al.
6,805,273	B2	10/2004	Bilotti et al.	7,044,353	B2	5/2006	Mastri et al.
6,806,808	B1	10/2004	Watters et al.	7,048,687	B1	5/2006	Reuss et al.
6,808,525	B2	10/2004	Latterell et al.	7,052,494	B2	5/2006	Goble et al.
6,814,741	B2	11/2004	Bowman et al.	7,055,730	B2	6/2006	Ehrenfels et al.
6,817,508	B1	11/2004	Racenet et al.	7,055,731	B2	6/2006	Shelton, IV et al.
6,817,509	B2	11/2004	Geiste et al.	7,056,284	B2	6/2006	Martone et al.
6,817,974	B2	11/2004	Cooper et al.	7,056,330	B2	6/2006	Gayton
6,821,273	B2	11/2004	Mollenauer	7,059,508	B2	6/2006	Shelton, IV et al.
6,821,284	B2	11/2004	Sturtz et al.	7,063,712	B2	6/2006	Vargas et al.
6,827,725	B2	12/2004	Batchelor et al.	7,066,879	B2	6/2006	Fowler et al.
6,828,902	B2	12/2004	Casden	7,066,944	B2	6/2006	Laufer et al.
6,830,174	B2	12/2004	Hillstead et al.	7,070,083	B2	7/2006	Jankowski
6,832,998	B2	12/2004	Goble	7,070,559	B2	7/2006	Adams et al.
6,834,001	B2	12/2004	Myono	7,071,287	B2	7/2006	Rhine et al.
6,835,199	B2	12/2004	McGuckin, Jr. et al.	7,075,770	B1	7/2006	Smith
6,843,403	B2	1/2005	Whitman	7,077,856	B2	7/2006	Whitman
6,843,789	B2	1/2005	Goble	7,080,769	B2	7/2006	Vresh et al.
6,846,307	B2	1/2005	Whitman et al.	7,081,114	B2	7/2006	Rashidi
6,846,308	B2	1/2005	Whitman et al.	7,083,073	B2	8/2006	Yoshie et al.
6,846,309	B2	1/2005	Whitman et al.	7,083,075	B2	8/2006	Swayze et al.
6,849,071	B2	2/2005	Whitman et al.	7,083,571	B2	8/2006	Wang et al.
RE38,708	E	3/2005	Bolanos et al.	7,083,615	B2*	8/2006	Peterson et al. 606/41
6,866,178	B2	3/2005	Adams et al.	7,087,071	B2	8/2006	Nicholas et al.
6,866,671	B2*	3/2005	Tierney et al. 606/130	7,090,637	B2	8/2006	Danitz et al.
6,872,214	B2	3/2005	Sonnenschein et al.	7,090,673	B2	8/2006	Dycus et al.
6,874,669	B2	4/2005	Adams et al.	7,090,683	B2	8/2006	Brock et al.
6,877,647	B2	4/2005	Ratcliff et al.	7,090,684	B2	8/2006	McGuckin, Jr. et al.
6,878,106	B1	4/2005	Herrmann	7,094,202	B2	8/2006	Nobis et al.
6,889,116	B2*	5/2005	Jinno 700/245	7,094,247	B2	8/2006	Monassevitch et al.

US 8,479,969 B2

7,097,089	B2	8/2006	Marczyk	7,303,106	B2	12/2007	Milliman et al.
7,098,794	B2	8/2006	Lindsay et al.	7,303,107	B2	12/2007	Milliman et al.
7,104,741	B2	9/2006	Krohn	7,303,108	B2	12/2007	Shelton, IV
7,108,695	B2	9/2006	Witt et al.	7,303,556	B2	12/2007	Metzger
7,108,701	B2	9/2006	Evens et al.	7,308,998	B2	12/2007	Mastri et al.
7,108,709	B2	9/2006	Cummins	7,322,975	B2	1/2008	Goble et al.
7,112,214	B2	9/2006	Peterson et al.	7,324,572	B2	1/2008	Chang
RE39,358	E	10/2006	Goble	7,328,828	B2	2/2008	Ortiz et al.
7,114,642	B2	10/2006	Whitman	7,328,829	B2	2/2008	Arad et al.
7,118,582	B1	10/2006	Wang et al.	7,330,004	B2	2/2008	DeJonge et al.
7,121,446	B2	10/2006	Arad et al.	7,334,717	B2	2/2008	Rethy et al.
7,122,028	B2	10/2006	Looper et al.	7,336,184	B2	2/2008	Smith et al.
7,128,253	B2	10/2006	Mastri et al.	7,338,513	B2	3/2008	Lee et al.
7,128,254	B2	10/2006	Shelton, IV et al.	7,343,920	B2	3/2008	Toby et al.
7,128,748	B2	10/2006	Mooradian et al.	7,348,763	B1	3/2008	Reinhart et al.
7,131,445	B2	11/2006	Amoah	7,351,258	B2	4/2008	Ricotta et al.
7,133,601	B2	11/2006	Phillips et al.	7,354,447	B2	4/2008	Shelton, IV et al.
7,140,527	B2	11/2006	Ehrenfels et al.	7,357,287	B2	4/2008	Shelton, IV et al.
7,140,528	B2	11/2006	Shelton, IV	7,364,060	B2	4/2008	Milliman
7,143,923	B2	12/2006	Shelton, IV et al.	7,364,061	B2	4/2008	Swayze et al.
7,143,924	B2	12/2006	Scirica et al.	7,377,928	B2	5/2008	Zubik et al.
7,143,925	B2	12/2006	Shelton, IV et al.	7,380,695	B2	6/2008	Doll et al.
7,143,926	B2	12/2006	Shelton, IV et al.	7,380,696	B2	6/2008	Shelton, IV et al.
7,147,138	B2	12/2006	Shelton, IV	7,388,217	B2	6/2008	Buschbeck et al.
7,147,139	B2	12/2006	Schwemmerger et al.	7,396,356	B2	7/2008	Mollenauer
7,147,637	B2	12/2006	Goble	7,397,364	B2	7/2008	Govari
7,147,650	B2	12/2006	Lee	7,398,907	B2	7/2008	Racenet et al.
7,150,748	B2	12/2006	Ebbutt et al.	7,398,908	B2	7/2008	Holsten et al.
7,153,300	B2	12/2006	Goble	7,401,721	B2	7/2008	Holsten et al.
7,156,863	B2	1/2007	Sonnenschein et al.	7,404,508	B2	7/2008	Smith et al.
7,159,750	B2	1/2007	Racenet et al.	7,404,509	B2	7/2008	Ortiz et al.
7,160,299	B2	1/2007	Baily	7,407,075	B2	8/2008	Holsten et al.
7,161,036	B2	1/2007	Oikawa et al.	7,407,078	B2	8/2008	Shelton, IV et al.
7,168,604	B2	1/2007	Milliman et al.	7,410,086	B2	8/2008	Ortiz et al.
7,172,104	B2	2/2007	Scirica et al.	7,416,101	B2	8/2008	Shelton, IV et al.
7,179,223	B2	2/2007	Motoki et al.	7,418,078	B2	8/2008	Blanz et al.
7,179,267	B2	2/2007	Nolan et al.	7,419,080	B2	9/2008	Smith et al.
7,182,239	B1	2/2007	Myers	7,422,136	B1	9/2008	Marczyk
7,188,758	B2	3/2007	Viola et al.	7,422,139	B2	9/2008	Shelton, IV et al.
7,189,207	B2	3/2007	Viola	7,424,965	B2	9/2008	Racenet et al.
7,195,627	B2	3/2007	Amoah et al.	7,431,188	B1	10/2008	Marczyk
7,204,835	B2	4/2007	Latterell et al.	7,431,189	B2	10/2008	Shelton, IV et al.
7,207,233	B2	4/2007	Wadge	7,431,694	B2	10/2008	Stefanchik et al.
7,207,471	B2	4/2007	Heinrich et al.	7,431,730	B2	10/2008	Viola
7,207,472	B2	4/2007	Wukusick et al.	7,434,715	B2	10/2008	Shelton, IV et al.
7,208,005	B2	4/2007	Frecker et al.	7,434,717	B2	10/2008	Shelton, IV et al.
7,210,609	B2	5/2007	Leiboff et	7,438,209	B1	10/2008	Hess et al.
7,211,081	B2	5/2007	Goble	7,439,354	B2	10/2008	Lenges et al.
7,211,084	B2	5/2007	Goble et al.	7,441,684	B2	10/2008	Shelton, IV et al.
7,213,736	B2	5/2007	Wales et al.	7,441,685	B1	10/2008	Boudreaux
7,214,224	B2	5/2007	Goble	7,442,201	B2	10/2008	Pugsley et al.
7,217,285	B2	5/2007	Vargas et al.	7,455,208	B2	11/2008	Wales et al.
7,220,260	B2	5/2007	Fleming et al.	7,455,676	B2	11/2008	Holsten et al.
7,220,272	B2	5/2007	Weadock	7,461,767	B2	12/2008	Viola et al.
7,225,963	B2	6/2007	Scirica	7,464,846	B2	12/2008	Shelton, IV et al.
7,225,964	B2	6/2007	Mastri et al.	7,464,847	B2	12/2008	Viola et al.
7,234,624	B2	6/2007	Gresham et al.	7,464,849	B2	12/2008	Shelton, IV et al.
7,235,089	B1	6/2007	McGuckin, Jr.	7,467,740	B2	12/2008	Shelton, IV et al.
7,235,302	B2	6/2007	Jing et al.	7,467,849	B2	12/2008	Silverbrook et al.
7,237,708	B1	7/2007	Guy et al.	7,472,814	B2	1/2009	Mastri et al.
7,238,195	B2	7/2007	Viola	7,472,815	B2	1/2009	Shelton, IV et al.
7,241,288	B2	7/2007	Braun	7,473,253	B2	1/2009	Dycus et al.
7,246,734	B2	7/2007	Shelton, IV	7,479,608	B2	1/2009	Smith
7,247,161	B2	7/2007	Johnston et al.	7,481,347	B2	1/2009	Roy
7,252,660	B2	8/2007	Kunz	7,481,349	B2	1/2009	Holsten et al.
7,255,696	B2	8/2007	Goble et al.	7,481,824	B2	1/2009	Boudreaux et al.
7,258,262	B2	8/2007	Mastri et al.	7,485,133	B2	2/2009	Cannon et al.
7,260,431	B2	8/2007	Libbus et al.	7,490,749	B2	2/2009	Schall et al.
7,265,374	B2	9/2007	Lee et al.	7,494,039	B2	2/2009	Racenet et al.
7,267,679	B2	9/2007	McGuckin, Jr. et al.	7,494,499	B2	2/2009	Nagase et al.
7,273,483	B2*	9/2007	Wiener et al. 606/169	7,500,979	B2	3/2009	Hueil et al.
7,278,562	B2	10/2007	Mastri et al.	7,501,198	B2	3/2009	Barlev et al.
7,278,563	B1	10/2007	Green	7,506,790	B2	3/2009	Shelton, IV
7,278,994	B2	10/2007	Goble	7,506,791	B2	3/2009	Omaitis et al.
7,282,048	B2	10/2007	Goble et al.	7,510,107	B2	3/2009	Timm et al.
7,295,907	B2	11/2007	Lu et al.	7,524,320	B2	4/2009	Tierney et al.
7,296,724	B2	11/2007	Green et al.	7,530,985	B2	5/2009	Takemoto et al.
7,297,149	B2	11/2007	Vitali et al.	7,546,940	B2	6/2009	Milliman et al.
7,300,450	B2	11/2007	Vleugels et al.	7,547,312	B2	6/2009	Bauman et al.

US 8,479,969 B2

7,549,564 B2	6/2009	Boudreaux	7,784,662 B2	8/2010	Wales et al.
7,552,854 B2	6/2009	Wixey et al.	7,793,812 B2	9/2010	Moore et al.
7,556,185 B2	7/2009	Viola	7,794,475 B2	9/2010	Hess et al.
7,556,186 B2	7/2009	Milliman	7,798,386 B2	9/2010	Schall et al.
7,559,450 B2	7/2009	Wales et al.	7,799,039 B2	9/2010	Shelton, IV et al.
7,559,452 B2	7/2009	Wales et al.	7,803,151 B2	9/2010	Whitman
7,563,862 B2	7/2009	Sieg et al.	7,806,891 B2	10/2010	Nowlin et al.
7,566,300 B2	7/2009	Devierre et al.	7,810,692 B2	10/2010	Hall et al.
7,568,603 B2	8/2009	Shelton, IV et al.	7,810,693 B2	10/2010	Broehl et al.
7,568,604 B2	8/2009	Ehrenfels et al.	7,815,092 B2	10/2010	Whitman et al.
7,568,619 B2	8/2009	Todd et al.	7,815,565 B2	10/2010	Stefanchik et al.
7,575,144 B2	8/2009	Ortiz et al.	7,819,296 B2	10/2010	Hueil et al.
7,588,175 B2	9/2009	Timm et al.	7,819,297 B2	10/2010	Doll et al.
7,588,176 B2	9/2009	Timm et al.	7,819,298 B2	10/2010	Hall et al.
7,597,229 B2	10/2009	Boudreaux et al.	7,819,299 B2	10/2010	Shelton, IV et al.
7,600,663 B2	10/2009	Green	7,824,401 B2	11/2010	Manzo et al.
7,604,150 B2	10/2009	Boudreaux	7,828,189 B2	11/2010	Holsten et al.
7,604,151 B2	10/2009	Hess et al.	7,828,794 B2	11/2010	Sartor
7,607,557 B2	10/2009	Shelton, IV et al.	7,828,808 B2	11/2010	Hinman et al.
7,611,038 B2	11/2009	Racenet et al.	7,832,408 B2	11/2010	Shelton, IV et al.
7,615,003 B2	11/2009	Stefanchik et al.	7,832,611 B2	11/2010	Boyden et al.
7,624,902 B2	12/2009	Marczyk et al.	7,832,612 B2	11/2010	Baxter, III et al.
7,631,793 B2	12/2009	Rethy et al.	7,836,400 B2	11/2010	May et al.
7,635,074 B2	12/2009	Olson et al.	7,837,080 B2	11/2010	Schwemberger
7,637,409 B2	12/2009	Marczyk	7,837,081 B2	11/2010	Holsten et al.
7,641,092 B2	1/2010	Kruszynski et al.	7,845,533 B2	12/2010	Marczyk et al.
7,641,093 B2	1/2010	Doll et al.	7,845,534 B2	12/2010	Viola et al.
7,644,848 B2	1/2010	Swayze et al.	7,845,537 B2	12/2010	Shelton, IV et al.
7,651,498 B2	1/2010	Shifrin et al.	7,846,149 B2	12/2010	Jankowski
7,656,131 B2	2/2010	Embrey et al.	7,857,185 B2	12/2010	Swayze et al.
7,658,311 B2	2/2010	Boudreaux	7,857,186 B2	12/2010	Baxter, III et al.
7,658,312 B2	2/2010	Vidal et al.	7,861,906 B2	1/2011	Doll et al.
7,665,646 B2	2/2010	Prommersberger	7,866,527 B2	1/2011	Hall et al.
7,665,647 B2	2/2010	Shelton, IV et al.	7,870,989 B2	1/2011	Viola et al.
7,669,746 B2	3/2010	Shelton, IV	7,871,418 B2	1/2011	Thompson et al.
7,669,747 B2	3/2010	Weisenburgh, II et al.	7,887,530 B2	2/2011	Zemlok et al.
7,670,334 B2	3/2010	Hueil et al.	7,900,805 B2	3/2011	Shelton, IV et al.
7,673,780 B2	3/2010	Shelton, IV et al.	7,905,380 B2	3/2011	Shelton, IV et al.
7,673,781 B2	3/2010	Swayze et al.	7,905,381 B2	3/2011	Baxter, III et al.
7,673,782 B2	3/2010	Hess et al.	7,909,191 B2	3/2011	Baker et al.
7,673,783 B2	3/2010	Morgan et al.	7,909,221 B2	3/2011	Viola et al.
7,674,255 B2	3/2010	Braun	7,913,891 B2	3/2011	Doll et al.
7,682,307 B2	3/2010	Danitz et al.	7,914,543 B2	3/2011	Roth et al.
7,686,826 B2	3/2010	Lee et al.	7,918,376 B1	4/2011	Knodel et al.
7,688,028 B2	3/2010	Phillips et al.	7,918,377 B2	4/2011	Measamer et al.
7,691,098 B2	4/2010	Wallace et al.	7,922,061 B2	4/2011	Shelton, IV et al.
7,699,204 B2	4/2010	Viola	7,922,063 B2	4/2011	Zemlok et al.
7,699,859 B2	4/2010	Bombard et al.	7,934,630 B2	5/2011	Shelton, IV et al.
7,708,180 B2	5/2010	Murray et al.	7,938,307 B2	5/2011	Bettuchi
7,708,758 B2	5/2010	Lee et al.	7,941,865 B2	5/2011	Seman, Jr. et al.
7,714,239 B2	5/2010	Smith	7,942,303 B2	5/2011	Shah
7,717,312 B2	5/2010	Beetel	7,942,890 B2	5/2011	D'Agostino et al.
7,721,930 B2	5/2010	McKenna et al.	7,944,175 B2	5/2011	Mori et al.
7,721,931 B2	5/2010	Shelton, IV et al.	7,950,560 B2	5/2011	Zemlok et al.
7,721,934 B2	5/2010	Shelton, IV et al.	7,954,682 B2	6/2011	Giordano et al.
7,721,936 B2	5/2010	Shalton, IV et al.	7,954,684 B2	6/2011	Boudreaux
7,722,610 B2	5/2010	Viola et al.	7,954,686 B2	6/2011	Baxter, III et al.
7,726,537 B2	6/2010	Olson et al.	7,959,050 B2	6/2011	Smith et al.
7,726,538 B2	6/2010	Holsten et al.	7,959,051 B2	6/2011	Smith et al.
7,731,072 B2	6/2010	Timm et al.	7,963,963 B2	6/2011	Francischelli et al.
7,735,703 B2	6/2010	Morgan et al.	7,966,799 B2	6/2011	Morgan et al.
7,738,971 B2	6/2010	Swayze et al.	7,967,180 B2	6/2011	Scirica
7,740,159 B2	6/2010	Shelton, IV et al.	7,972,298 B2	7/2011	Wallace et al.
7,743,960 B2	6/2010	Whitman et al.	7,980,443 B2	7/2011	Scheib et al.
7,744,627 B2	6/2010	Orban, III et al.	7,997,469 B2	8/2011	Olson et al.
7,753,245 B2	7/2010	Boudreaux et al.	8,002,795 B2	8/2011	Beetel
7,753,904 B2	7/2010	Shelton, IV et al.	8,011,551 B2	9/2011	Marczyk et al.
7,766,209 B2	8/2010	Baxter, III et al.	8,011,555 B2	9/2011	Tarinelli et al.
7,766,210 B2	8/2010	Shelton, IV et al.	8,020,742 B2	9/2011	Marczyk
7,766,821 B2	8/2010	Brunnen et al.	8,020,743 B2	9/2011	Shelton, IV
7,766,894 B2	8/2010	Weitzner et al.	8,025,199 B2	9/2011	Whitman et al.
7,770,775 B2	8/2010	Shelton, IV et al.	8,028,883 B2	10/2011	Stopek
7,771,396 B2	8/2010	Stefanchik et al.	8,034,077 B2	10/2011	Smith et al.
7,772,720 B2	8/2010	McGee et al.	8,038,045 B2	10/2011	Bettuchi et al.
7,776,060 B2	8/2010	Mooradian et al.	8,038,046 B2	10/2011	Smith et al.
7,780,054 B2	8/2010	Wales	8,056,787 B2	11/2011	Boudreaux et al.
7,780,055 B2	8/2010	Scirica et al.	8,062,330 B2	11/2011	Prommersberger et al.
7,780,663 B2	8/2010	Yates et al.	8,066,167 B2	11/2011	Measamer et al.
7,780,685 B2	8/2010	Hunt et al.	D650,074 S	12/2011	Hunt et al.

8,083,120	B2	12/2011	Shelton, IV et al.	2004/0097987	A1	5/2004	Pugsley et al.
8,084,001	B2	12/2011	Burns et al.	2004/0101822	A1	5/2004	Wiesner et al.
8,091,756	B2	1/2012	Viola	2004/0108357	A1	6/2004	Milliman et al.
8,097,017	B2	1/2012	Viola	2004/0111081	A1	6/2004	Whitman et al.
8,108,072	B2	1/2012	Zhao et al.	2004/0115022	A1	6/2004	Albertson et al.
8,113,410	B2	2/2012	Hall et al.	2004/0116952	A1	6/2004	Sakurai et al.
8,123,103	B2	2/2012	Milliman	2004/0147909	A1	7/2004	Johnston et al.
8,136,712	B2	3/2012	Zingman	2004/0164123	A1	8/2004	Racenet et al.
8,141,762	B2	3/2012	Bedi et al.	2004/0167572	A1	8/2004	Roth et al.
8,152,041	B2	4/2012	Kostrzewski	2004/0173659	A1	9/2004	Green et al.
8,157,145	B2	4/2012	Shelton, IV et al.	2004/0181219	A1	9/2004	Goble et al.
8,157,152	B2	4/2012	Holsten et al.	2004/0186470	A1	9/2004	Goble et al.
8,157,153	B2	4/2012	Shelton, IV et al.	2004/0193189	A1	9/2004	Kortenbach et al.
8,161,977	B2	4/2012	Shelton, IV et al.	2004/0222268	A1	11/2004	Bilotti et al.
8,167,185	B2	5/2012	Shelton, IV et al.	2004/0230214	A1	11/2004	Donofrio et al.
8,167,895	B2	5/2012	D'Agostino et al.	2004/0232201	A1	11/2004	Wenchell et al.
8,172,124	B2	5/2012	Shelton, IV et al.	2004/0243151	A1	12/2004	Demmy et al.
8,186,555	B2	5/2012	Shelton, IV et al.	2004/0243163	A1	12/2004	Casiano et al.
8,186,560	B2	5/2012	Hess et al.	2004/0243176	A1	12/2004	Hahnen et al.
8,196,795	B2	6/2012	Moore et al.	2004/0254566	A1	12/2004	Plicchi et al.
8,196,796	B2	6/2012	Shelton, IV et al.	2004/0254608	A1	12/2004	Huitema et al.
8,205,781	B2	6/2012	Baxter, III et al.	2004/0260315	A1	12/2004	Dell et al.
8,210,411	B2	7/2012	Yates et al.	2004/0267310	A1	12/2004	Racenet et al.
8,211,125	B2	7/2012	Spivey	2005/0006434	A1*	1/2005	Wales et al. 227/180.1
8,215,531	B2	7/2012	Shelton, IV et al.	2005/0032511	A1	2/2005	Malone et al.
8,220,468	B2	7/2012	Cooper et al.	2005/0033357	A1	2/2005	Braun
8,220,688	B2	7/2012	Laurent et al.	2005/0054946	A1	3/2005	Krzyzanowski
8,220,690	B2	7/2012	Hess et al.	2005/0059997	A1	3/2005	Bauman et al.
8,225,799	B2	7/2012	Bettuchi	2005/0070929	A1	3/2005	Dalessandro et al.
8,245,898	B2	8/2012	Smith et al.	2005/0080454	A1	4/2005	Drews et al.
8,245,901	B2	8/2012	Stopek	2005/0085693	A1	4/2005	Belson et al.
8,256,654	B2	9/2012	Bettuchi et al.	2005/0090817	A1	4/2005	Phan
8,257,391	B2	9/2012	Orban, III et al.	2005/0103819	A1	5/2005	Racenet et al.
8,267,300	B2	9/2012	Boudreaux	2005/0107814	A1	5/2005	Johnston et al.
8,292,155	B2	10/2012	Shelton, IV et al.	2005/0107824	A1	5/2005	Hillstead et al.
8,298,677	B2	10/2012	Wiesner et al.	2005/0113820	A1	5/2005	Goble et al.
8,308,040	B2	11/2012	Huang et al.	2005/0119525	A1	6/2005	Takemoto
8,317,070	B2	11/2012	Hucil et al.	2005/0119669	A1	6/2005	Demmy
8,322,455	B2	12/2012	Shelton, IV et al.	2005/0124855	A1	6/2005	Jaffe et al.
8,322,589	B2	12/2012	Boudreaux	2005/0125009	A1	6/2005	Perry et al.
8,333,313	B2	12/2012	Boudreaux et al.	2005/0131173	A1	6/2005	McDaniel et al.
8,348,129	B2	1/2013	Bedi et al.	2005/0131211	A1	6/2005	Bayley et al.
8,348,131	B2	1/2013	Omais et al.	2005/0131390	A1	6/2005	Heinrich et al.
8,353,437	B2	1/2013	Boudreaux	2005/0131436	A1	6/2005	Johnston et al.
8,353,438	B2	1/2013	Baxter, III et al.	2005/0131437	A1	6/2005	Johnston et al.
8,353,439	B2	1/2013	Baxter, III et al.	2005/0131457	A1	6/2005	Douglas et al.
8,360,296	B2	1/2013	Zingman	2005/0137454	A1	6/2005	Saadat et al.
8,360,297	B2	1/2013	Shelton, IV et al.	2005/0137455	A1	6/2005	Ewers et al.
8,365,976	B2	2/2013	Hess et al.	2005/0143759	A1	6/2005	Kelly
8,371,491	B2	2/2013	Huitema et al.	2005/0145675	A1	7/2005	Hartwick et al.
2002/0022836	A1	2/2002	Goble et al.	2005/0154258	A1	7/2005	Tartaglia et al.
2002/0029036	A1	3/2002	Goble et al.	2005/0165419	A1	7/2005	Sauer et al.
2002/0117534	A1	8/2002	Green et al.	2005/0165435	A1	7/2005	Johnston et al.
2002/0134811	A1	9/2002	Napier et al.	2005/0169974	A1	8/2005	Tenerz et al.
2002/0165541	A1	11/2002	Whitman	2005/0171522	A1	8/2005	Christopherson
2002/0177843	A1*	11/2002	Anderson et al. 606/1	2005/0177181	A1	8/2005	Kagan et al.
2003/0093103	A1	5/2003	Malackowski et al.	2005/0182298	A1	8/2005	Ikeda et al.
2003/0105478	A1	6/2003	Whitman et al.	2005/0184121	A1	8/2005	Heinrich
2003/0130677	A1	7/2003	Whitman et al.	2005/0187545	A1	8/2005	Hooven et al.
2003/0139741	A1	7/2003	Goble et al.	2005/0187572	A1	8/2005	Johnston et al.
2003/0153908	A1	8/2003	Goble et al.	2005/0187576	A1	8/2005	Whitman et al.
2003/0195387	A1	10/2003	Kortenbach et al.	2005/0189397	A1	9/2005	Jankowski
2003/0205029	A1	11/2003	Chapolini et al.	2005/0192609	A1	9/2005	Whitman et al.
2003/0216732	A1	11/2003	Truckai et al.	2005/0192628	A1	9/2005	Viola
2003/0220660	A1	11/2003	Kortenbach et al.	2005/0203550	A1	9/2005	Laufer et al.
2004/0002726	A1	1/2004	Nunez et al.	2005/0216055	A1	9/2005	Scirica et al.
2004/0006335	A1	1/2004	Garrison	2005/0228224	A1	10/2005	Okada et al.
2004/0006340	A1	1/2004	Latterell et al.	2005/0240222	A1	10/2005	Shipp
2004/0006372	A1	1/2004	Racenet et al.	2005/0245965	A1	11/2005	Orban, III et al.
2004/0030333	A1	2/2004	Goble	2005/0251128	A1	11/2005	Amoah
2004/0034357	A1	2/2004	Beane et al.	2005/0256522	A1	11/2005	Francischelli et al.
2004/0034369	A1	2/2004	Sauer et al.	2005/0261676	A1	11/2005	Hall et al.
2004/0044364	A1	3/2004	DeVries et al.	2005/0261677	A1	11/2005	Hall et al.
2004/0068161	A1	4/2004	Couvillon, Jr.	2005/0263563	A1	12/2005	Racenet et al.
2004/0068307	A1	4/2004	Goble	2005/0267455	A1	12/2005	Eggers et al.
2004/0070369	A1	4/2004	Sakakibara	2005/0274768	A1	12/2005	Cummins et al.
2004/0078037	A1	4/2004	Batchelor et al.	2006/0004407	A1	1/2006	Hiles et al.
2004/0093024	A1	5/2004	Lousararian et al.	2006/0008787	A1	1/2006	Hayman et al.
2004/0094597	A1	5/2004	Whitman et al.	2006/0011699	A1	1/2006	Olson et al.

US 8,479,969 B2

2006/0015009	A1	1/2006	Jaffe et al.	2007/0221700	A1	9/2007	Ortiz et al.
2006/0020247	A1	1/2006	Kagan et al.	2007/0221701	A1	9/2007	Ortiz et al.
2006/0020258	A1	1/2006	Strauss et al.	2007/0225562	A1	9/2007	Spivey et al.
2006/0020336	A1	1/2006	Liddicoat	2007/0239028	A1	10/2007	Houser et al.
2006/0025811	A1	2/2006	Shelton, IV	2007/0246505	A1	10/2007	Pace-Florida et al.
2006/0025812	A1	2/2006	Shelton, IV	2007/0260278	A1	11/2007	Wheeler et al.
2006/0025813	A1	2/2006	Shelton et al.	2007/0270784	A1	11/2007	Smith et al.
2006/0047275	A1	3/2006	Goble	2007/0270884	A1	11/2007	Smith et al.
2006/0047303	A1	3/2006	Ortiz et al.	2007/0288044	A1	12/2007	Jinno et al.
2006/0047307	A1	3/2006	Ortiz et al.	2007/0299427	A1*	12/2007	Yeung et al. 606/1
2006/0049229	A1	3/2006	Milliman et al.	2008/0015598	A1	1/2008	Prommersberger
2006/0052825	A1	3/2006	Ransick et al.	2008/0029570	A1	2/2008	Shelton et al.
2006/0060630	A1	3/2006	Shelton, IV et al.	2008/0029573	A1	2/2008	Shelton et al.
2006/0064086	A1	3/2006	Odom	2008/0029574	A1	2/2008	Shelton et al.
2006/0079735	A1	4/2006	Martone et al.	2008/0029575	A1	2/2008	Shelton et al.
2006/0085031	A1	4/2006	Bettuchi	2008/0029577	A1*	2/2008	Shelton et al. 227/176.1
2006/0085033	A1	4/2006	Criscuolo et al.	2008/0030170	A1	2/2008	Dacquay et al.
2006/0086032	A1	4/2006	Valencic et al.	2008/0035701	A1	2/2008	Racenet et al.
2006/0100643	A1	5/2006	Laufer et al.	2008/0041916	A1	2/2008	Milliman et al.
2006/0108393	A1	5/2006	Heinrich et al.	2008/0041917	A1	2/2008	Racenet et al.
2006/0111711	A1	5/2006	Goble	2008/0078800	A1	4/2008	Hess et al.
2006/0111723	A1	5/2006	Chapolini et al.	2008/0078802	A1	4/2008	Hess et al.
2006/0122636	A1	6/2006	Bailly et al.	2008/0078803	A1	4/2008	Shelton et al.
2006/0142772	A1	6/2006	Ralph et al.	2008/0082114	A1	4/2008	McKenna et al.
2006/0149163	A1	7/2006	Hibner et al.	2008/0082125	A1	4/2008	Murray et al.
2006/0161185	A1	7/2006	Saadat et al.	2008/0082126	A1	4/2008	Murray et al.
2006/0173470	A1	8/2006	Oray et al.	2008/0083813	A1	4/2008	Zemlok et al.
2006/0180634	A1	8/2006	Shelton, IV et al.	2008/0114385	A1	5/2008	Byrum et al.
2006/0200123	A1	9/2006	Ryan	2008/0129253	A1	6/2008	Shiue et al.
2006/0212069	A1	9/2006	Shelton, IV	2008/0140115	A1	6/2008	Stopek
2006/0217729	A1	9/2006	Eskridge et al.	2008/0167522	A1	7/2008	Giordano et al.
2006/0226196	A1	10/2006	Hueil et al.	2008/0167672	A1	7/2008	Giordano et al.
2006/0235469	A1	10/2006	Viola	2008/0169328	A1	7/2008	Shelton
2006/0241655	A1	10/2006	Viola	2008/0169329	A1	7/2008	Shelton et al.
2006/0241692	A1	10/2006	McGuckin, Jr. et al.	2008/0169330	A1	7/2008	Shelton et al.
2006/0244460	A1	11/2006	Weaver	2008/0169331	A1	7/2008	Shelton et al.
2006/0258904	A1	11/2006	Stefanchik et al.	2008/0169332	A1	7/2008	Shelton et al.
2006/0259073	A1	11/2006	Miyamoto et al.	2008/0169333	A1	7/2008	Shelton et al.
2006/0264927	A1	11/2006	Ryan	2008/0172087	A1	7/2008	Fuchs et al.
2006/0264929	A1	11/2006	Goble et al.	2008/0172088	A1	7/2008	Smith et al.
2006/0271042	A1	11/2006	Latterell et al.	2008/0183193	A1	7/2008	Omori et al.
2006/0271102	A1	11/2006	Bosshard et al.	2008/0185419	A1	8/2008	Smith et al.
2006/0278680	A1	12/2006	Viola et al.	2008/0197167	A1	8/2008	Viola et al.
2006/0278681	A1	12/2006	Viola et al.	2008/0200835	A1*	8/2008	Monson et al. 600/567
2006/0289602	A1	12/2006	Wales et al.	2008/0228029	A1	9/2008	Mikkaichi et al.
2006/0291981	A1	12/2006	Viola et al.	2008/0245841	A1	10/2008	Smith et al.
2007/0016174	A1*	1/2007	Millman et al. 606/1	2008/0251568	A1	10/2008	Zemlok et al.
2007/0023476	A1	2/2007	Whitman et al.	2008/0251569	A1	10/2008	Smith et al.
2007/0023477	A1	2/2007	Whitman et al.	2008/0255413	A1	10/2008	Zemlok et al.
2007/0027468	A1	2/2007	Wales et al.	2008/0262654	A1	10/2008	Omori et al.
2007/0027469	A1	2/2007	Smith et al.	2008/0283570	A1	11/2008	Boyden et al.
2007/0034668	A1	2/2007	Holsten et al.	2008/0287944	A1	11/2008	Pearson et al.
2007/0039997	A1*	2/2007	Mather et al. 227/176.1	2008/0290134	A1	11/2008	Bettuchi et al.
2007/0055219	A1	3/2007	Whitman et al.	2008/0296346	A1	12/2008	Shelton, IV et al.
2007/0070574	A1	3/2007	Nerheim et al.	2008/0308602	A1	12/2008	Timm et al.
2007/0073341	A1	3/2007	Smith	2008/0308603	A1	12/2008	Shelton, IV et al.
2007/0078484	A1	4/2007	Talarico et al.	2008/0308608	A1	12/2008	Prommersberger
2007/0083193	A1	4/2007	Werneth et al.	2008/0314960	A1	12/2008	Marczyk et al.
2007/0084897	A1	4/2007	Shelton, IV et al.	2009/0001121	A1	1/2009	Hess et al.
2007/0102472	A1	5/2007	Shelton, IV	2009/0001122	A1	1/2009	Prommersberger et al.
2007/0106113	A1	5/2007	Ravo	2009/0001124	A1	1/2009	Hess et al.
2007/0106317	A1	5/2007	Shelton, IV et al.	2009/0001130	A1	1/2009	Hess et al.
2007/0114261	A1	5/2007	Ortiz et al.	2009/0005807	A1	1/2009	Hess et al.
2007/0118175	A1	5/2007	Butler et al.	2009/0005808	A1	1/2009	Hess et al.
2007/0129605	A1	6/2007	Schaaf	2009/0005809	A1	1/2009	Hess et al.
2007/0135803	A1	6/2007	Belson	2009/0012534	A1*	1/2009	Madhani et al. 606/130
2007/0158358	A1	7/2007	Mason, II et al.	2009/0012556	A1	1/2009	Boudreaux et al.
2007/0170225	A1	7/2007	Shelton, IV et al.	2009/0020958	A1	1/2009	Soul
2007/0173806	A1	7/2007	Orszulak et al.	2009/0054908	A1	2/2009	Zand et al.
2007/0173813	A1	7/2007	Odom	2009/0057369	A1	3/2009	Smith et al.
2007/0175949	A1	8/2007	Shelton, IV et al.	2009/0088774	A1	4/2009	Swarup et al.
2007/0175950	A1	8/2007	Shelton, IV et al.	2009/0090763	A1	4/2009	Zemlok et al.
2007/0175951	A1	8/2007	Shelton, IV et al.	2009/0093728	A1	4/2009	Hyde et al.
2007/0175955	A1	8/2007	Shelton, IV et al.	2009/0108048	A1	4/2009	Zemlok et al.
2007/0181632	A1	8/2007	Milliman	2009/0112229	A1	4/2009	Omori et al.
2007/0194079	A1	8/2007	Hueil et al.	2009/0114701	A1	5/2009	Zemlok et al.
2007/0194082	A1	8/2007	Morgan et al.	2009/0143805	A1	6/2009	Palmer et al.
2007/0203510	A1	8/2007	Bettuchi	2009/0149871	A9	6/2009	Kagan et al.
2007/0213750	A1	9/2007	Weadock	2009/0157067	A1	6/2009	Kane et al.

2009/0206125	A1	8/2009	Huitema et al.	2011/0101065	A1	5/2011	Milliman
2009/0206126	A1	8/2009	Huitema et al.	2011/0114697	A1	5/2011	Baxter, III et al.
2009/0206131	A1	8/2009	Weisenburgh, II et al.	2011/0114700	A1	5/2011	Baxter, III et al.
2009/0206132	A1	8/2009	Hueil et al.	2011/0118761	A1	5/2011	Baxter, III et al.
2009/0206133	A1	8/2009	Morgan et al.	2011/0125176	A1	5/2011	Yates et al.
2009/0206137	A1	8/2009	Hall et al.	2011/0125177	A1	5/2011	Yates et al.
2009/0206139	A1	8/2009	Hall et al.	2011/0132963	A1	6/2011	Giordano et al.
2009/0206141	A1	8/2009	Huitema et al.	2011/0132964	A1	6/2011	Weisenburgh, II et al.
2009/0206142	A1	8/2009	Huitema et al.	2011/0132965	A1	6/2011	Moore et al.
2009/0209946	A1	8/2009	Swayze et al.	2011/0144430	A1	6/2011	Spivey et al.
2009/0209979	A1	8/2009	Yates et al.	2011/0147433	A1	6/2011	Shelton, IV et al.
2009/0209990	A1	8/2009	Yates et al.	2011/0147434	A1	6/2011	Hueil et al.
2009/0213685	A1	8/2009	Mak et al.	2011/0155781	A1	6/2011	Swensgard et al.
2009/0218384	A1	9/2009	Aranyi	2011/0155787	A1	6/2011	Baxter, III et al.
2009/0242610	A1	10/2009	Shelton, IV et al.	2011/0163147	A1	7/2011	Laurent et al.
2009/0255974	A1	10/2009	Viola	2011/0174861	A1	7/2011	Shelton, IV et al.
2009/0255975	A1	10/2009	Zemlok et al.	2011/0174863	A1	7/2011	Shelton, IV et al.
2009/0255976	A1	10/2009	Marczyk et al.	2011/0178536	A1	7/2011	Kostrzewski
2009/0255977	A1	10/2009	Zemlok	2011/0192882	A1	8/2011	Hess et al.
2009/0255978	A1	10/2009	Viola et al.	2011/0210156	A1	9/2011	Smith et al.
2009/0292283	A1	11/2009	Odom	2011/0226837	A1	9/2011	Baxter, III et al.
2009/0308907	A1	12/2009	Nalagatla et al.	2011/0275901	A1	11/2011	Shelton, IV
2010/0012704	A1	1/2010	Tarinelli Racenet et al.	2011/0276083	A1	11/2011	Shelton, IV et al.
2010/0023024	A1	1/2010	Zeiner et al.	2011/0288573	A1	11/2011	Yates et al.
2010/0049084	A1	2/2010	Nock et al.	2011/0290851	A1	12/2011	Shelton, IV
2010/0069942	A1	3/2010	Shelton, IV	2011/0290853	A1	12/2011	Shelton, IV et al.
2010/0072254	A1	3/2010	Aranyi et al.	2011/0290854	A1	12/2011	Timm et al.
2010/0076475	A1	3/2010	Yates et al.	2011/0290855	A1*	12/2011	Moore et al. 227/180.1
2010/0089970	A1	4/2010	Smith et al.	2011/0290856	A1	12/2011	Shelton, IV et al.
2010/0096431	A1	4/2010	Smith et al.	2011/0295242	A1	12/2011	Spivey et al.
2010/0108740	A1	5/2010	Pastorelli et al.	2011/0295269	A1	12/2011	Swensgard et al.
2010/0108741	A1	5/2010	Hessler et al.	2011/0295270	A1	12/2011	Giordano et al.
2010/0127042	A1	5/2010	Shelton, IV	2011/0295295	A1	12/2011	Shelton, IV et al.
2010/0133317	A1	6/2010	Shelton, IV et al.	2012/0022523	A1	1/2012	Smith et al.
2010/0145146	A1	6/2010	Melder	2012/0024934	A1	2/2012	Shelton, IV et al.
2010/0147922	A1	6/2010	Olson	2012/0024935	A1	2/2012	Shelton, IV et al.
2010/0163598	A1	7/2010	Belzer	2012/0024936	A1	2/2012	Baxter, III et al.
2010/0179382	A1	7/2010	Shelton, IV et al.	2012/0029272	A1	2/2012	Shelton, IV et al.
2010/0186219	A1	7/2010	Smith	2012/0029544	A1	2/2012	Shelton, IV et al.
2010/0193566	A1	8/2010	Scheib et al.	2012/0029547	A1	2/2012	Shelton, IV et al.
2010/0193567	A1	8/2010	Scheib et al.	2012/0046692	A1	2/2012	Smith et al.
2010/0193568	A1	8/2010	Scheib et al.	2012/0071711	A1	3/2012	Shelton, IV et al.
2010/0193569	A1	8/2010	Yates et al.	2012/0071866	A1	3/2012	Kerr et al.
2010/0198220	A1	8/2010	Boudreaux et al.	2012/0074196	A1	3/2012	Shelton, IV et al.
2010/0200637	A1	8/2010	Beetel	2012/0074198	A1	3/2012	Huitema et al.
2010/0213241	A1	8/2010	Bedi et al.	2012/0074200	A1	3/2012	Schmid et al.
2010/0222901	A1	9/2010	Swayze et al.	2012/0074201	A1	3/2012	Baxter, III et al.
2010/0224669	A1	9/2010	Shelton, IV et al.	2012/0080332	A1	4/2012	Shelton, IV et al.
2010/0230465	A1	9/2010	Smith et al.	2012/0080333	A1	4/2012	Woodard, Jr. et al.
2010/0243707	A1	9/2010	Olson et al.	2012/0080334	A1	4/2012	Shelton, IV et al.
2010/0243708	A1	9/2010	Aranyi et al.	2012/0080335	A1	4/2012	Shelton, IV et al.
2010/0243709	A1	9/2010	Hess et al.	2012/0080336	A1	4/2012	Shelton, IV et al.
2010/0258611	A1	10/2010	Smith et al.	2012/0080337	A1	4/2012	Shelton, IV et al.
2010/0264193	A1	10/2010	Huang et al.	2012/0080338	A1	4/2012	Shelton, IV et al.
2010/0276471	A1	11/2010	Whitman	2012/0080339	A1	4/2012	Shelton, IV et al.
2010/0294827	A1	11/2010	Boyden et al.	2012/0080340	A1	4/2012	Shelton, IV et al.
2010/0294829	A1	11/2010	Giordano et al.	2012/0080344	A1	4/2012	Shelton, IV
2010/0301095	A1	12/2010	Shelton, IV et al.	2012/0080345	A1	4/2012	Morgan et al.
2010/0305552	A1	12/2010	Shelton, IV et al.	2012/0080475	A1	4/2012	Smith et al.
2010/0312261	A1	12/2010	Suzuki et al.	2012/0080477	A1	4/2012	Leimbach et al.
2011/0006099	A1	1/2011	Hall et al.	2012/0080478	A1	4/2012	Morgan et al.
2011/0006101	A1	1/2011	Hall et al.	2012/0080479	A1	4/2012	Shelton, IV
2011/0006103	A1	1/2011	Laurent et al.	2012/0080480	A1	4/2012	Woodard, Jr. et al.
2011/0011914	A1	1/2011	Baxter, III et al.	2012/0080481	A1	4/2012	Widenhouse et al.
2011/0011915	A1	1/2011	Shelton, IV	2012/0080482	A1	4/2012	Schall et al.
2011/0017801	A1	1/2011	Zemlok et al.	2012/0080483	A1	4/2012	Riestenberg et al.
2011/0022032	A1	1/2011	Zemlok et al.	2012/0080484	A1	4/2012	Morgan et al.
2011/0024477	A1	2/2011	Hall	2012/0080485	A1	4/2012	Woodard, Jr. et al.
2011/0024478	A1	2/2011	Shelton, IV	2012/0080486	A1	4/2012	Woodard, Jr. et al.
2011/0024479	A1	2/2011	Swensgard et al.	2012/0080487	A1	4/2012	Woodard, Jr. et al.
2011/0036887	A1	2/2011	Zemlok et al.	2012/0080488	A1	4/2012	Shelton, IV et al.
2011/0042441	A1	2/2011	Shelton, IV et al.	2012/0080489	A1	4/2012	Shelton, IV et al.
2011/0060363	A1	3/2011	Hess et al.	2012/0080490	A1	4/2012	Shelton, IV et al.
2011/0068145	A1	3/2011	Bedi et al.	2012/0080491	A1	4/2012	Shelton, IV et al.
2011/0068148	A1	3/2011	Hall et al.	2012/0080493	A1	4/2012	Shelton, IV et al.
2011/0084112	A1	4/2011	Kostrzewski	2012/0080496	A1	4/2012	Schall et al.
2011/0087276	A1	4/2011	Bedi et al.	2012/0080498	A1	4/2012	Shelton, IV et al.
2011/0087279	A1	4/2011	Shah et al.	2012/0080499	A1	4/2012	Schall et al.
2011/0095068	A1	4/2011	Patel	2012/0080500	A1	4/2012	Morgan et al.

2012/0080501	A1	4/2012	Morgan et al.	DE	19509116	A1	9/1996
2012/0080502	A1	4/2012	Morgan et al.	DE	19851291	A1	1/2000
2012/0080503	A1	4/2012	Woodard, Jr. et al.	DE	19924311	A1	11/2000
2012/0083833	A1	4/2012	Shelton, IV et al.	DE	69328576	T2	1/2001
2012/0083834	A1	4/2012	Shelton, IV et al.	DE	10052679	A1	5/2001
2012/0083835	A1	4/2012	Shelton, IV et al.	DE	20112837	U1	10/2001
2012/0083836	A1	4/2012	Shelton, IV et al.	DE	20121753	U1	4/2003
2012/0132450	A1	5/2012	Timm et al.	DE	10314072	A1	10/2004
2012/0138660	A1	6/2012	Shelton, IV	DE	202007003114	U1	6/2007
2012/0160721	A1	6/2012	Shelton, IV et al.	EP	0122046	A1	10/1984
2012/0175399	A1	7/2012	Shelton et al.	EP	0070230	B1	10/1985
2012/0187179	A1	7/2012	Gleiman	EP	0156774	A2	10/1985
2012/0199630	A1	8/2012	Shelton, IV et al.	EP	0387980	B1	10/1985
2012/0199631	A1	8/2012	Shelton, IV et al.	EP	0033548	B1	5/1986
2012/0199632	A1	8/2012	Spivey et al.	EP	0129442	B1	11/1987
2012/0199633	A1	8/2012	Shelton, IV et al.	EP	0276104	A2	7/1988
2012/0203247	A1	8/2012	Shelton, IV et al.	EP	0178941	B1	1/1991
2012/0205421	A1	8/2012	Shelton, IV	EP	0248844	B1	1/1993
2012/0234890	A1	9/2012	Aronhalt et al.	EP	0545029	A1	6/1993
2012/0234891	A1	9/2012	Aronhalt et al.	EP	0277959	B1	10/1993
2012/0234892	A1	9/2012	Aronhalt et al.	EP	0233940	B1	11/1993
2012/0234893	A1	9/2012	Schuckmann et al.	EP	0261230	B1	11/1993
2012/0234895	A1	9/2012	O'Connor et al.	EP	0639349	A2	2/1994
2012/0234896	A1	9/2012	Ellerhorst et al.	EP	0324636	B1	3/1994
2012/0234897	A1	9/2012	Shelton, IV et al.	EP	0593920	A1	4/1994
2012/0234898	A1	9/2012	Shelton, IV et al.	EP	0594148	A1	4/1994
2012/0234899	A1	9/2012	Scheib et al.	EP	0427949	B1	6/1994
2012/0234900	A1	9/2012	Swayze	EP	0523174	B1	6/1994
2012/0238823	A1	9/2012	Hagerty et al.	EP	0600182	A2	6/1994
2012/0238824	A1	9/2012	Widenhouse et al.	EP	0310431	B1	11/1994
2012/0238826	A1	9/2012	Yoo et al.	EP	0375302	B1	11/1994
2012/0238829	A1	9/2012	Shelton, IV et al.	EP	0376562	B1	11/1994
2012/0239009	A1	9/2012	Mollere et al.	EP	0630612	A1	12/1994
2012/0239010	A1	9/2012	Shelton, IV et al.	EP	0634144	A1	1/1995
2012/0239012	A1	9/2012	Laurent et al.	EP	0646356	A2	4/1995
2012/0239075	A1	9/2012	Widenhouse et al.	EP	0646357	A1	4/1995
2012/0239082	A1	9/2012	Shelton, IV et al.	EP	0653189	A2	5/1995
2012/0241491	A1	9/2012	Aldridge et al.	EP	0669104	A1	8/1995
2012/0241492	A1	9/2012	Shelton, IV et al.	EP	0511470	B1	10/1995
2012/0241493	A1	9/2012	Baxter, III et al.	EP	0679367	A2	11/1995
2012/0241496	A1	9/2012	Mandakolathur Vasudevan et al.	EP	0392547	B1	12/1995
2012/0241497	A1	9/2012	Mandakolathur Vasudevan et al.	EP	0685204	A1	12/1995
2012/0241498	A1	9/2012	Gonzalez et al.	EP	0364216	B1	1/1996
2012/0241499	A1	9/2012	Baxter, III et al.	EP	0699418	A1	3/1996
2012/0241500	A1	9/2012	Timmer et al.	EP	0702937	A1	3/1996
2012/0241501	A1	9/2012	Swayze et al.	EP	0705571	A1	4/1996
2012/0241502	A1	9/2012	Aldridge et al.	EP	0711611	A2	5/1996
2012/0241503	A1	9/2012	Baxter, III et al.	EP	0484677	B2	6/1996
2012/0241505	A1	9/2012	Alexander, III et al.	EP	0541987	B1	7/1996
2012/0248169	A1	10/2012	Widenhouse et al.	EP	0667119	B1	7/1996
2012/0253298	A1	10/2012	Henderson et al.	EP	0708618	B1	3/1997
2012/0265230	A1	10/2012	Yates et al.	EP	0770355	A1	5/1997
2012/0273551	A1	11/2012	Shelton, IV et al.	EP	0503662	B1	6/1997
2012/0283707	A1	11/2012	Giordano et al.	EP	0447121	B1	7/1997
2012/0286019	A1	11/2012	Hueil et al.	EP	0625077	B1	7/1997
2012/0292367	A1	11/2012	Morgan et al.	EP	0633749	B1	8/1997
2012/0292370	A1	11/2012	Hess et al.	EP	0710090	B1	8/1997
2012/0298719	A1	11/2012	Shelton, IV et al.	EP	0578425	B1	9/1997
2013/0012931	A1	1/2013	Spivey et al.	EP	0625335	B1	11/1997
2013/0012957	A1	1/2013	Shelton, IV et al.	EP	0552423	B1	1/1998
2013/0020376	A1	1/2013	Shelton, IV et al.	EP	0592244	B1	1/1998
2013/0023861	A1	1/2013	Shelton, IV et al.	EP	0648476	B1	1/1998
2013/0026208	A1	1/2013	Shelton, IV et al.	EP	0649290	B1	3/1998
2013/0026210	A1	1/2013	Shelton, IV et al.	EP	0598618	B1	9/1998
2013/0041371	A1	2/2013	Yates et al.	EP	0676173	B1	9/1998
				EP	0678007	B1	9/1998
				EP	0603472	B1	11/1998
				EP	0605351	B1	11/1998
				EP	0878169	A1	11/1998
				EP	0879742	A1	11/1998
				EP	0695144	B1	12/1998
				EP	0722296	B1	12/1998
				EP	0760230	B1	2/1999
				EP	0623316	B1	3/1999
				EP	0650701	B1	3/1999
				EP	0537572	B1	6/1999
				EP	0923907	A1	6/1999
				EP	0843906	B1	3/2000
				EP	0552050	B1	5/2000
FOREIGN PATENT DOCUMENTS							
CA	2514274	A1	1/2006				
CN	2488482	Y	5/2002				
CN	1634601	A	7/2005				
CN	1868411	A	11/2006				
CN	1915180	A	2/2007				
CN	101011286	A	8/2007				
CN	101095621	A	1/2008				
DE	273689	C	5/1914				
DE	1775926	A	1/1972				
DE	3036217	A1	4/1982				
DE	3210466	A1	9/1983				
DE	9412228	U	9/1994				

US 8,479,969 B2

Page 14

EP	0833592	B1	5/2000	EP	1632191	A2	3/2006
EP	0830094	B1	9/2000	EP	1065981	B1	5/2006
EP	1034747	A1	9/2000	EP	1082944	B1	5/2006
EP	1034748	A1	9/2000	EP	1652481	A2	5/2006
EP	0694290	B1	11/2000	EP	1382303	B1	6/2006
EP	1050278	A1	11/2000	EP	1253866	B1	7/2006
EP	1053719	A1	11/2000	EP	1032318	B1	8/2006
EP	1053720	A1	11/2000	EP	1045672	B1	8/2006
EP	1055399	A1	11/2000	EP	1617768	B1	8/2006
EP	1055400	A1	11/2000	EP	1693015	A2	8/2006
EP	1080694	A1	3/2001	EP	1400214	B1	9/2006
EP	1090592	A1	4/2001	EP	1702567	A2	9/2006
EP	1095627	A1	5/2001	EP	1129665	B1	11/2006
EP	1256318	B1	5/2001	EP	1400206	B1	11/2006
EP	0806914	B1	9/2001	EP	1721568	A1	11/2006
EP	0768840	B1	12/2001	EP	1256317	B1	12/2006
EP	0908152	B1	1/2002	EP	1285633	B1	12/2006
EP	0872213	B1	5/2002	EP	1728473	A1	12/2006
EP	0862386	B1	6/2002	EP	1728475	A2	12/2006
EP	0949886	B1	9/2002	EP	1479346	B1	1/2007
EP	1238634	A2	9/2002	EP	1484024	B1	1/2007
EP	0858295	B1	12/2002	EP	1754445	A2	2/2007
EP	0656188	B1	1/2003	EP	1759812	A1	3/2007
EP	1284120	A1	2/2003	EP	1767163	A1	3/2007
EP	1287788	A1	3/2003	EP	1769756	A1	4/2007
EP	0717966	B1	4/2003	EP	1769758	A1	4/2007
EP	0869742	B1	5/2003	EP	1581128	B1	5/2007
EP	0829235	B1	6/2003	EP	1780825	A1	5/2007
EP	0887046	B1	7/2003	EP	1785097	A2	5/2007
EP	0852480	B1	8/2003	EP	1790293	A2	5/2007
EP	0891154	B1	9/2003	EP	1800610	A1	6/2007
EP	0813843	B1	10/2003	EP	1300117	B1	8/2007
EP	0873089	B1	10/2003	EP	1813199	A1	8/2007
EP	0856326	B1	11/2003	EP	1813201	A1	8/2007
EP	1374788	A1	1/2004	EP	1813202	A1	8/2007
EP	0741996	B1	2/2004	EP	1813203	A2	8/2007
EP	0814712	B1	2/2004	EP	1813207	A1	8/2007
EP	1402837	A1	3/2004	EP	1813209	A1	8/2007
EP	0705570	B1	4/2004	EP	1487359	B1	10/2007
EP	0959784	B1	4/2004	EP	1599146	B1	10/2007
EP	1407719	A2	4/2004	EP	1839596	A1	10/2007
EP	1086713	B1	5/2004	EP	2110083	A2	10/2007
EP	0996378	B1	6/2004	EP	1857057	A2	11/2007
EP	1426012	A1	6/2004	EP	1402821	B1	12/2007
EP	0833593	B2	7/2004	EP	1872727	A1	1/2008
EP	1442694	A1	8/2004	EP	1897502	A1	3/2008
EP	0888749	B1	9/2004	EP	1330201	B1	6/2008
EP	0959786	B1	9/2004	EP	1702568	B1	7/2008
EP	1459695	A1	9/2004	EP	1943955	A2	7/2008
EP	1473819	A1	11/2004	EP	1943957	A2	7/2008
EP	1477119	A1	11/2004	EP	1943964	A1	7/2008
EP	1479345	A1	11/2004	EP	1943976	A2	7/2008
EP	1479347	A1	11/2004	EP	1593337	B1	8/2008
EP	1479348	A1	11/2004	EP	1970014	A1	9/2008
EP	0754437	B2	12/2004	EP	1980213	A2	10/2008
EP	1025807	B1	12/2004	EP	1759645	B1	11/2008
EP	1001710	B1	1/2005	EP	1990014	A2	11/2008
EP	1520521	A1	4/2005	EP	1693008	B1	12/2008
EP	1520523	A1	4/2005	EP	1759640	B1	12/2008
EP	1520525	A1	4/2005	EP	2000102	A2	12/2008
EP	1522264	A1	4/2005	EP	2008595	A2	12/2008
EP	1523942	A2	4/2005	EP	1736104	B1	3/2009
EP	1550408	A1	7/2005	EP	1749486	B1	3/2009
EP	1557129	A1	7/2005	EP	2039316	A2	3/2009
EP	1064883	B1	8/2005	EP	1721576	B1	4/2009
EP	1067876	B1	8/2005	EP	1733686	B1	4/2009
EP	0870473	B1	9/2005	EP	2044890	A1	4/2009
EP	1157666	B1	9/2005	EP	1550409	A1	6/2009
EP	0880338	B1	10/2005	EP	1550413	B1	6/2009
EP	1158917	B1	11/2005	EP	1745748	B1	8/2009
EP	1344498	B1	11/2005	EP	2090237	A1	8/2009
EP	1330989	B1	12/2005	EP	2090244	A2	8/2009
EP	0771176	B2	1/2006	EP	2090245	A1	8/2009
EP	1621138	A2	2/2006	EP	2090256	A2	8/2009
EP	1621139	A2	2/2006	EP	2095777	A2	9/2009
EP	1621141	A2	2/2006	EP	2110082	A1	10/2009
EP	1621145	A2	2/2006	EP	1813208	B1	11/2009
EP	1621151	A2	2/2006	EP	2116195	A1	11/2009
EP	1034746	B1	3/2006	EP	1607050	B1	12/2009

US 8,479,969 B2

Page 15

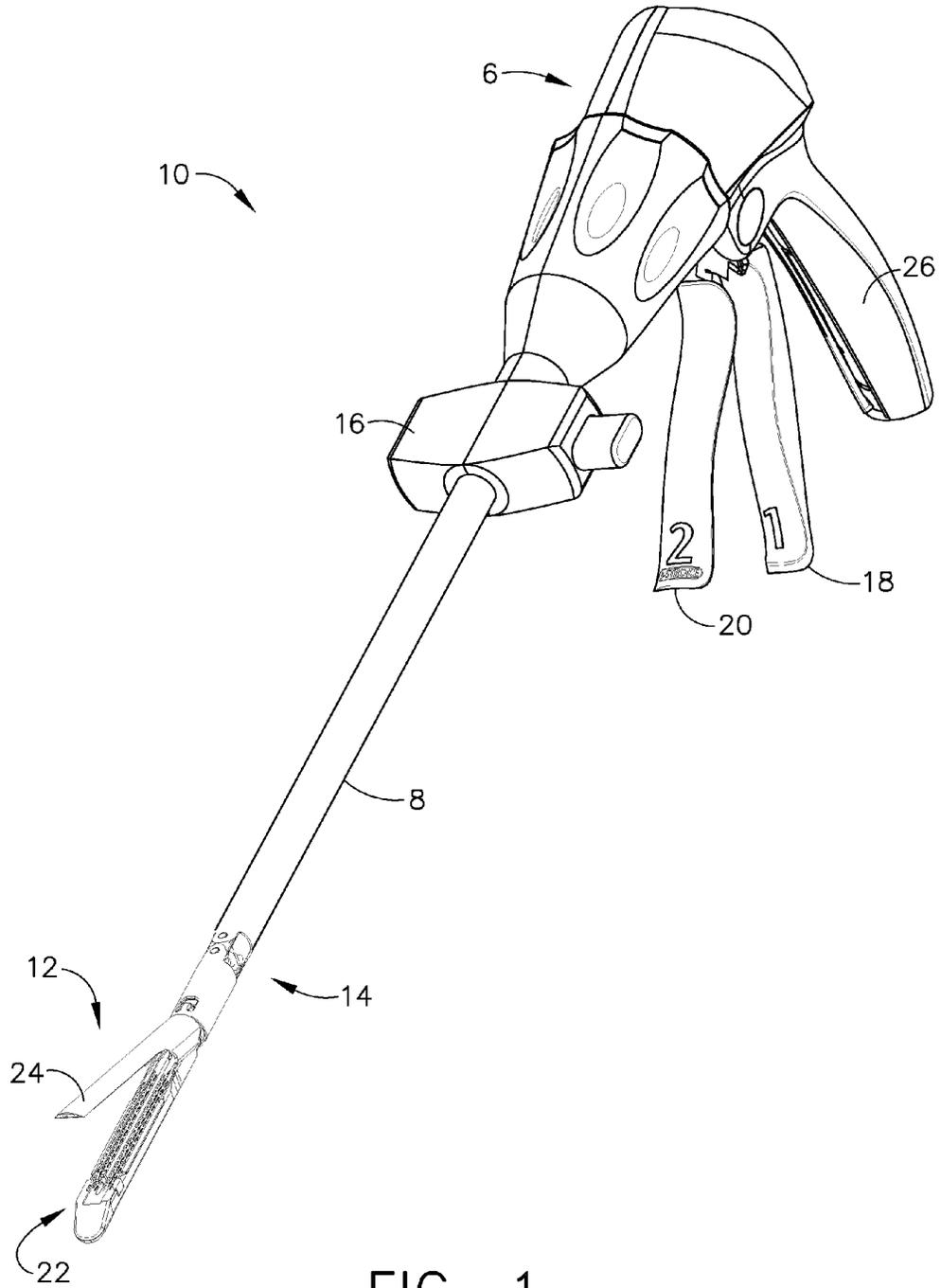
EP	1815804	B1	12/2009	WO	WO 92/20295	A1	11/1992
EP	1566150	B1	4/2010	WO	WO 92/21300	A1	12/1992
EP	1813206	B1	4/2010	WO	WO 93/08755	A1	5/1993
EP	1769754	B1	6/2010	WO	WO 93/13718	A1	7/1993
EP	1535565	B1	10/2010	WO	WO 93/14690	A1	8/1993
EP	1702570	B1	10/2010	WO	WO 93/15648	A1	8/1993
EP	1785098	B1	10/2010	WO	WO 93/15850	A1	8/1993
EP	2005896	B1	10/2010	WO	WO 93/19681	A1	10/1993
EP	2030578	B1	11/2010	WO	WO 94/00060	A1	1/1994
EP	1627605	B1	12/2010	WO	WO 94/11057	A1	5/1994
EP	1813205	B1	6/2011	WO	WO 94/12108	A1	6/1994
EP	2090243	B1	6/2011	WO	WO 94/18893	A1	9/1994
EP	1785102	B1	1/2012	WO	WO 94/22378	A1	10/1994
FR	999646	A	2/1952	WO	WO 94/23659	A1	10/1994
FR	1112936	A	3/1956	WO	WO 95/02369	A1	1/1995
FR	2598905	A1	11/1987	WO	WO 95/03743	A1	2/1995
FR	2765794	A	1/1999	WO	WO 95/06817	A1	3/1995
GB	939929	A	10/1963	WO	WO 95/09576	A1	4/1995
GB	1210522	A	10/1970	WO	WO 95/09577	A1	4/1995
GB	1217159	A	12/1970	WO	WO 95/14436	A1	6/1995
GB	1339394	A	12/1973	WO	WO 95/17855	A1	7/1995
GB	2109241	A	6/1983	WO	WO 95/18383	A1	7/1995
GB	2272159	A	5/1994	WO	WO 95/18572	A1	7/1995
GB	2284242	A	5/1995	WO	WO 95/19739	A1	7/1995
GB	2336214	A	10/1999	WO	WO 95/20360	A1	8/1995
GB	2425903	A	11/2006	WO	WO 95/23557	A1	9/1995
JP	50-33988	U	4/1975	WO	WO 95/24865	A1	9/1995
JP	S 58500053	A	1/1983	WO	WO 95/25471	A3	9/1995
JP	61-98249	A	5/1986	WO	WO 95/26562	A1	10/1995
JP	S 61502036	A	9/1986	WO	WO 95/29639	A1	11/1995
JP	63-203149	A	8/1988	WO	WO 96/04858	A1	2/1996
JP	3-12126	A	1/1991	WO	WO 96/19151	A1	6/1996
JP	5-212039	A	8/1993	WO	WO 96/19152	A1	6/1996
JP	6007357	A	1/1994	WO	WO 96/20652	A1	7/1996
JP	7051273	A	2/1995	WO	WO 96/21119	A1	7/1996
JP	7-124166	A	5/1995	WO	WO 96/22055	A1	7/1996
JP	8-33642	A	2/1996	WO	WO 96/23448	A1	8/1996
JP	8033641	A	2/1996	WO	WO 96/24301	A1	8/1996
JP	8229050	A	9/1996	WO	WO 96/27337	A1	9/1996
JP	2000033071	A	2/2000	WO	WO 96/31155	A1	10/1996
JP	2000171730	A	6/2000	WO	WO 96/35464	A1	11/1996
JP	2000287987	A	10/2000	WO	WO 96/39085	A1	12/1996
JP	2000325303	A	11/2000	WO	WO 96/39086	A1	12/1996
JP	2001-514541	A	9/2001	WO	WO 96/39087	A1	12/1996
JP	2001286477	A	10/2001	WO	WO 96/39088	A1	12/1996
JP	2002143078	A	5/2002	WO	WO 96/39089	A1	12/1996
JP	2002369820	A	12/2002	WO	WO 97/00646	A1	1/1997
JP	2003-500153	A	1/2003	WO	WO 97/00647	A1	1/1997
JP	2003-521301	A	7/2003	WO	WO 97/06582	A1	2/1997
JP	2004-344663	A	12/2004	WO	WO 97/10763	A1	3/1997
JP	2005-028149	A	2/2005	WO	WO 97/10764	A1	3/1997
JP	2005505322	T	2/2005	WO	WO 97/11648	A2	4/1997
JP	2005103293	A	4/2005	WO	WO 97/11649	A1	4/1997
JP	2005131163	A	5/2005	WO	WO 97/15237	A1	5/1997
JP	2005131164	A	5/2005	WO	WO 97/24073	A1	7/1997
JP	2005131173	A	5/2005	WO	WO 97/24993	A1	7/1997
JP	2005131211	A	5/2005	WO	WO 97/30644	A1	8/1997
JP	2005131212	A	5/2005	WO	WO 97/34533	A1	9/1997
JP	2005137423	A	6/2005	WO	WO 97/37598	A1	10/1997
JP	2005152416	A	6/2005	WO	WO 97/39688	A2	10/1997
JP	2005-523105	A	8/2005	WO	WO 98/17180	A1	4/1998
JP	2005524474	A	8/2005	WO	WO 98/27880	A1	7/1998
JP	2006-281405	A	10/2006	WO	WO 98/30153	A1	7/1998
RU	2008830	C1	3/1994	WO	WO 98/47436	A1	10/1998
RU	2141279	C1	11/1999	WO	WO 99/03407	A1	1/1999
RU	2187249	C2	8/2002	WO	WO 99/03408	A1	1/1999
RU	2225170	C2	3/2004	WO	WO 99/03409	A1	1/1999
SU	189517	A	1/1967	WO	WO 99/12483	A1	3/1999
SU	328636	A	9/1972	WO	WO 99/12487	A1	3/1999
SU	886900	A1	12/1981	WO	WO 99/12488	A1	3/1999
SU	1009439	A	4/1983	WO	WO 99/15086	A1	4/1999
SU	1333319	A2	8/1987	WO	WO 99/15091	A1	4/1999
SU	1377053	A1	2/1988	WO	WO 99/23933	A2	5/1999
SU	1561964	A1	5/1990	WO	WO 99/23959	A1	5/1999
SU	1708312	A1	1/1992	WO	WO 99/25261	A1	5/1999
SU	1722476	A1	3/1992	WO	WO 99/29244	A1	6/1999
SU	1752361	A1	8/1992	WO	WO 99/34744	A1	7/1999
WO	WO 82/02824	A1	9/1982	WO	WO 99/45849	A1	9/1999
WO	WO 91/15157	A1	10/1991	WO	WO 99/48430	A1	9/1999

WO	WO 99/51158	A1	10/1999	WO	WO 2004/056277	A1	7/2004
WO	WO 00/24322	A1	5/2000	WO	WO 2004/062516	A1	7/2004
WO	WO 00/24330	A1	5/2000	WO	WO 2004/078050	A2	9/2004
WO	WO 00/41638	A1	7/2000	WO	WO 2004/078051	A2	9/2004
WO	WO 00/48506	A1	8/2000	WO	WO 2004/086987	A1	10/2004
WO	WO 00/53112	A2	9/2000	WO	WO 2004/096015	A2	11/2004
WO	WO 00/54653	A1	9/2000	WO	WO 2004/096057	A2	11/2004
WO	WO 00/57796	A1	10/2000	WO	WO 2004/103157	A2	12/2004
WO	WO 00/64365	A1	11/2000	WO	WO 2004/105593	A1	12/2004
WO	WO 00/72762	A1	12/2000	WO	WO 2004/105621	A1	12/2004
WO	WO 00/72765	A1	12/2000	WO	WO 2004/112618	A2	12/2004
WO	WO 01/03587	A1	1/2001	WO	WO 2004/112652	A2	12/2004
WO	WO 01/05702	A1	1/2001	WO	WO 2005/027983	A2	3/2005
WO	WO 01/10482	A1	2/2001	WO	WO 2005/037329	A2	4/2005
WO	WO 01/35845	A1	5/2001	WO	WO 2005/044078	A2	5/2005
WO	WO 01/54594	A1	8/2001	WO	WO 2005/055846	A1	6/2005
WO	WO 01/58371	A1	8/2001	WO	WO 2005/072634	A2	8/2005
WO	WO 01/62158	A2	8/2001	WO	WO 2005/078892	A1	8/2005
WO	WO 01/62161	A1	8/2001	WO	WO 2005/079675	A2	9/2005
WO	WO 01/62162	A1	8/2001	WO	WO 2005/096954	A2	10/2005
WO	WO 01/62164	A2	8/2001	WO	WO 2005/112806	A2	12/2005
WO	WO 01/62169	A2	8/2001	WO	WO 2005/112808	A1	12/2005
WO	WO 01/78605	A2	10/2001	WO	WO 2005/115251	A2	12/2005
WO	WO 01/91646	A1	12/2001	WO	WO 2005/115253	A2	12/2005
WO	WO 02/07608	A2	1/2002	WO	WO 2005/117735	A1	12/2005
WO	WO 02/07618	A1	1/2002	WO	WO 2005/122936	A1	12/2005
WO	WO 02/17799	A1	3/2002	WO	WO 2006/023486	A1	3/2006
WO	WO 02/19920	A1	3/2002	WO	WO 2006/027014	A1	3/2006
WO	WO 02/19932	A1	3/2002	WO	WO 2006/044490	A2	4/2006
WO	WO 02/30297	A2	4/2002	WO	WO 2006/044581	A2	4/2006
WO	WO 02/32322	A2	4/2002	WO	WO 2006/044810	A2	4/2006
WO	WO 02/36028	A1	5/2002	WO	WO 2006/051252	A1	5/2006
WO	WO 02/43571	A2	6/2002	WO	WO 2006/059067	A1	6/2006
WO	WO 02/058568	A1	8/2002	WO	WO 2006/083748	A1	8/2006
WO	WO 02/060328	A1	8/2002	WO	WO 2006/092563	A1	9/2006
WO	WO 02/067785	A2	9/2002	WO	WO 2006/092565	A1	9/2006
WO	WO 02/098302	A1	12/2002	WO	WO 2006/115958	A1	11/2006
WO	WO 03/000138	A2	1/2003	WO	WO 2006/125940	A1	11/2006
WO	WO 03/001329	A2	1/2003	WO	WO 2006/132992	A1	12/2006
WO	WO 03/013363	A1	2/2003	WO	WO 2007/002180	A2	1/2007
WO	WO 03/015604	A2	2/2003	WO	WO 2007/016290	A2	2/2007
WO	WO 03/020106	A2	3/2003	WO	WO 2007/018898	A2	2/2007
WO	WO 03/020139	A2	3/2003	WO	WO 2007/098220	A2	8/2007
WO	WO 03/024339	A1	3/2003	WO	WO 2007/121579	A1	11/2007
WO	WO 03/079909	A3	3/2003	WO	WO 2007/131110	A2	11/2007
WO	WO 03/030743	A2	4/2003	WO	WO 2007/137304	A2	11/2007
WO	WO 03/037193	A1	5/2003	WO	WO 2007/139734	A2	12/2007
WO	WO 03/047436	A3	6/2003	WO	WO 2007/142625	A2	12/2007
WO	WO 03/055402	A1	7/2003	WO	WO 2007/147439	A1	12/2007
WO	WO 03/057048	A1	7/2003	WO	WO 2008/021969	A2	2/2008
WO	WO 03/057058	A1	7/2003	WO	WO 2008/039249	A1	4/2008
WO	WO 03/063694	A1	8/2003	WO	WO 2008/039270	A1	4/2008
WO	WO 03/077769	A1	9/2003	WO	WO 2008/045383	A2	4/2008
WO	WO 03/079911	A1	10/2003	WO	WO 2008/070763	A1	6/2008
WO	WO 03/082126	A1	10/2003	WO	WO 2008/089404	A2	7/2008
WO	WO 03/088845	A2	10/2003	WO	WO 2008/109125	A1	9/2008
WO	WO 03/090630	A2	11/2003	WO	WO 2010/063795	A1	6/2010
WO	WO 03/094743	A1	11/2003	WO	WO 2010/098871	A2	9/2010
WO	WO 03/094745	A1	11/2003	WO	WO 2012/021671	A1	2/2012
WO	WO 03/094746	A1	11/2003	WO	WO 2012/044844	A2	4/2012
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 2004/021868	A2	3/2004				
WO	WO 2004/028585	A2	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 2004/034875	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				

OTHER PUBLICATIONS

- European Search Report, Application No. 08250080.2, dated Nov. 4, 2009 (7 pages).
- European Examination Report, Application No. 08250093.5, dated Jun. 14, 2010 (5 pages).
- European Examination Report, Application No. 08250080.2, dated Jun. 14, 2010 (4 pages).
- International Search Report for PCT/US2012/026997, May 7, 2012 (5 pages).
- Written Opinion for PCT/US2012/026997, May 7, 2012 (6 pages).
- International Search Report for PCT/US2012/039156, Oct. 29, 2012 (4 pages).
- Written Opinion for PCT/US2012/039156, Oct. 29, 2012 (6 pages).
- European Search Report for Application No. 12173458.6, dated Dec. 6, 2012 (8 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://electronicdesign.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).
- U.S. Appl. No. 12/031,542, filed Feb. 14, 2008.
- U.S. Appl. No. 12/031,556, filed Feb. 14, 2008.
- U.S. Appl. No. 12/031,573, filed Feb. 14, 2008.
- U.S. Appl. No. 13/310,107, filed Dec. 2, 2011.
- U.S. Appl. No. 13/369,629, filed Feb. 9, 2012.
- U.S. Appl. No. 13/486,175, filed Jun. 1, 2012.
- * cited by examiner



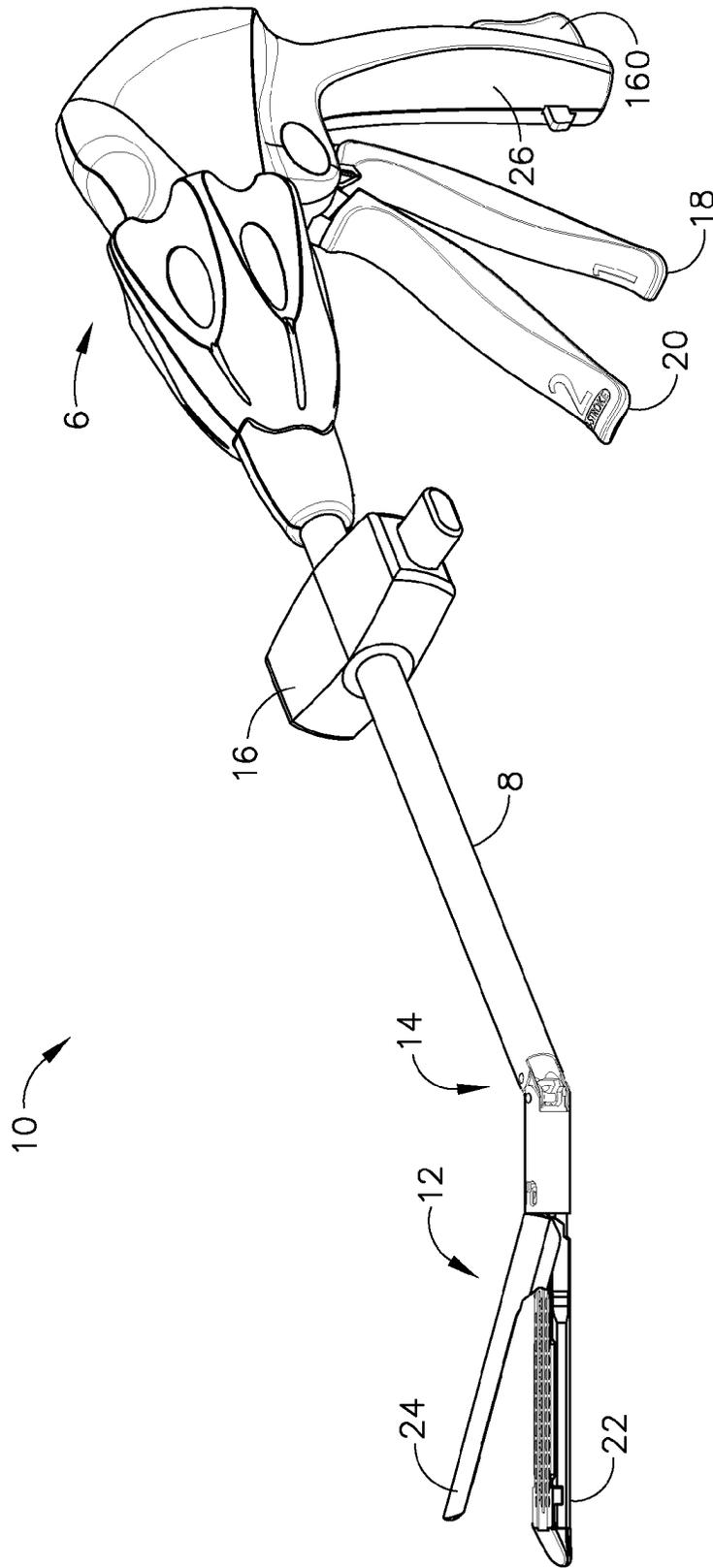


FIG. 2

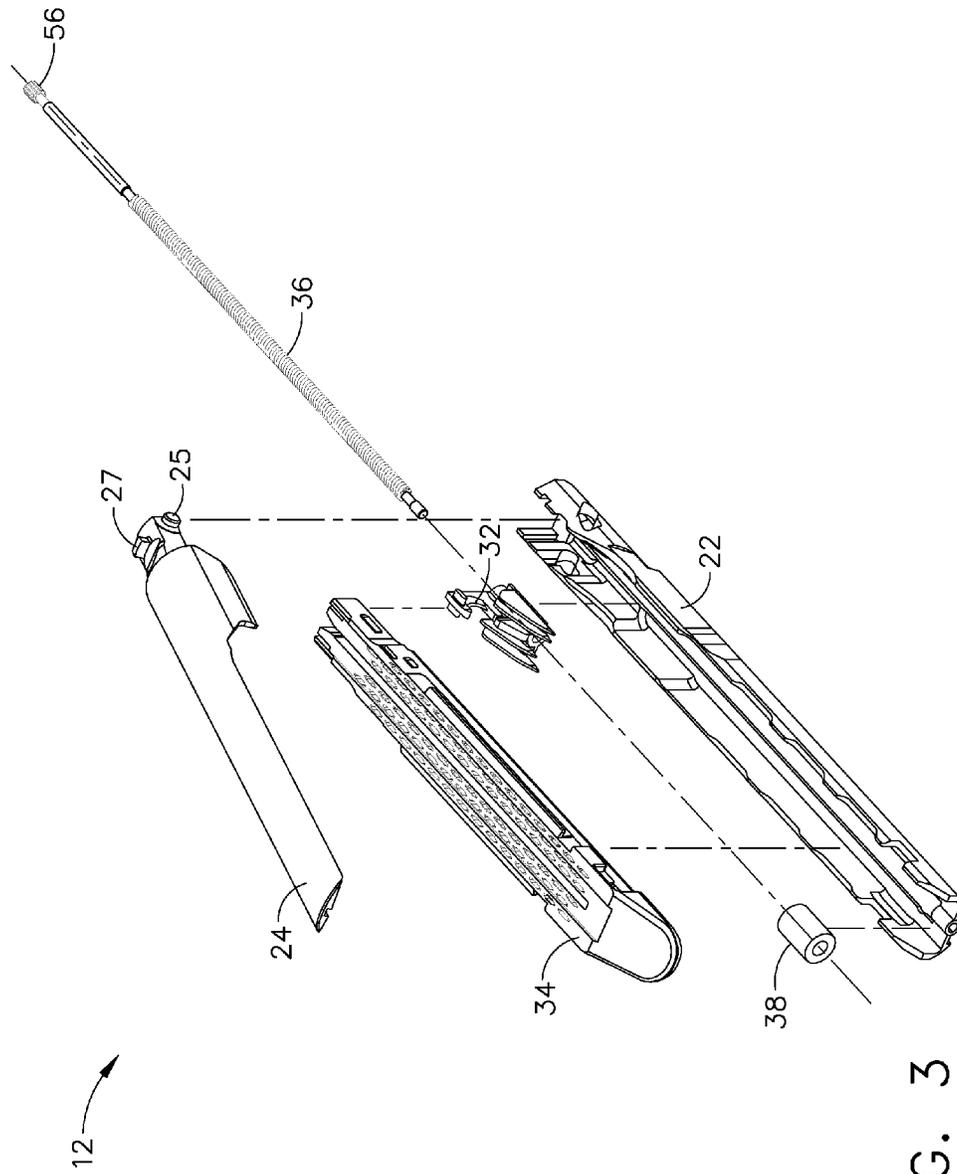


FIG. 3

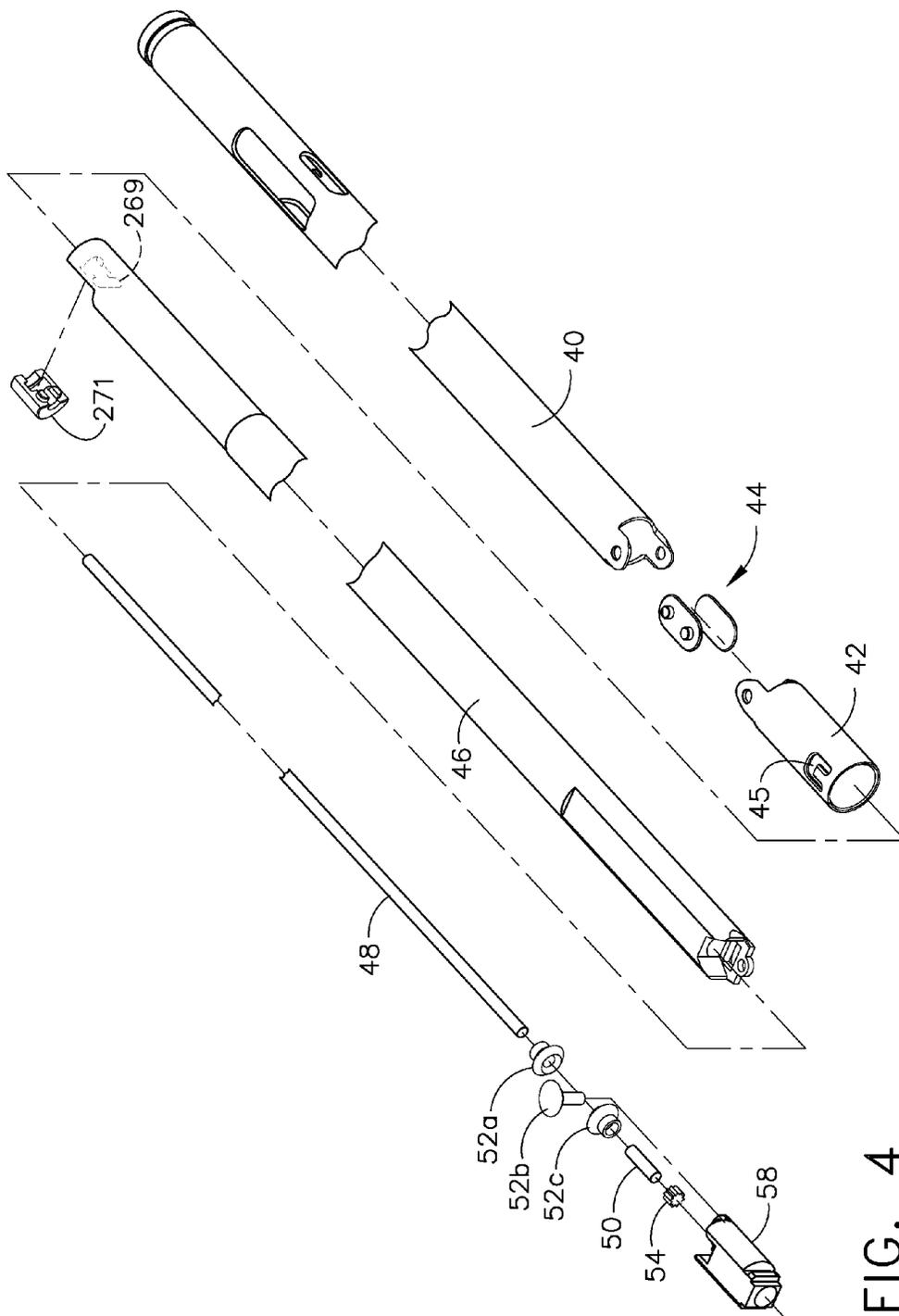
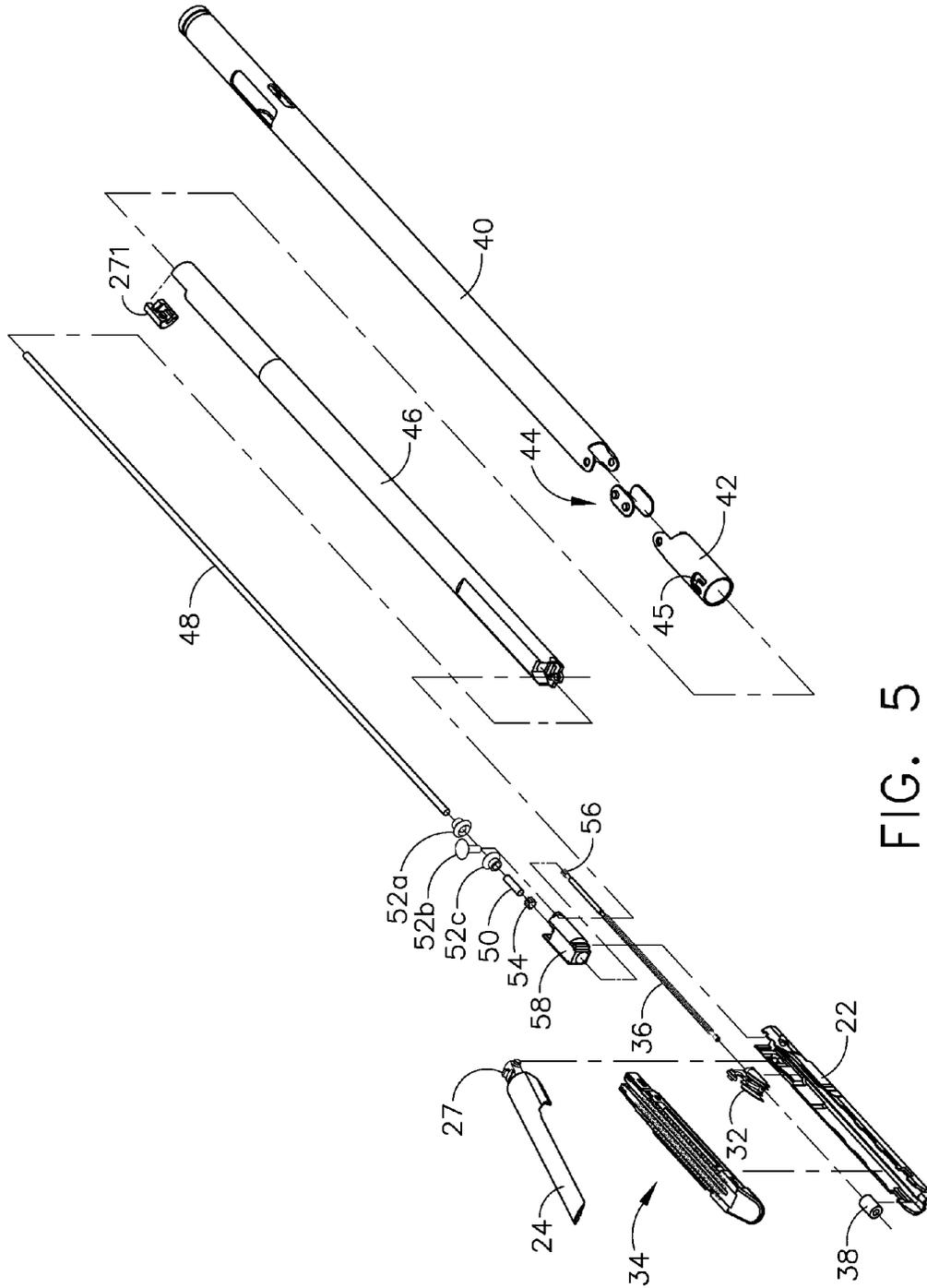


FIG. 4



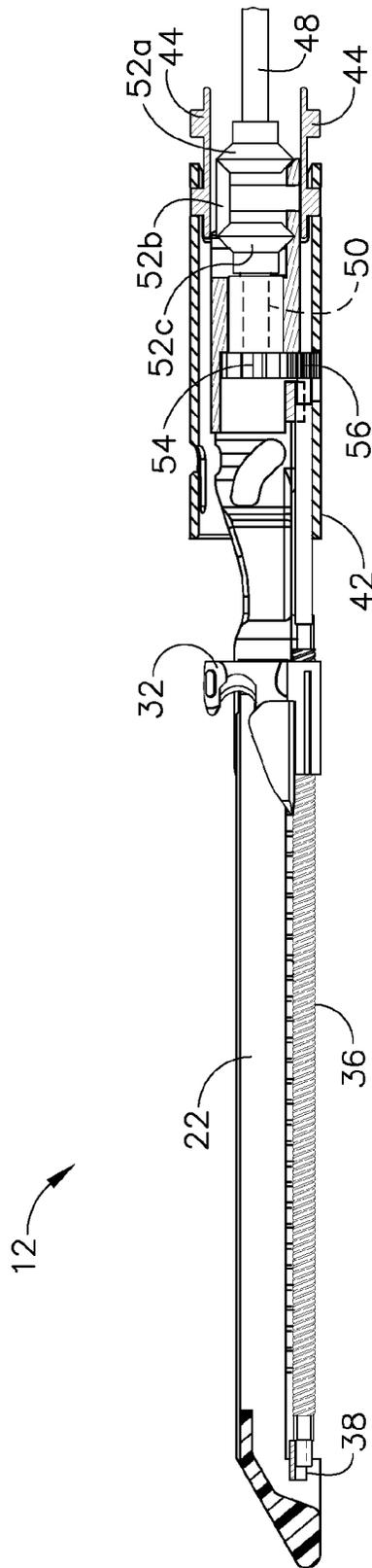


FIG. 6

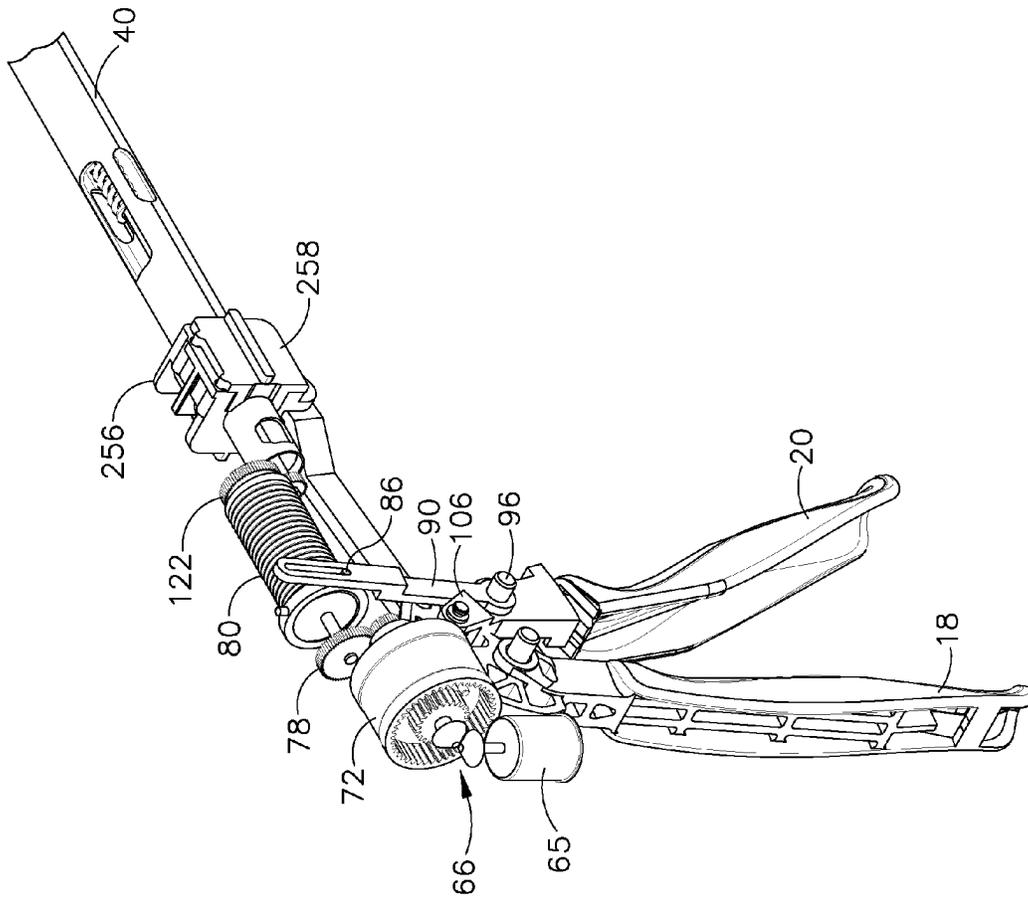


FIG. 8

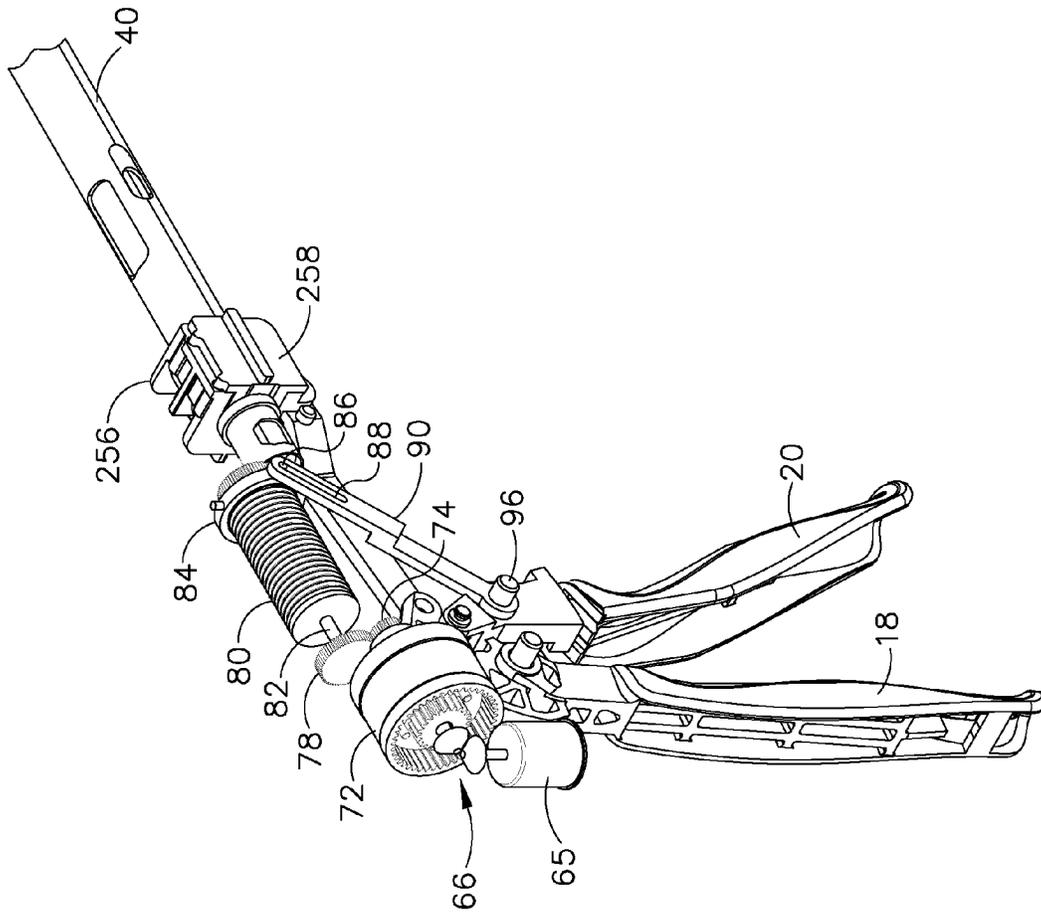


FIG. 9

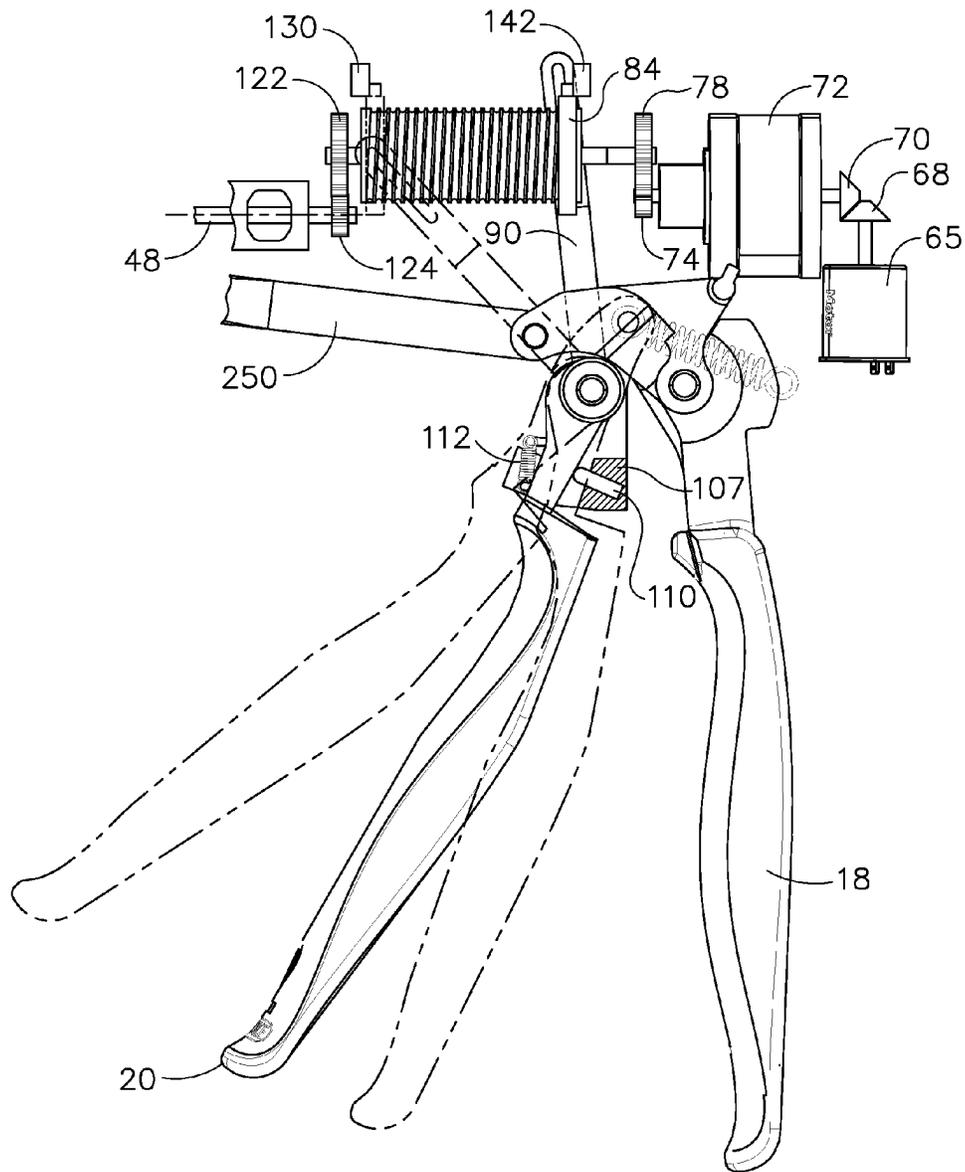


FIG. 10

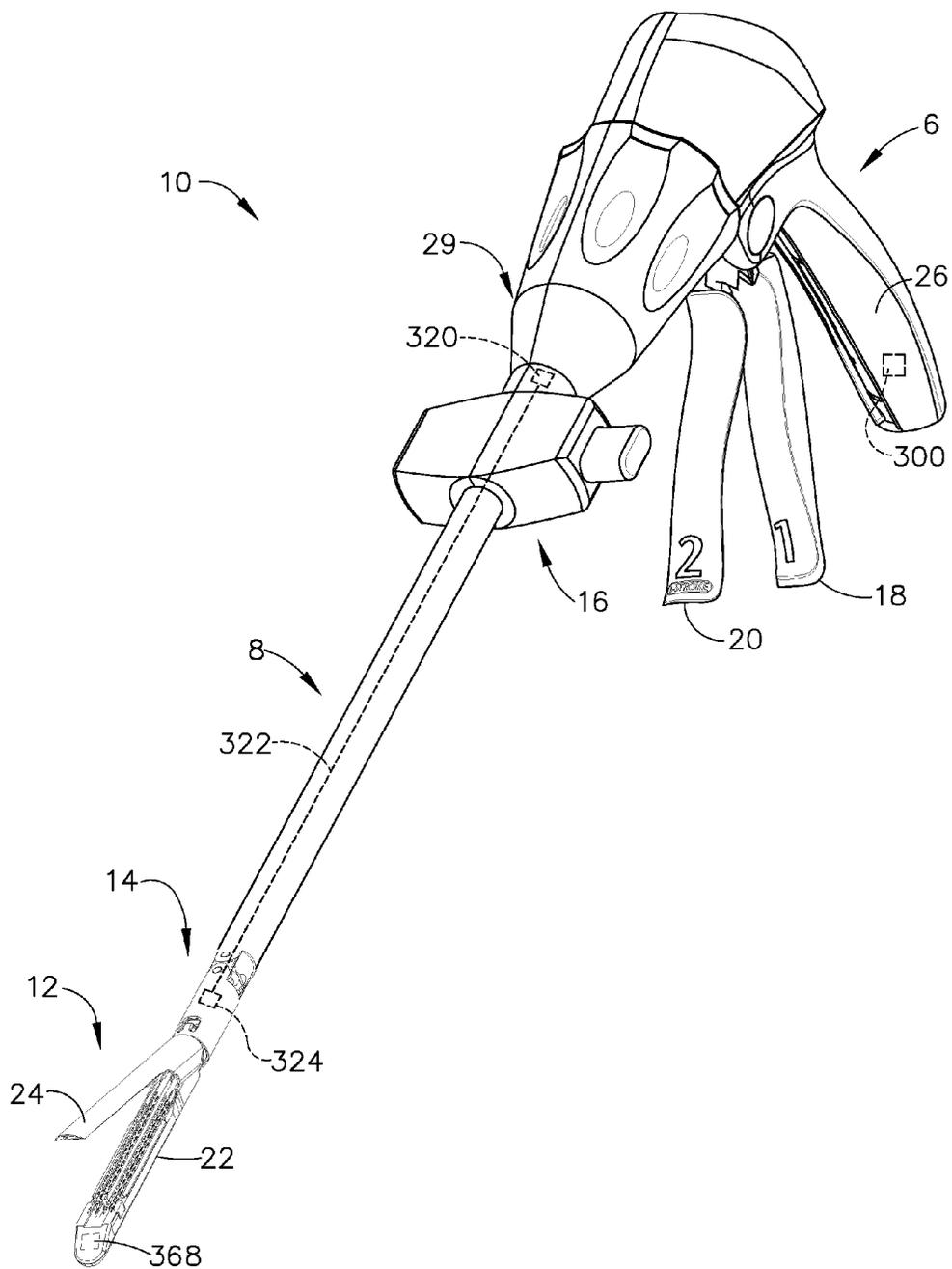


FIG. 11

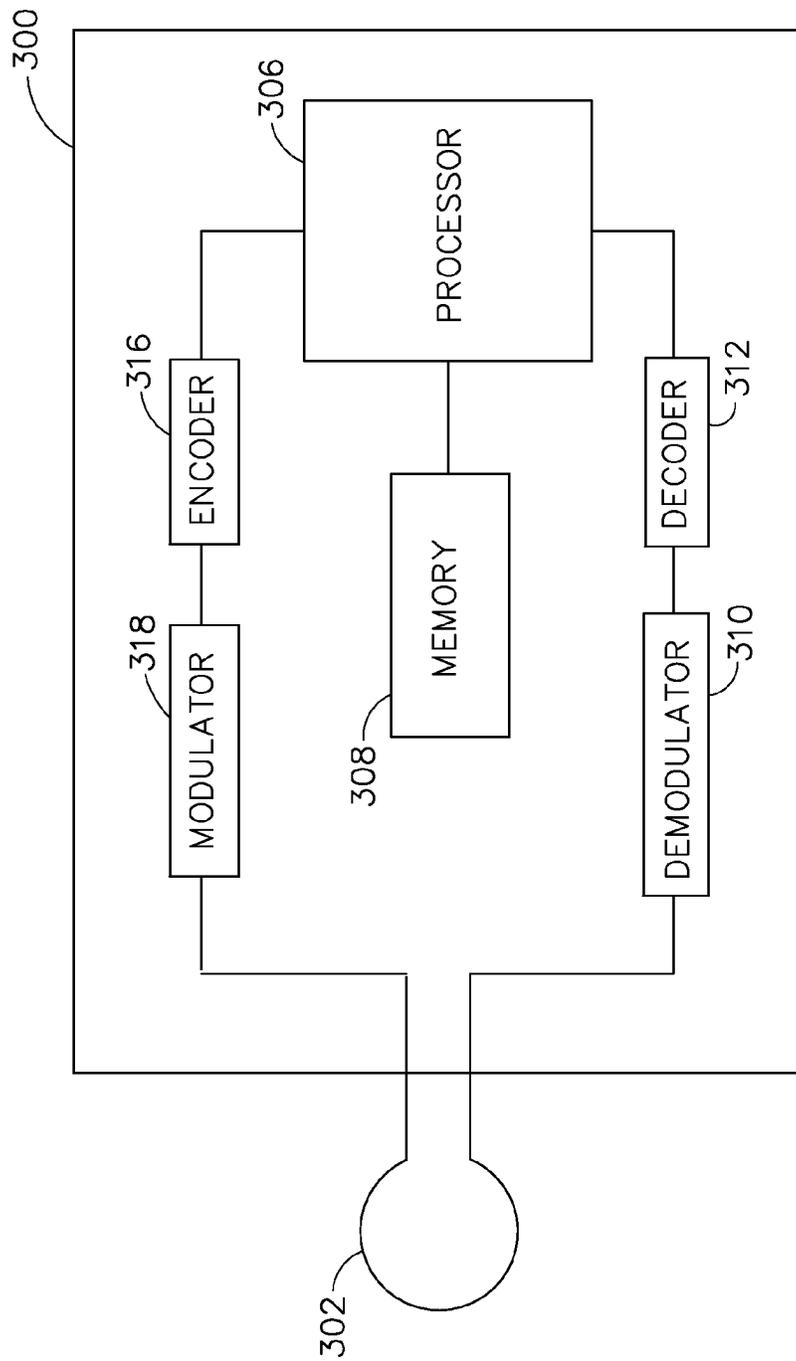


FIG. 12

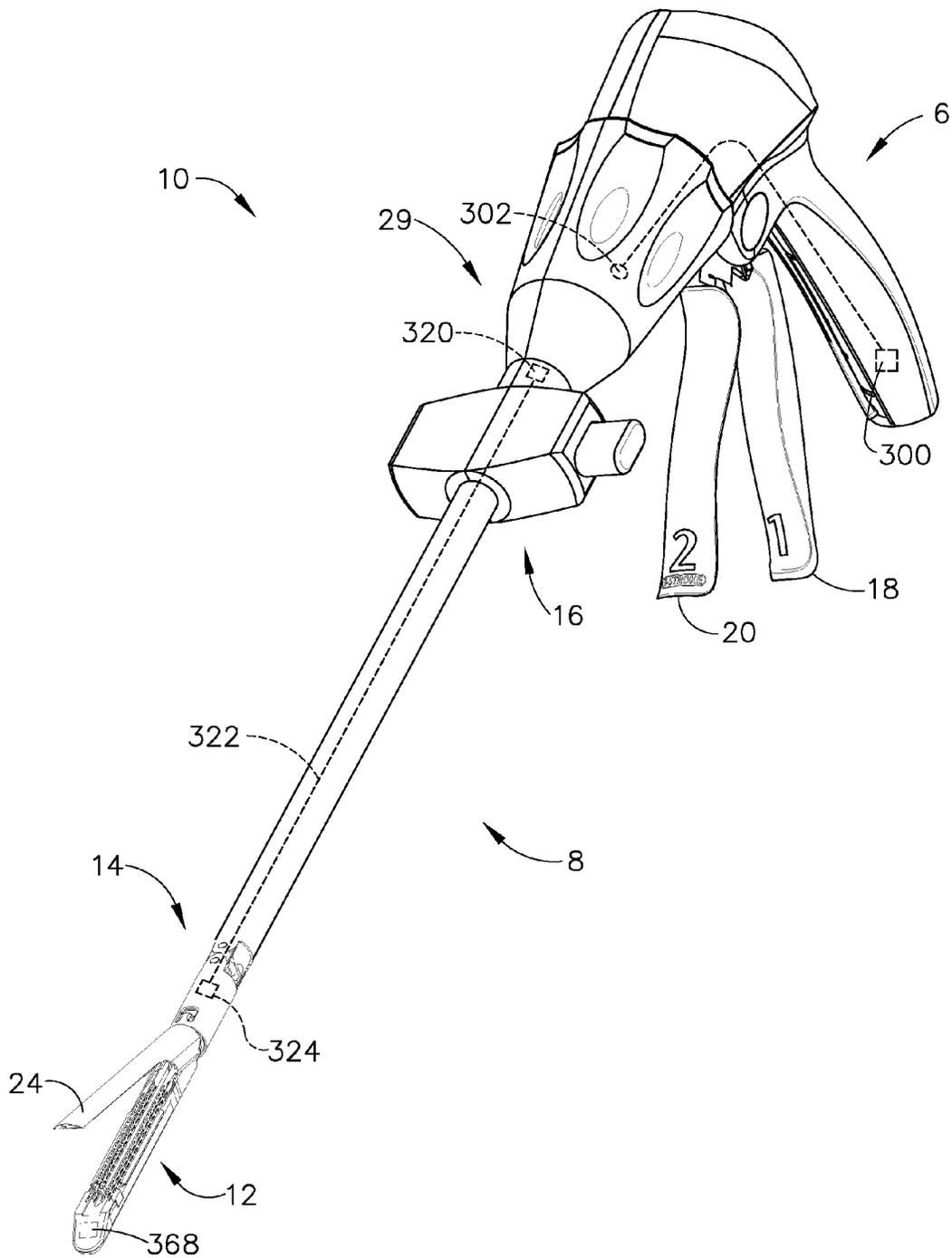


FIG. 13

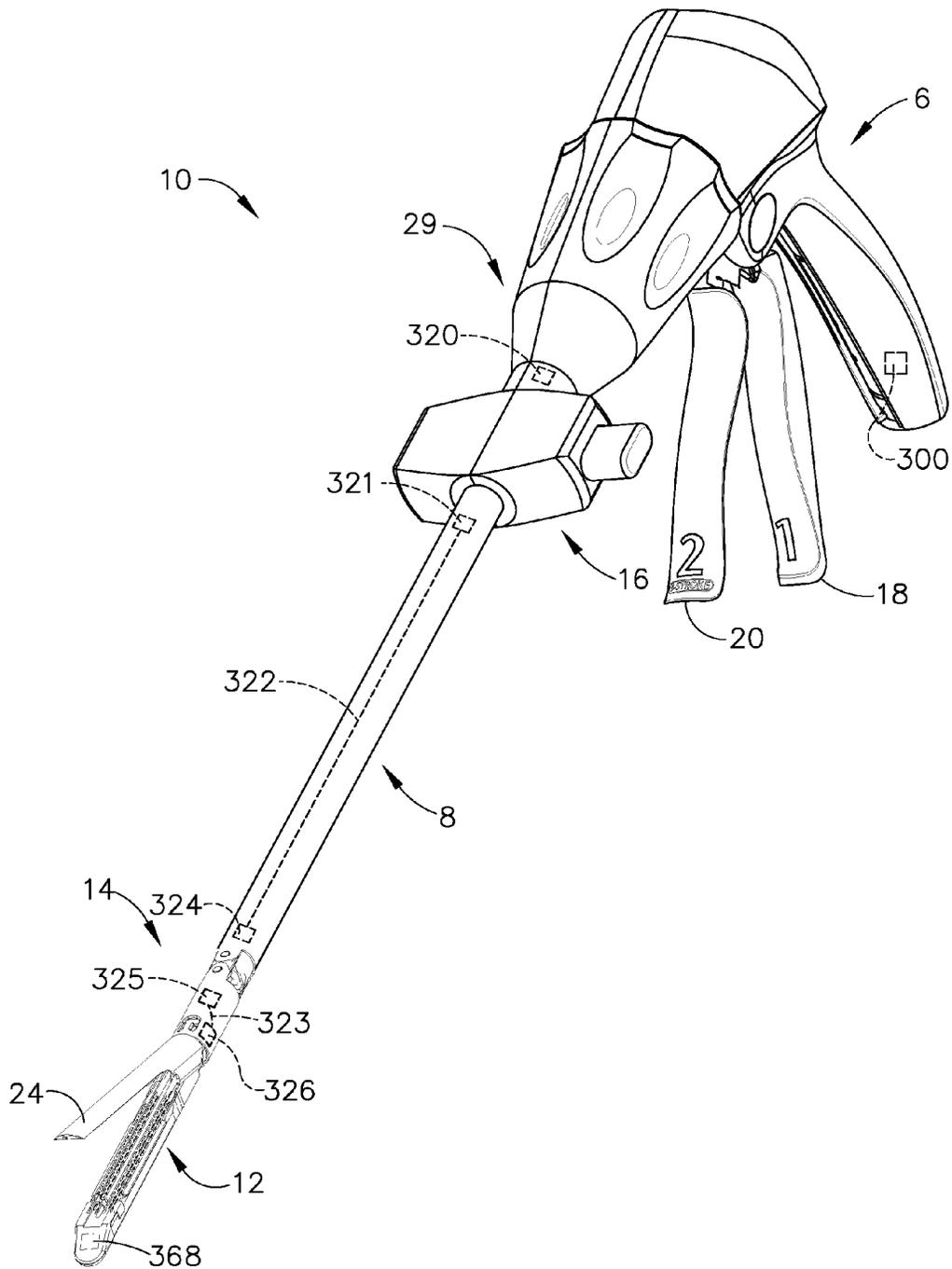


FIG. 14

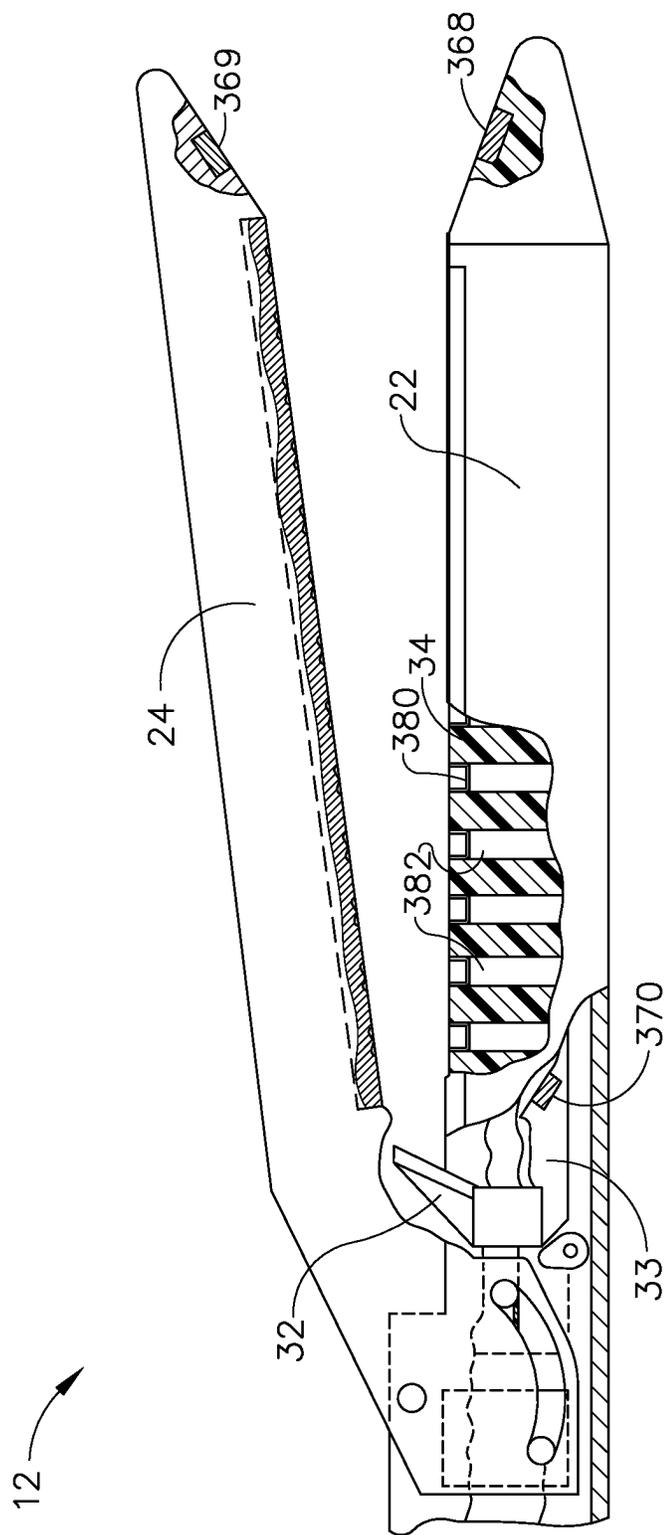


FIG. 15

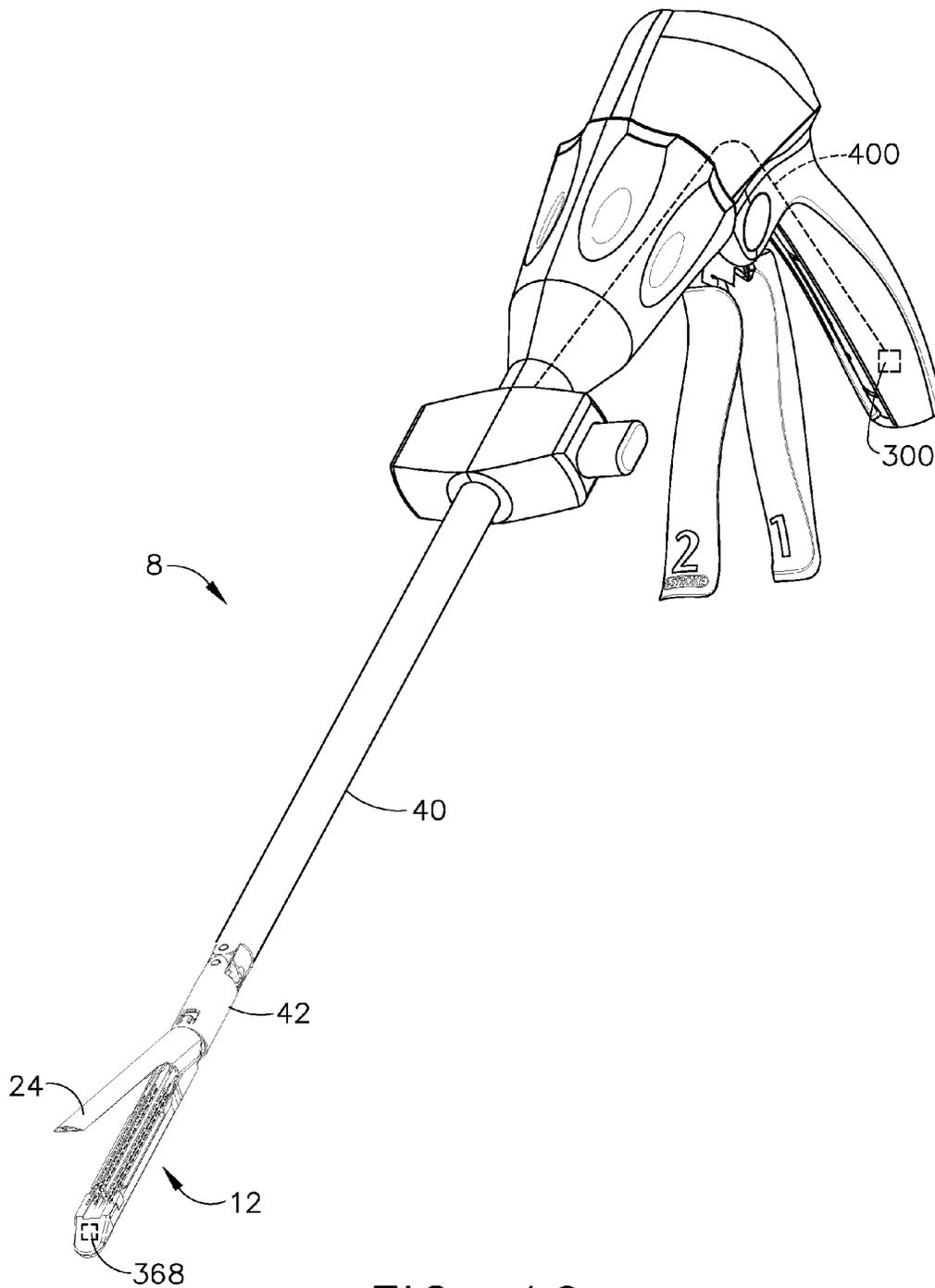


FIG. 16

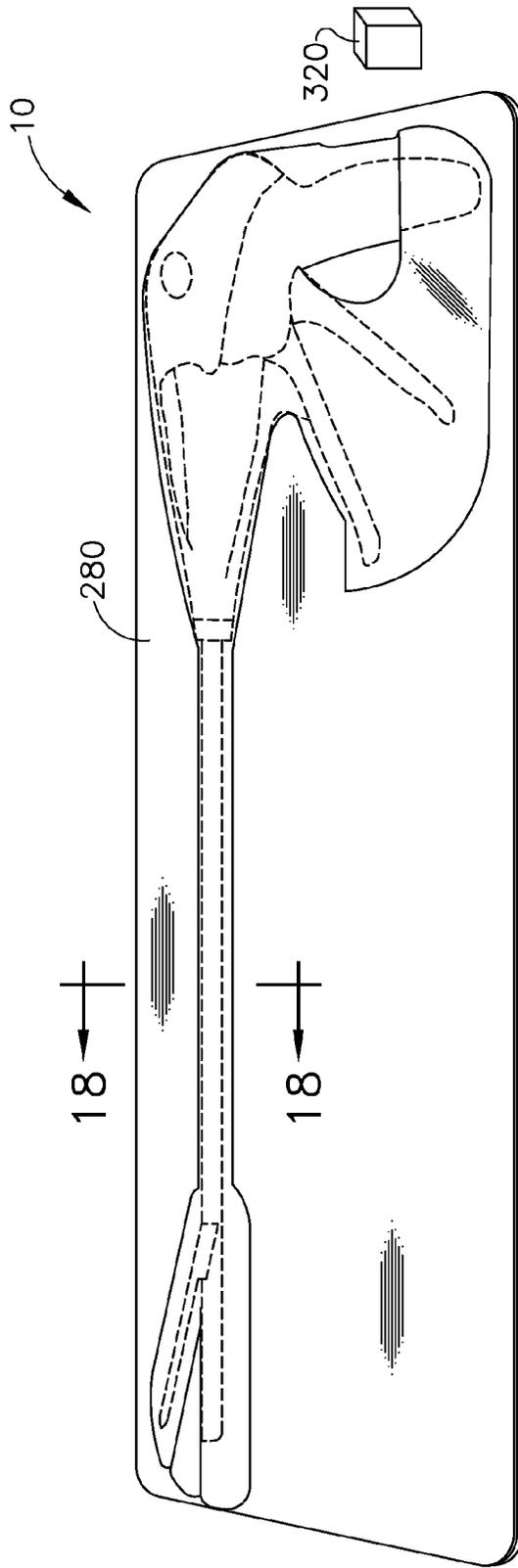


FIG. 17



FIG. 18

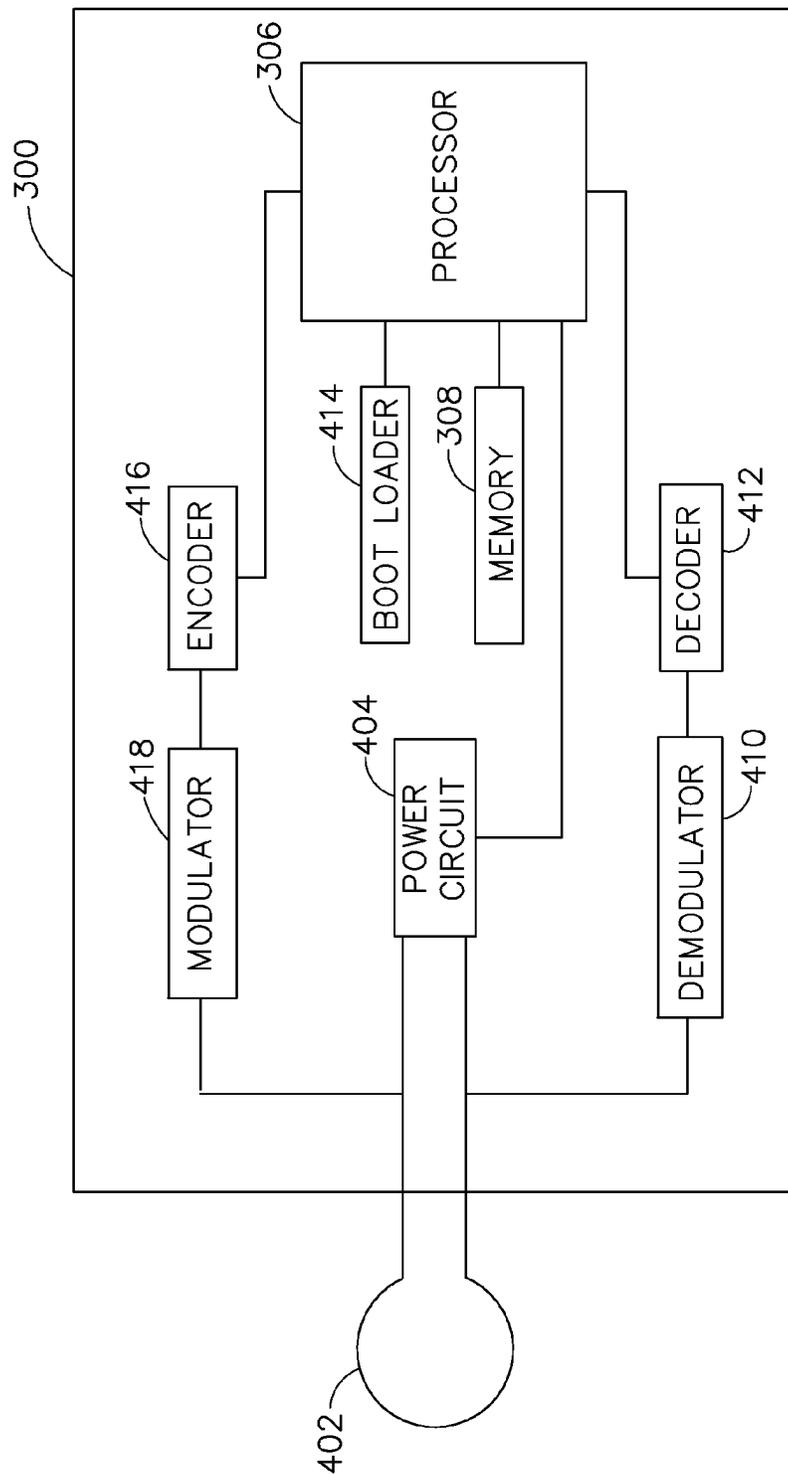


FIG. 19

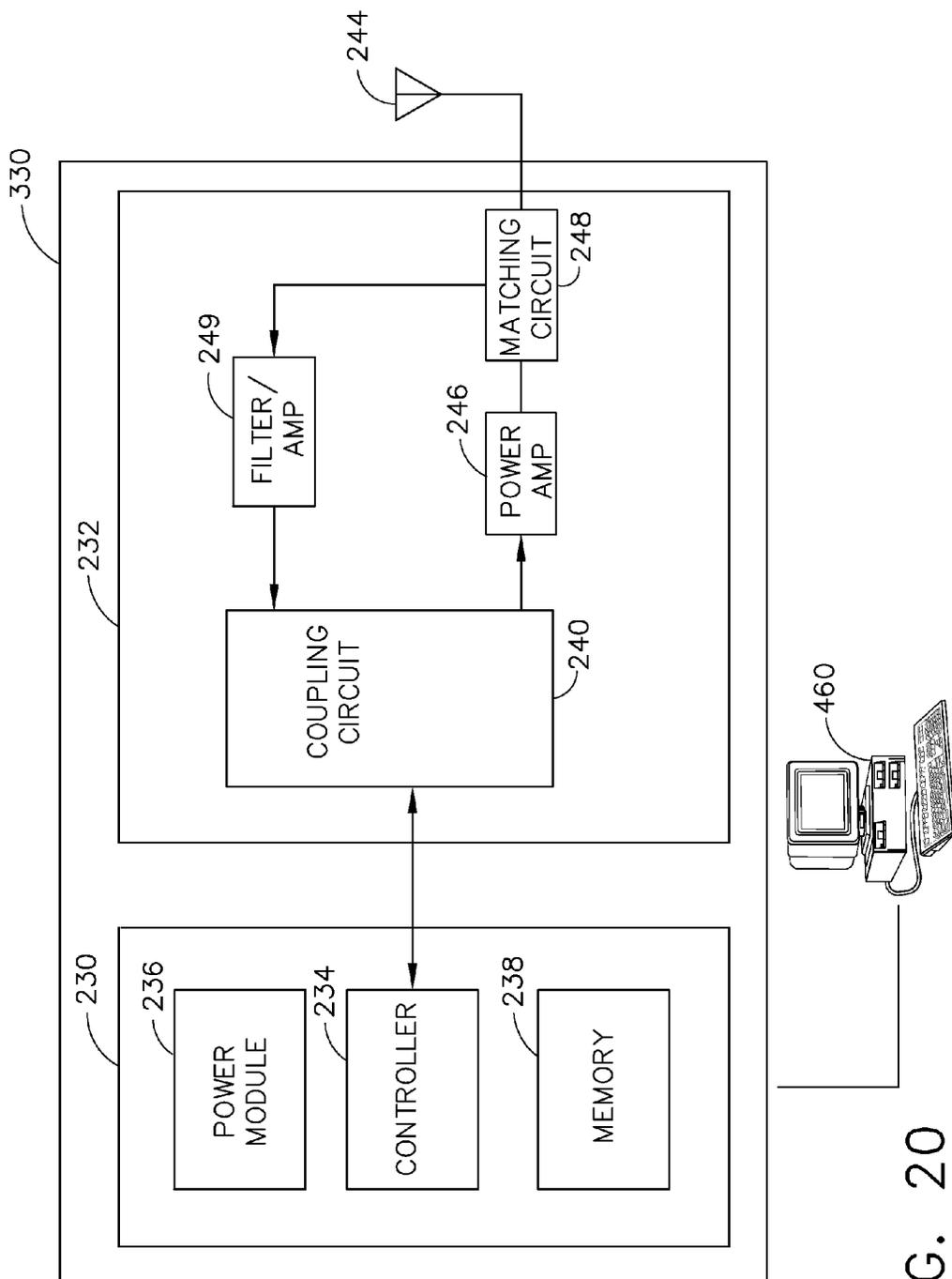


FIG. 20

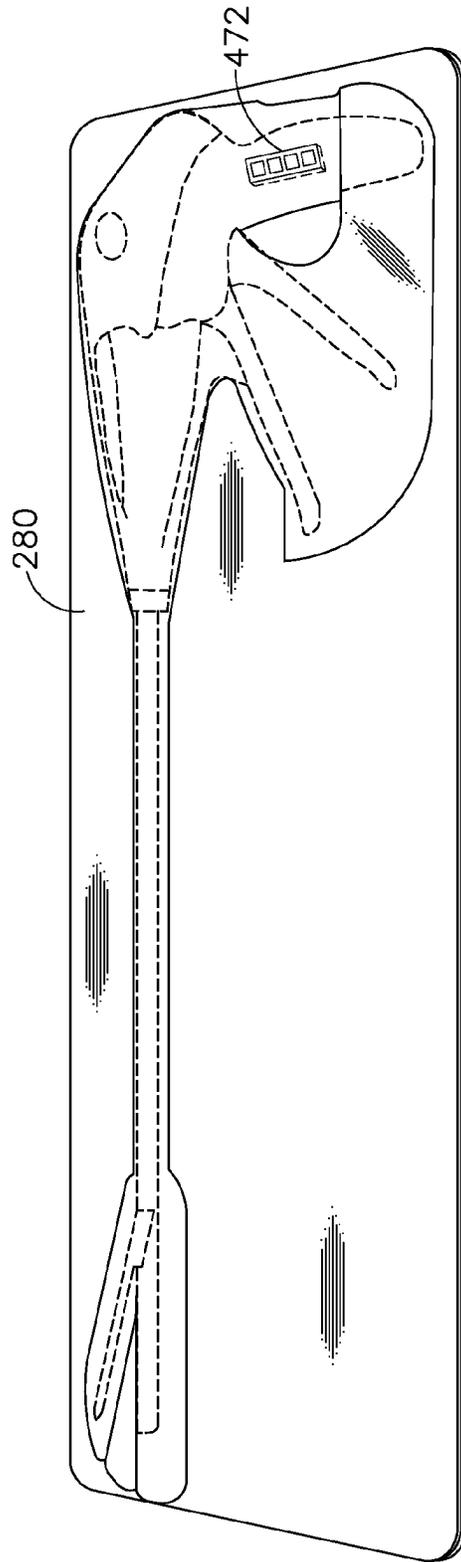


FIG. 21

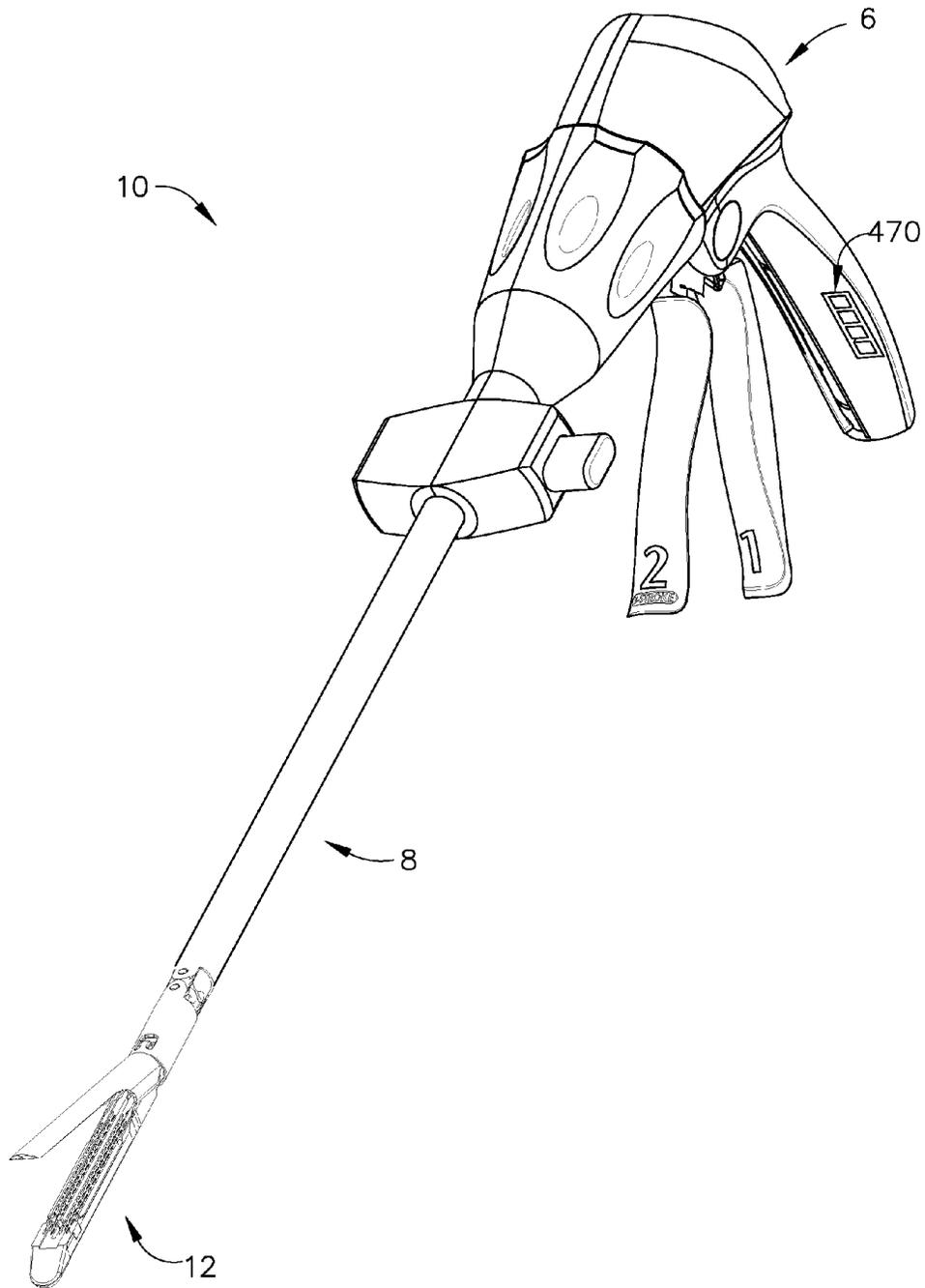


FIG. 22

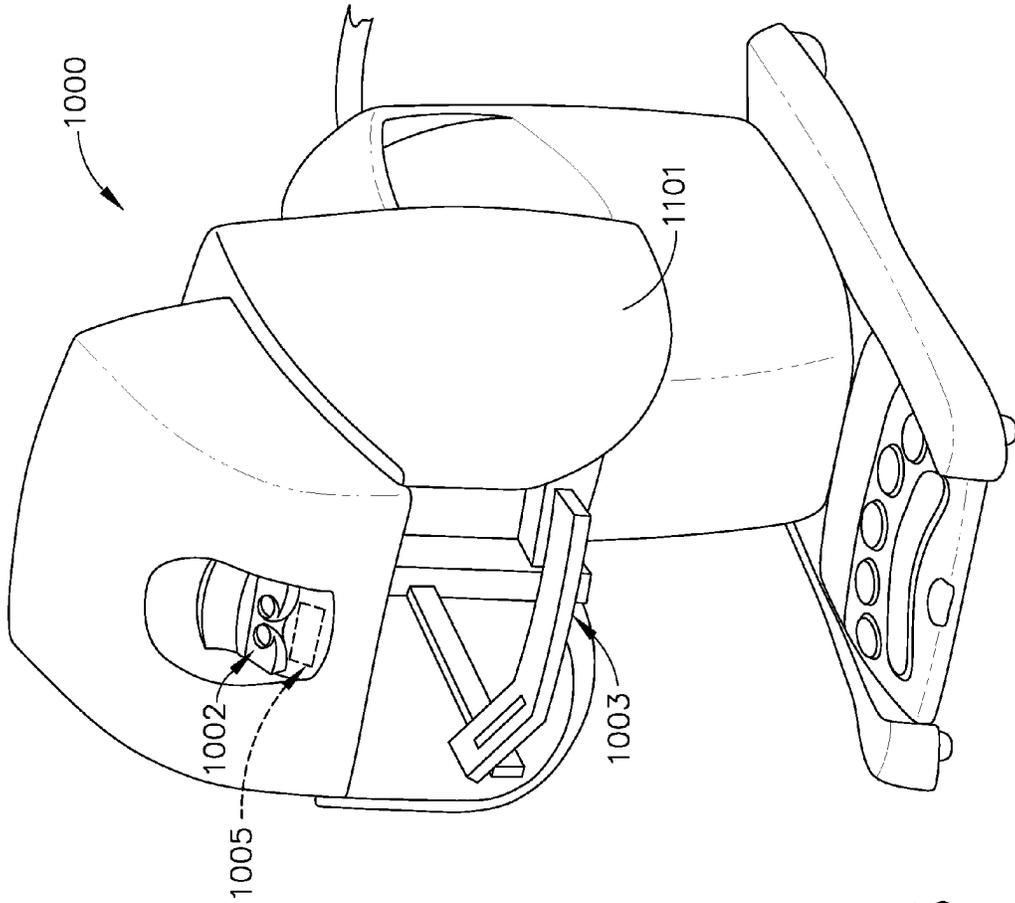


FIG. 23

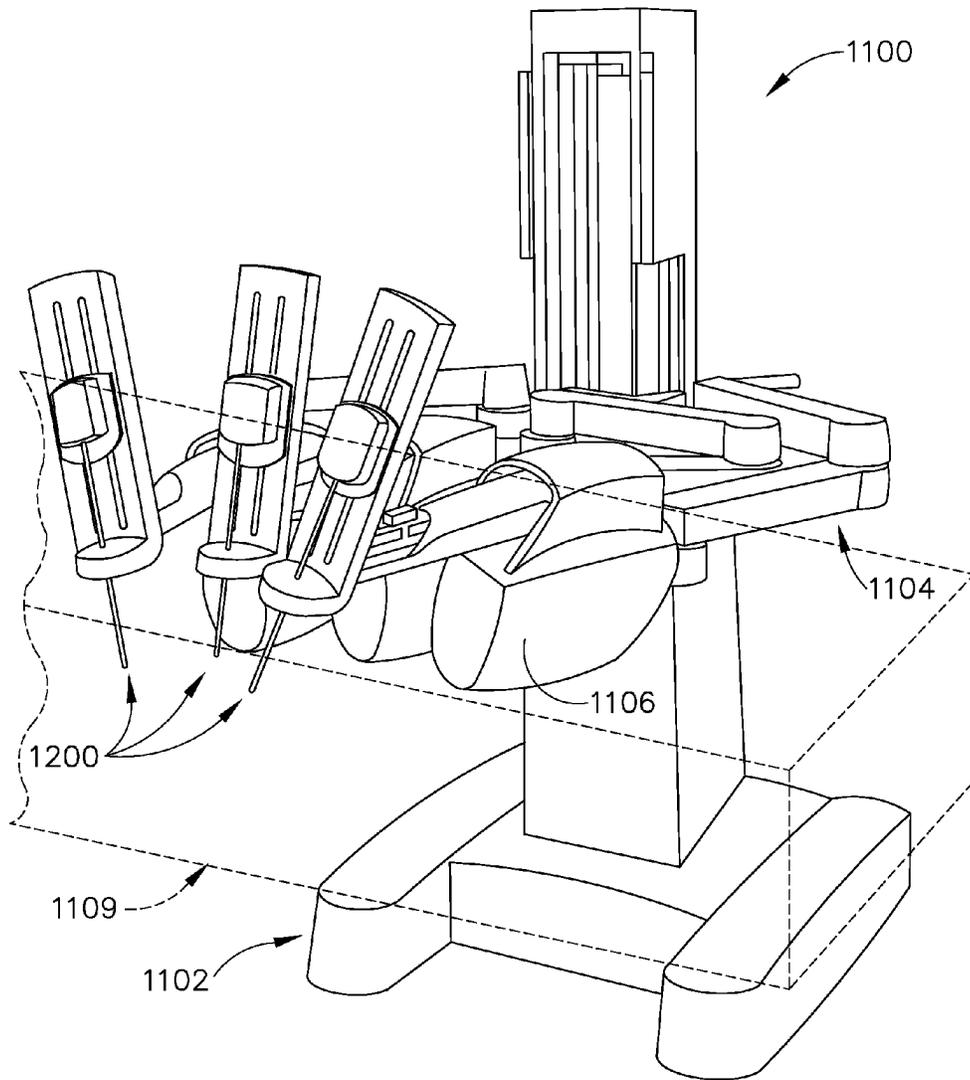


FIG. 23A

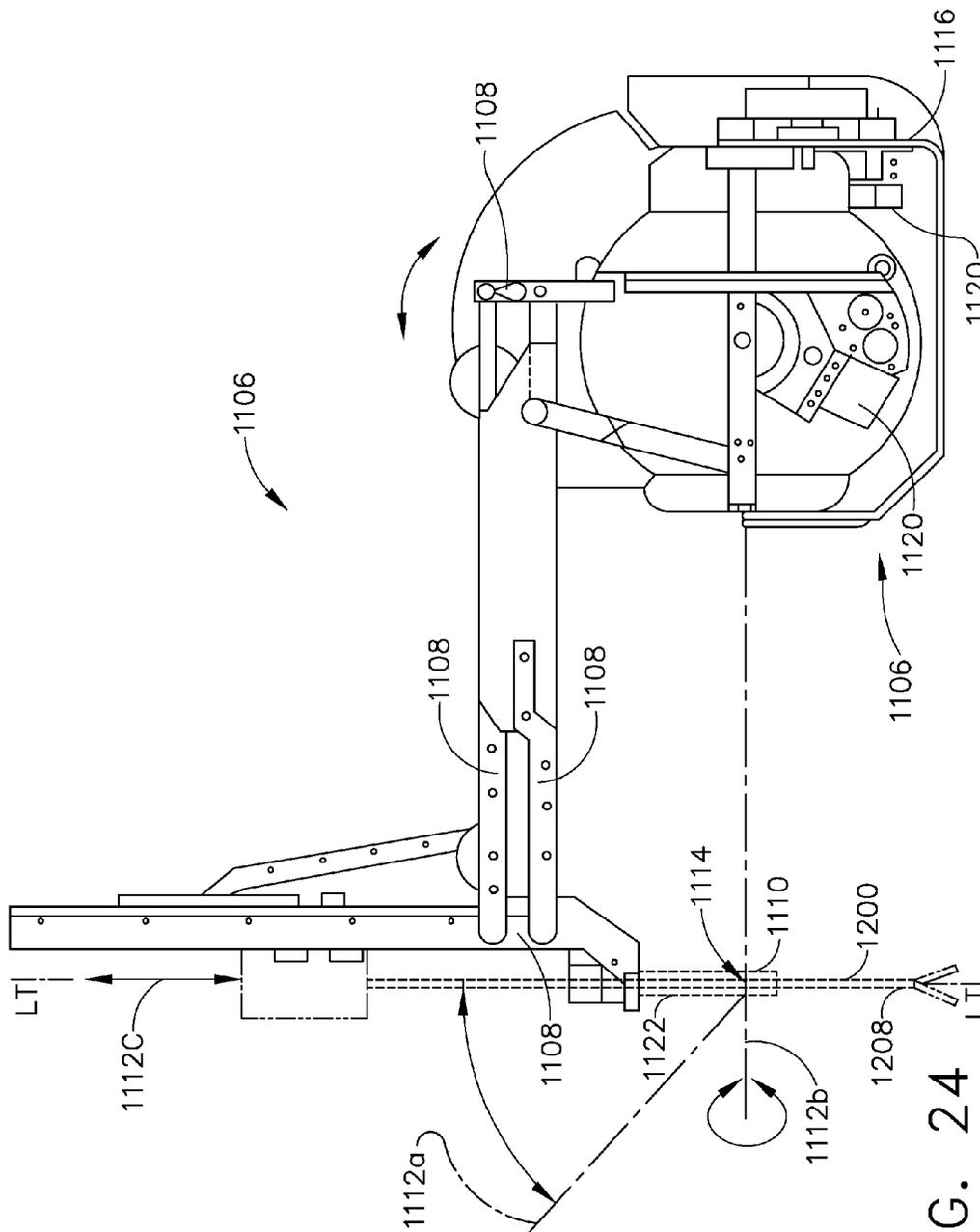


FIG. 24

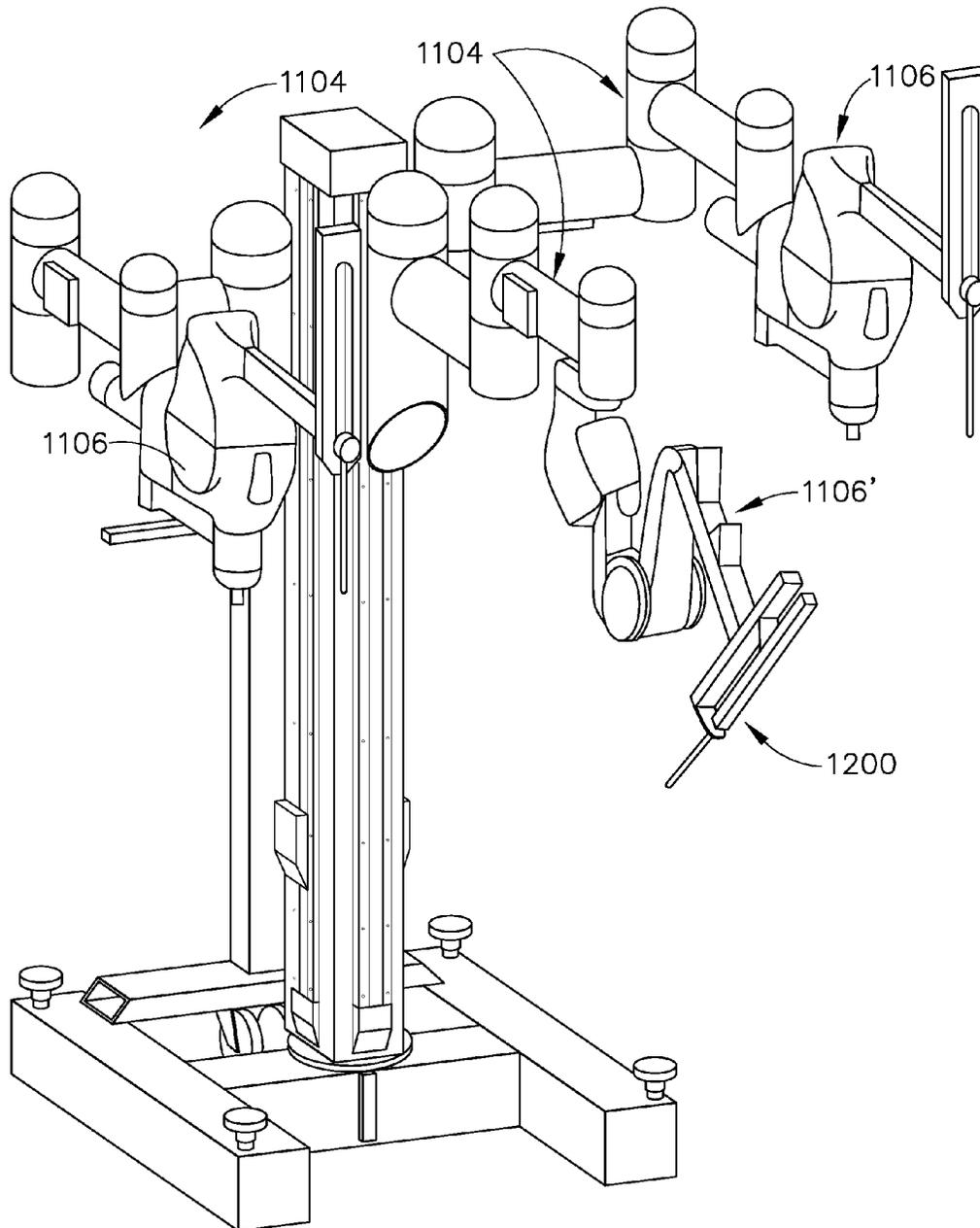


FIG. 25

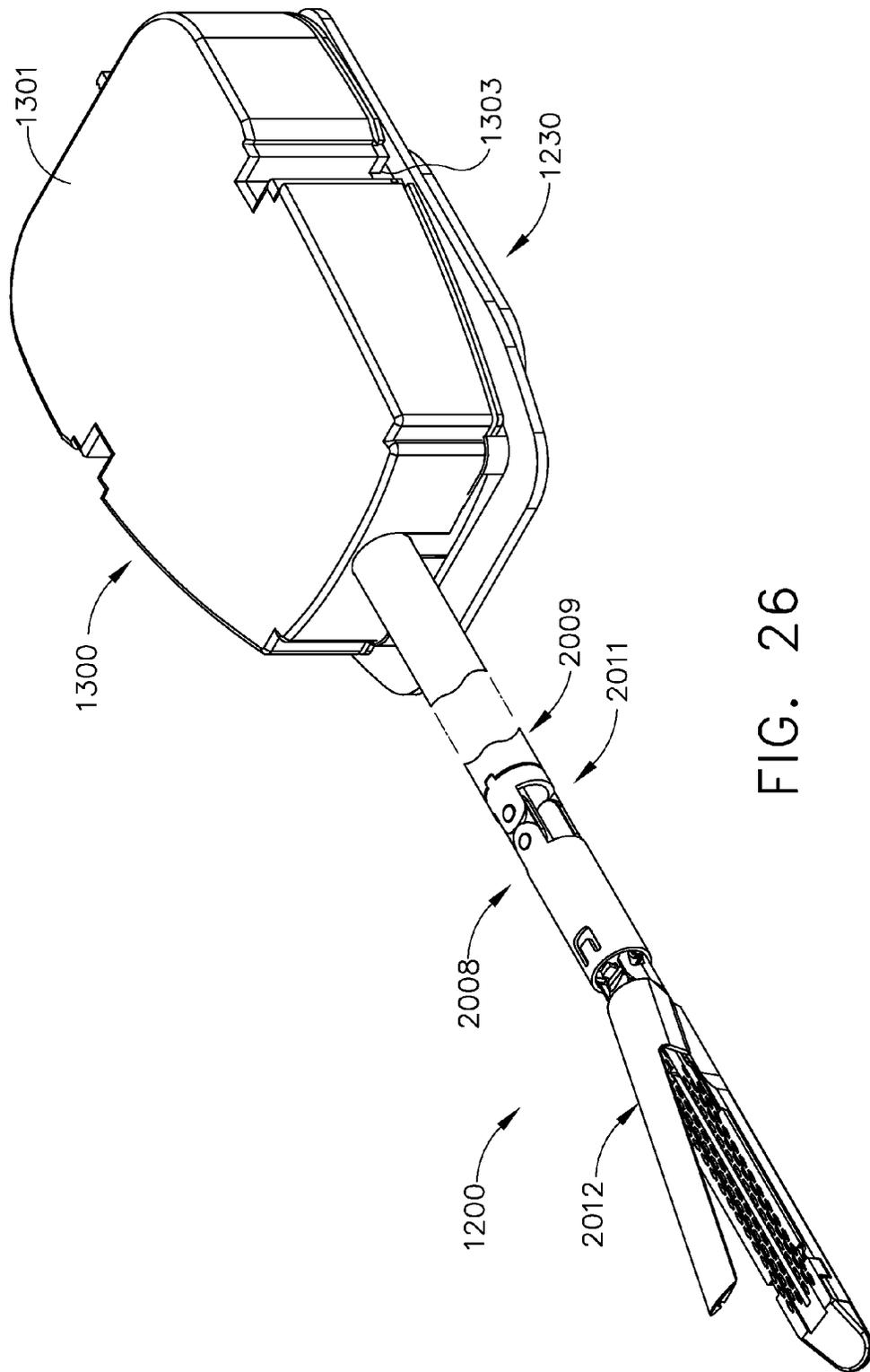


FIG. 26

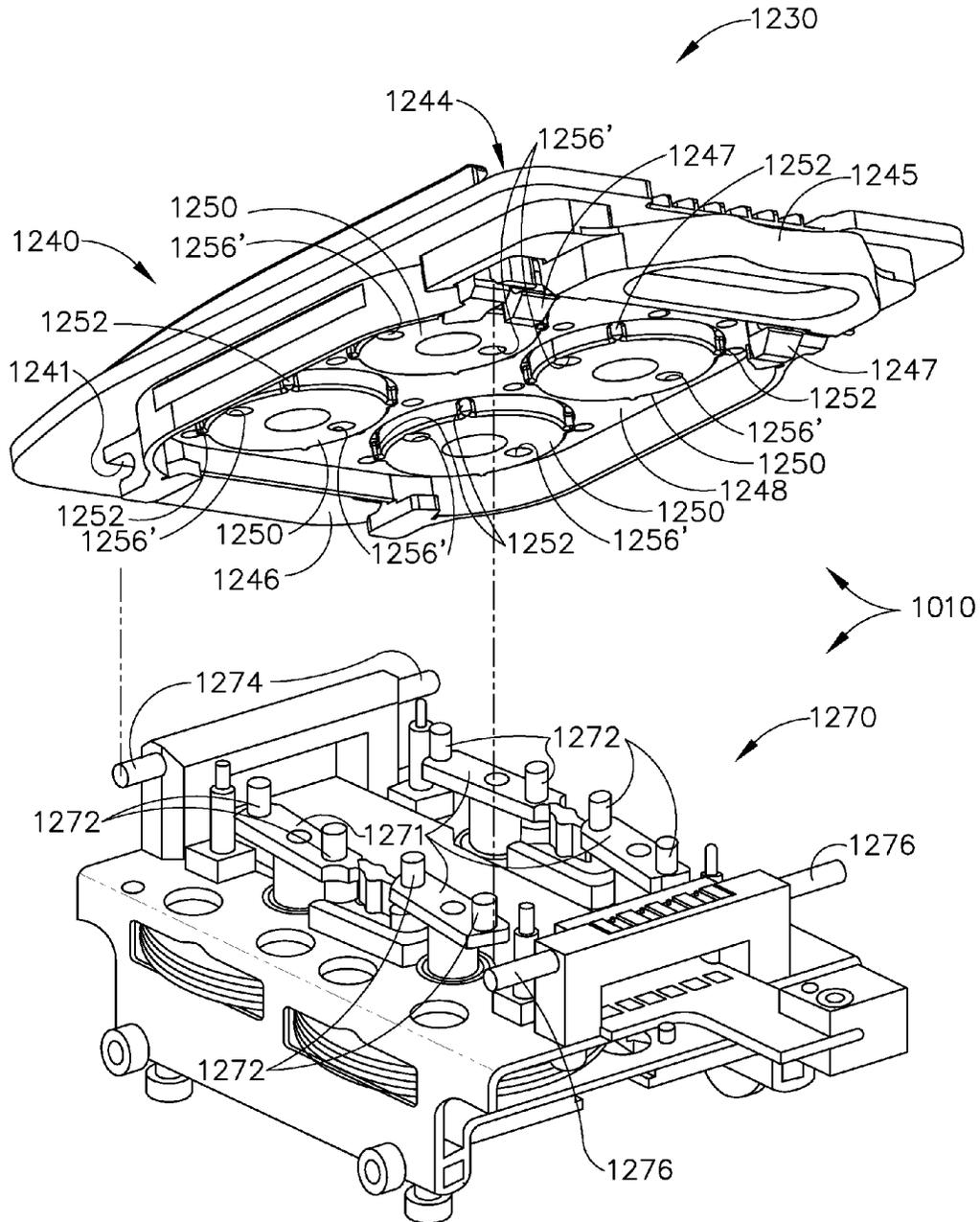


FIG. 27

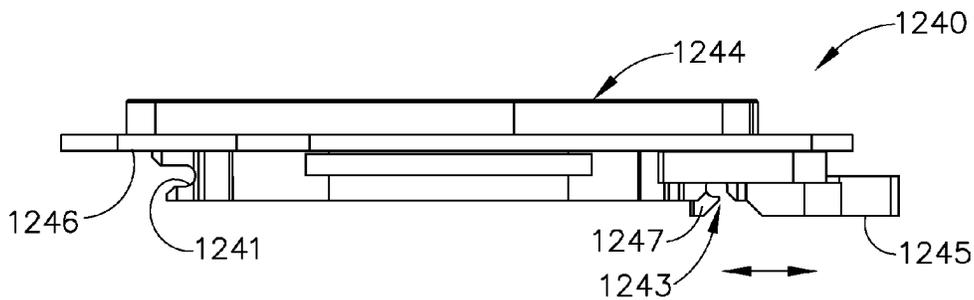


FIG. 28

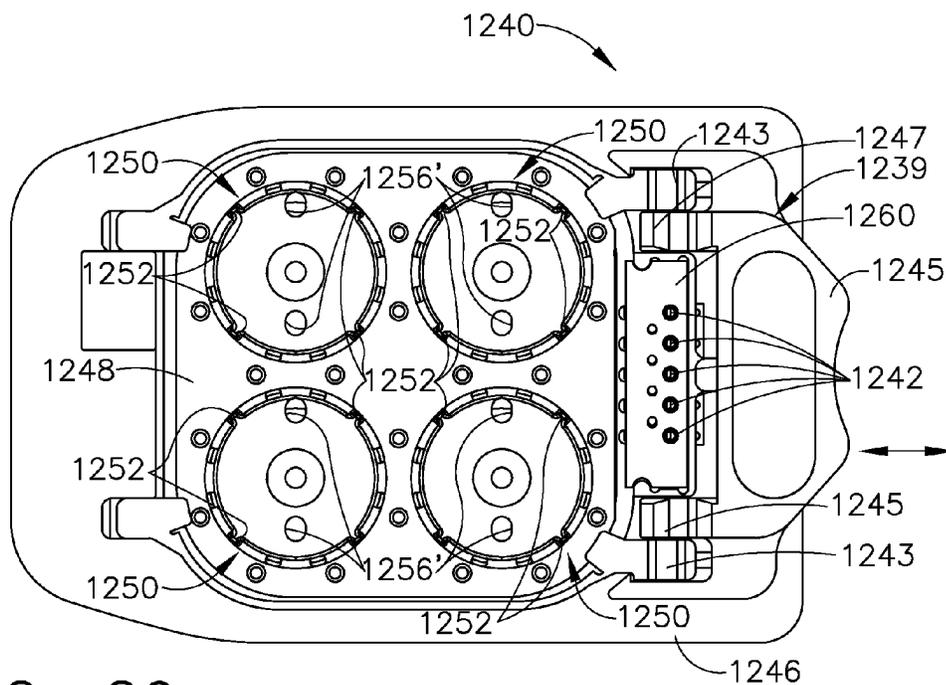


FIG. 29

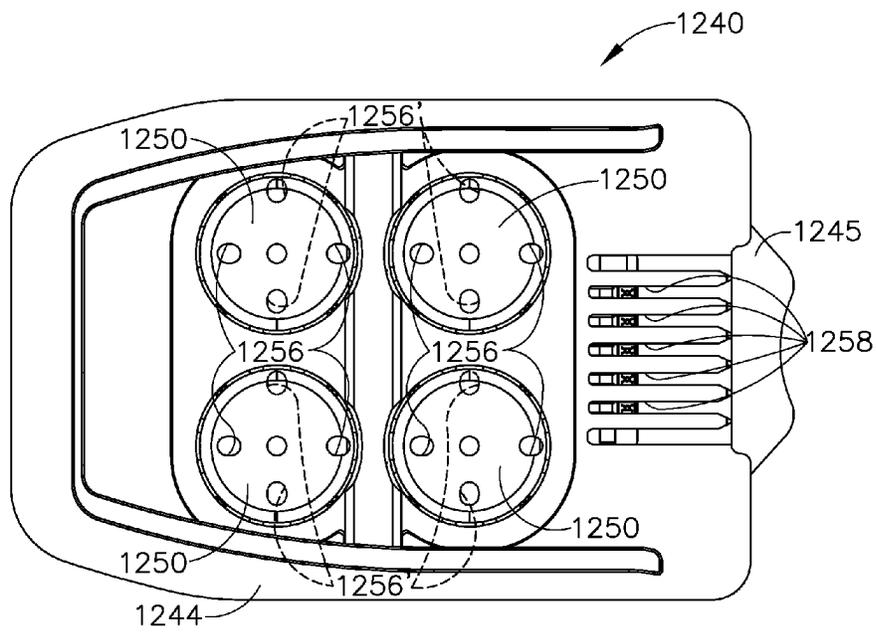


FIG. 30

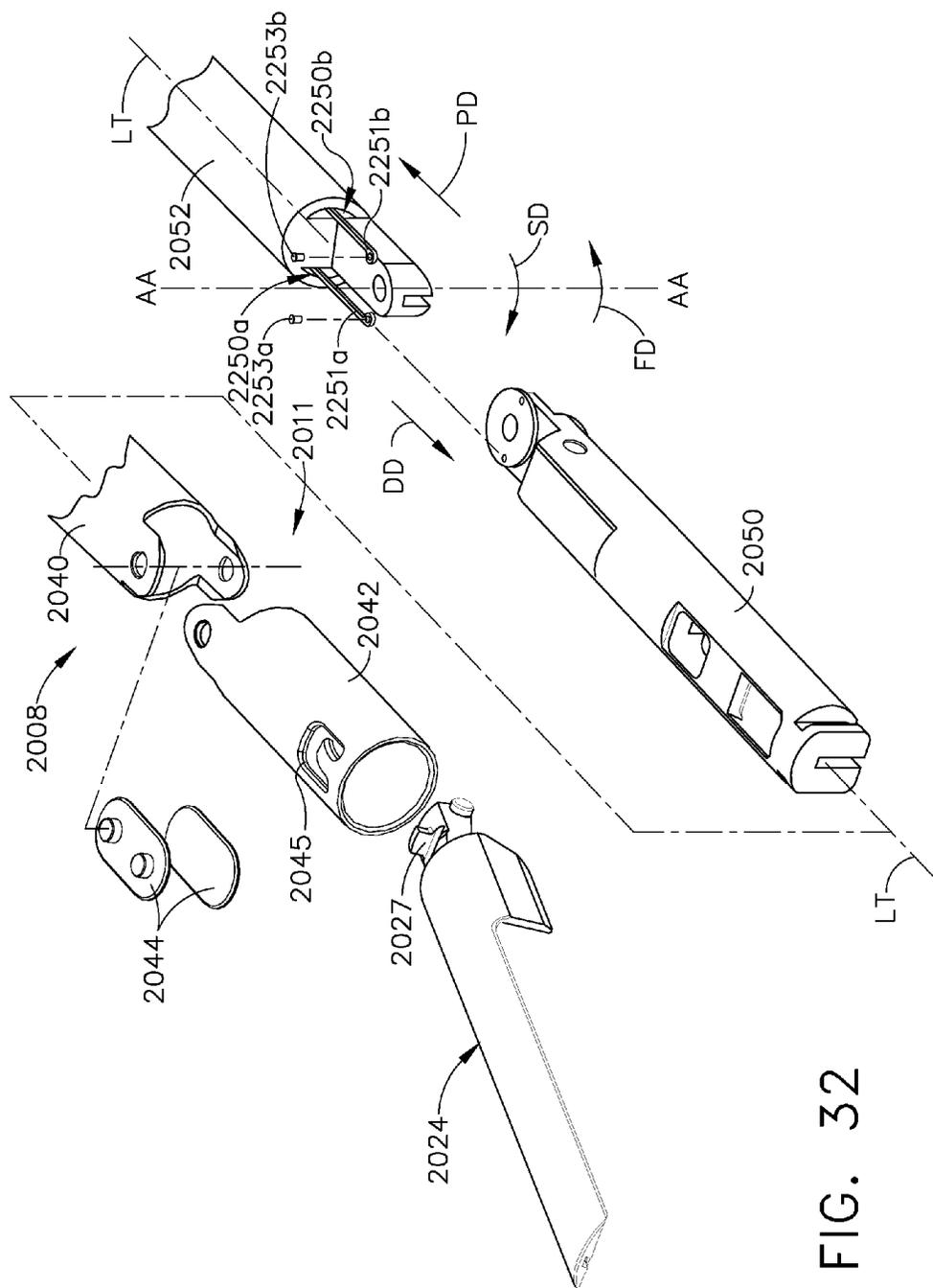


FIG. 32

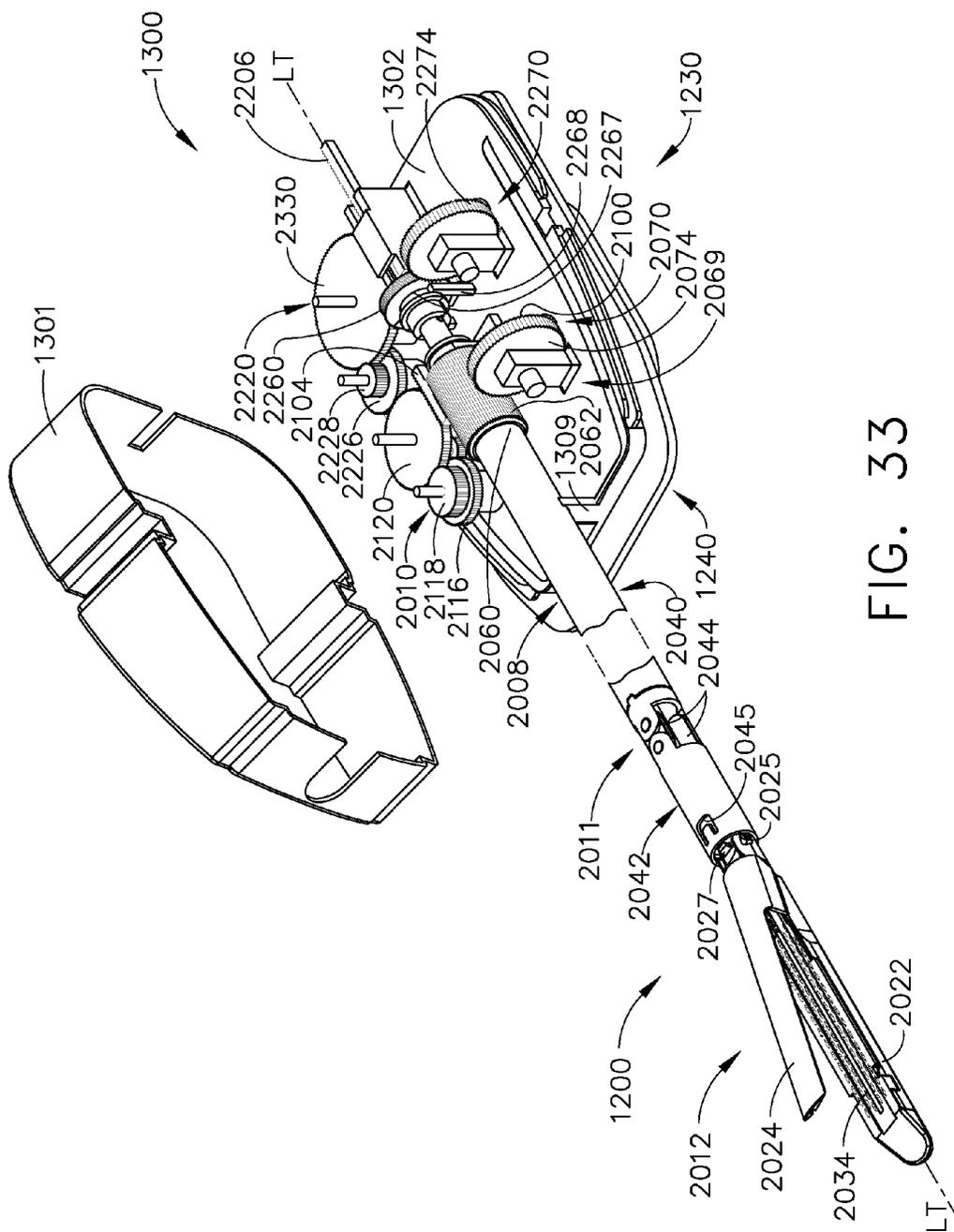


FIG. 33

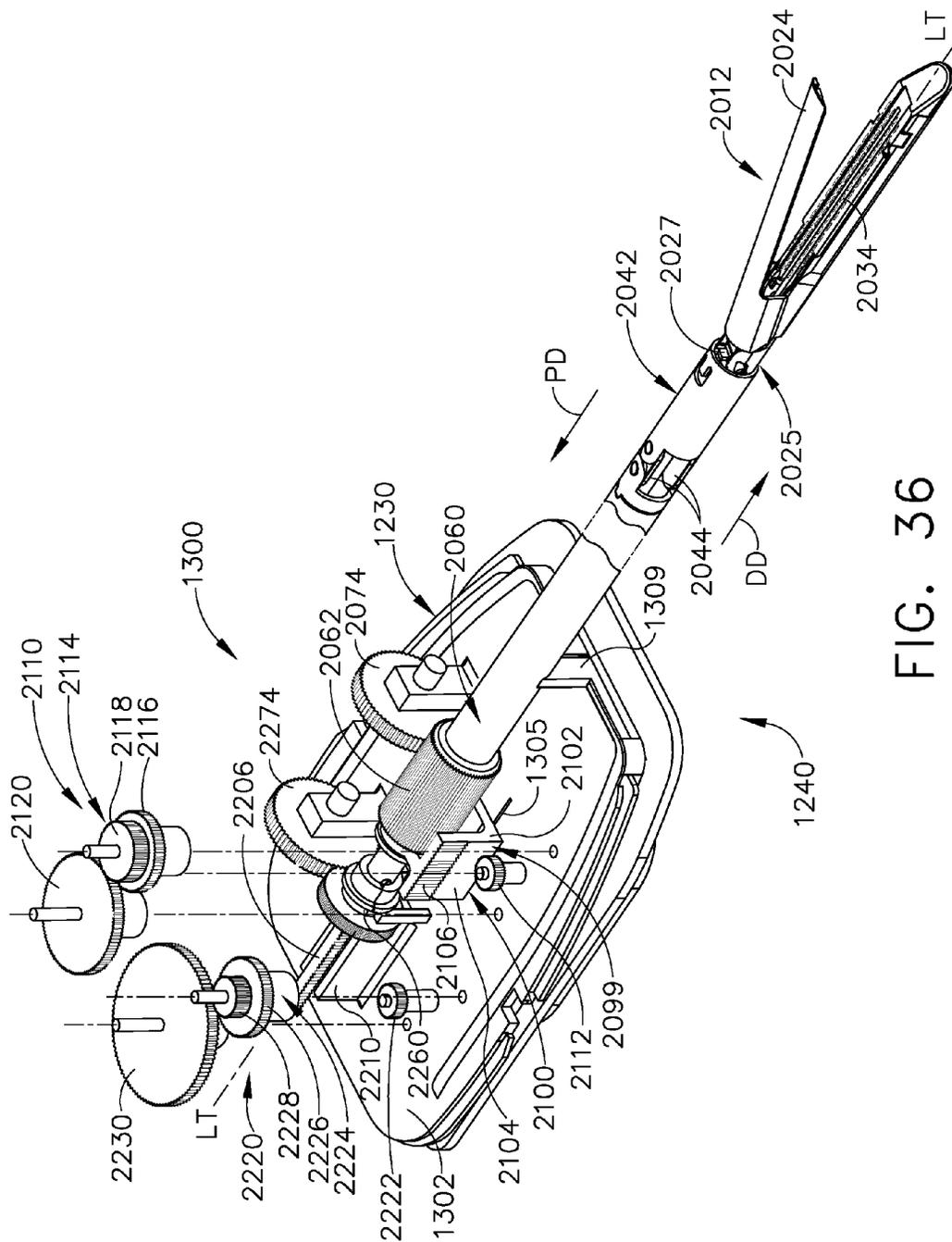


FIG. 36

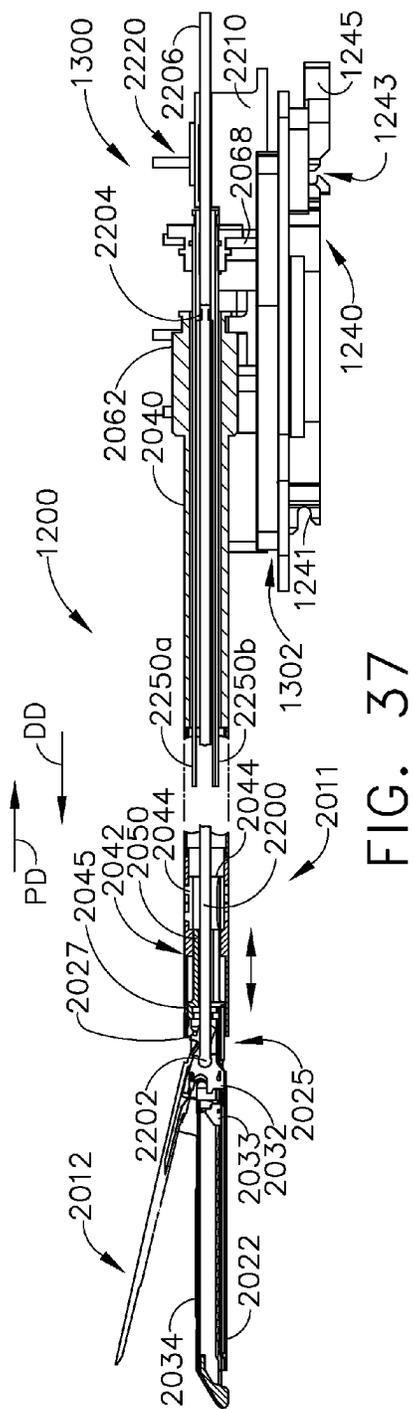


FIG. 37

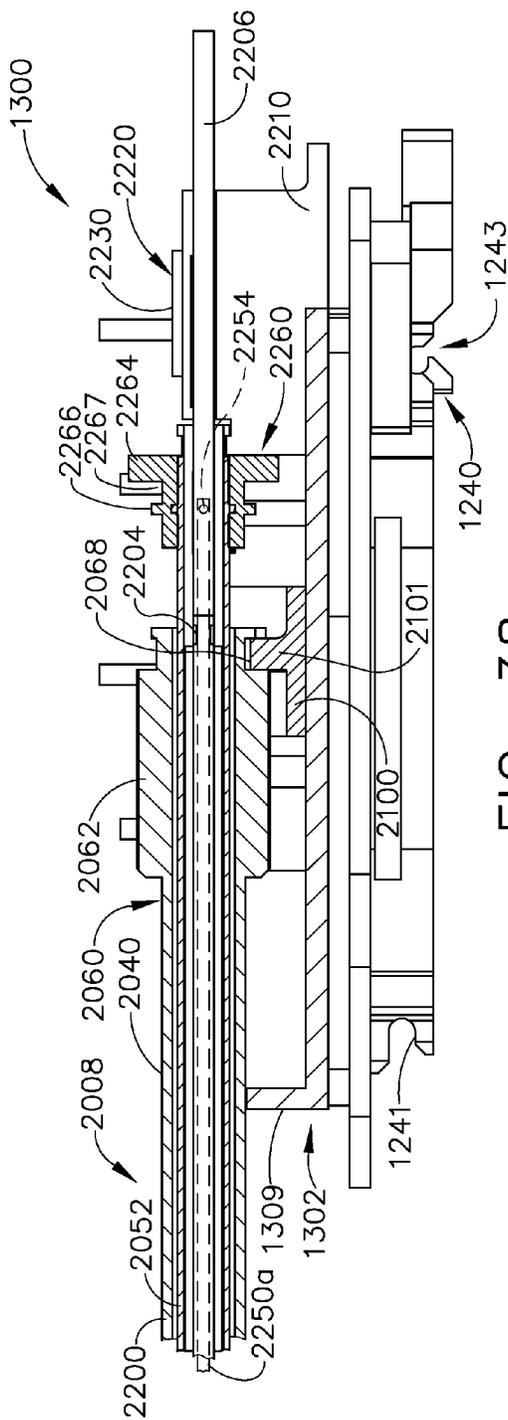


FIG. 38

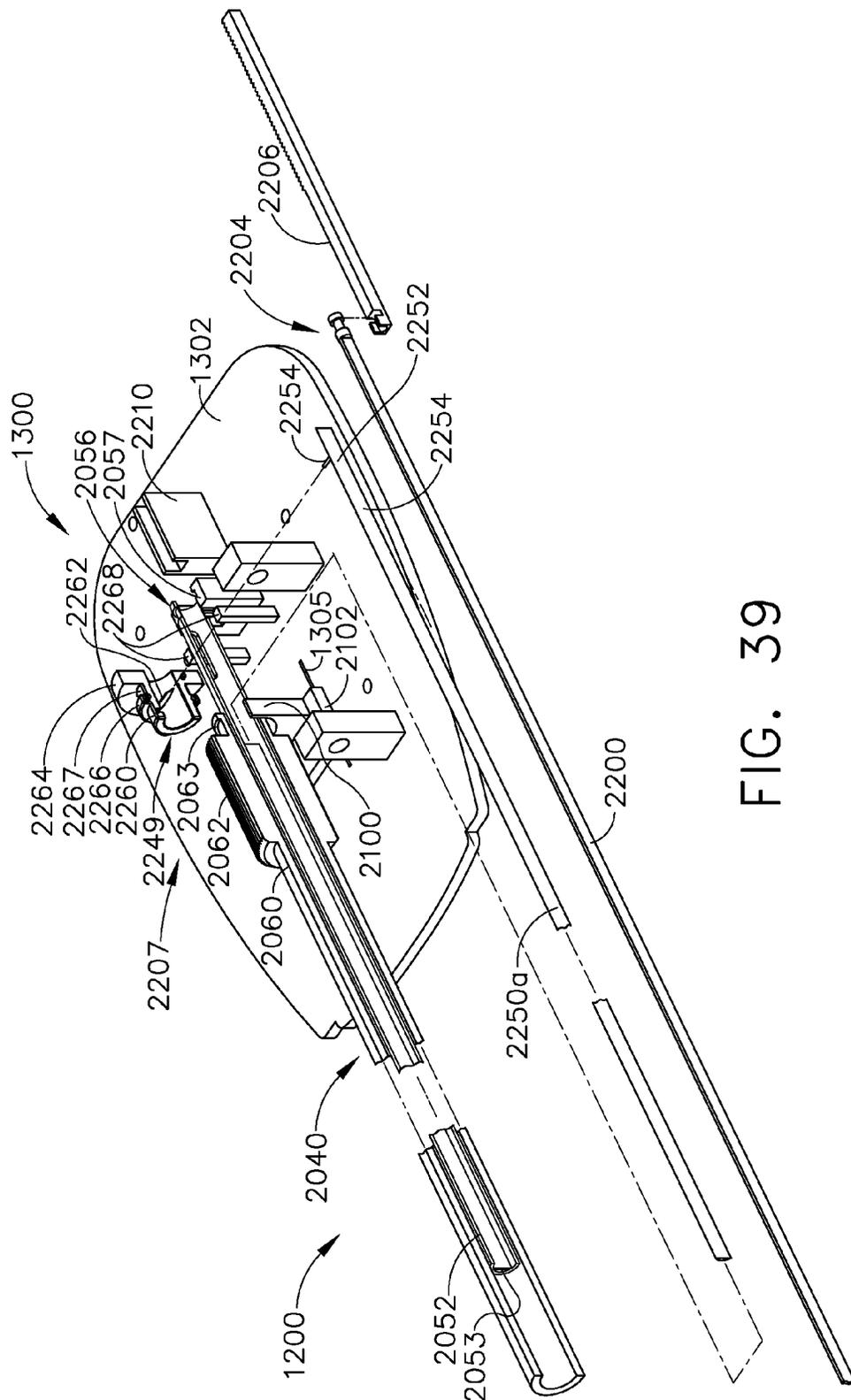


FIG. 39

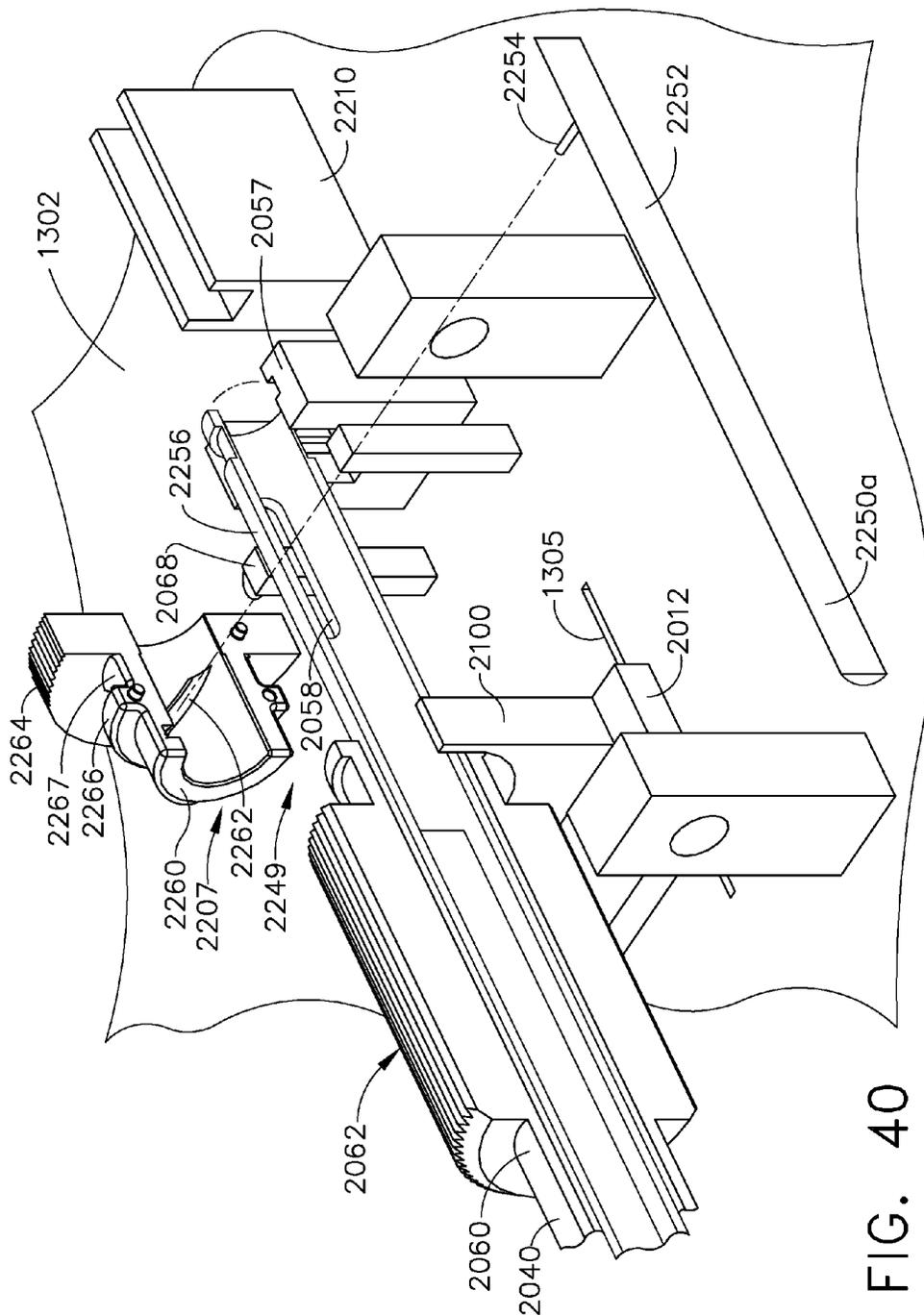


FIG. 40

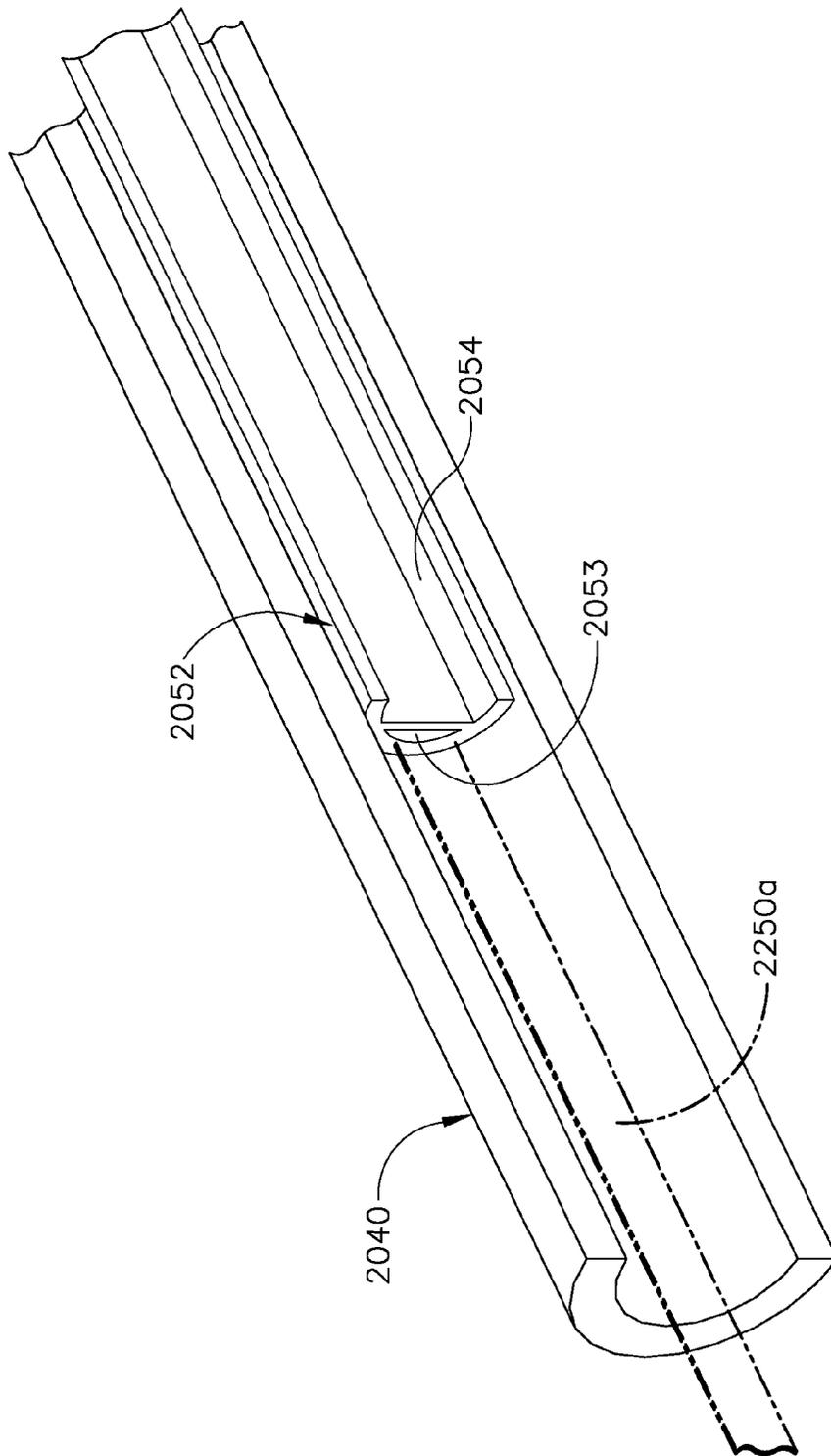


FIG. 41

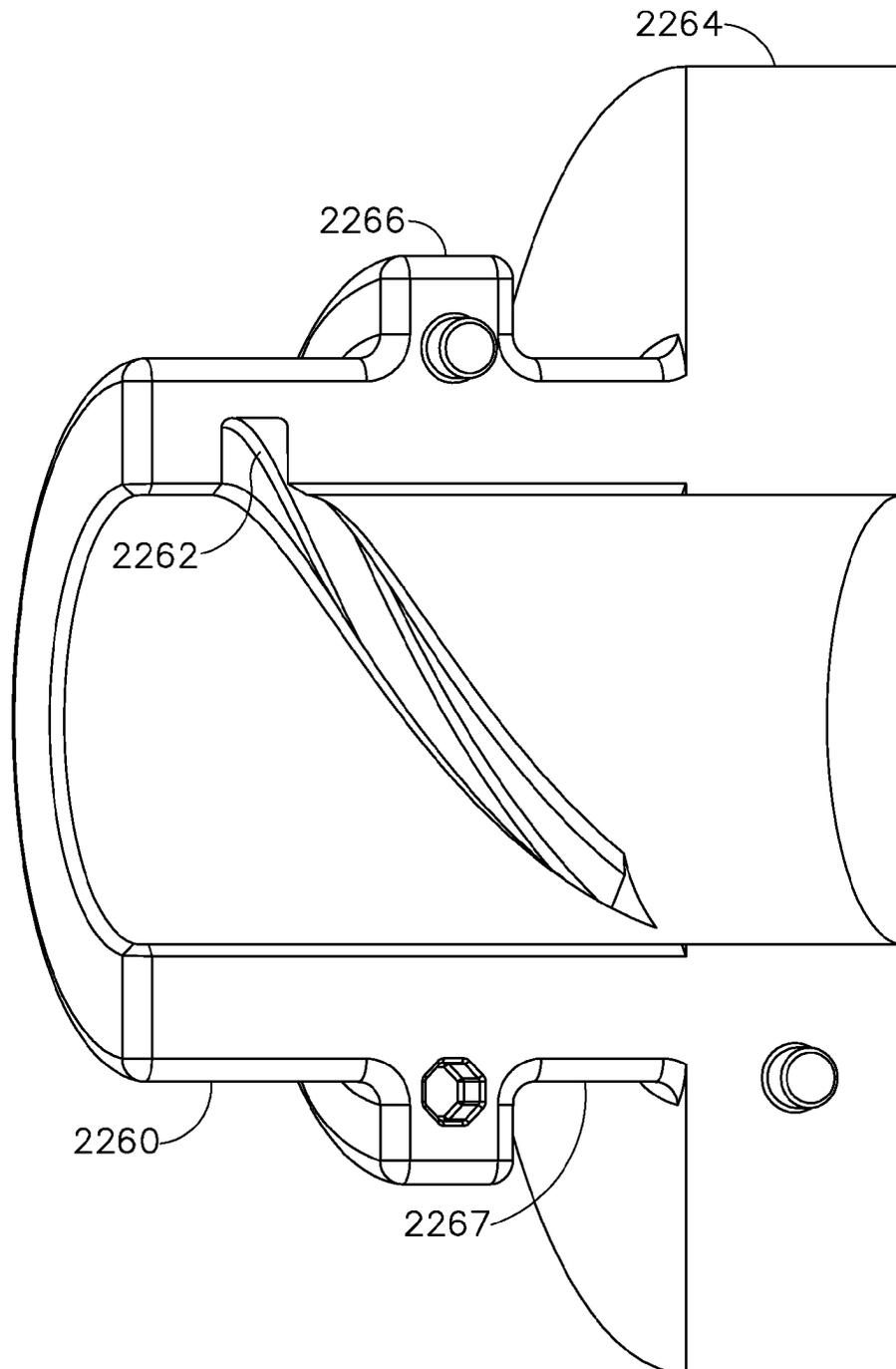


FIG. 42

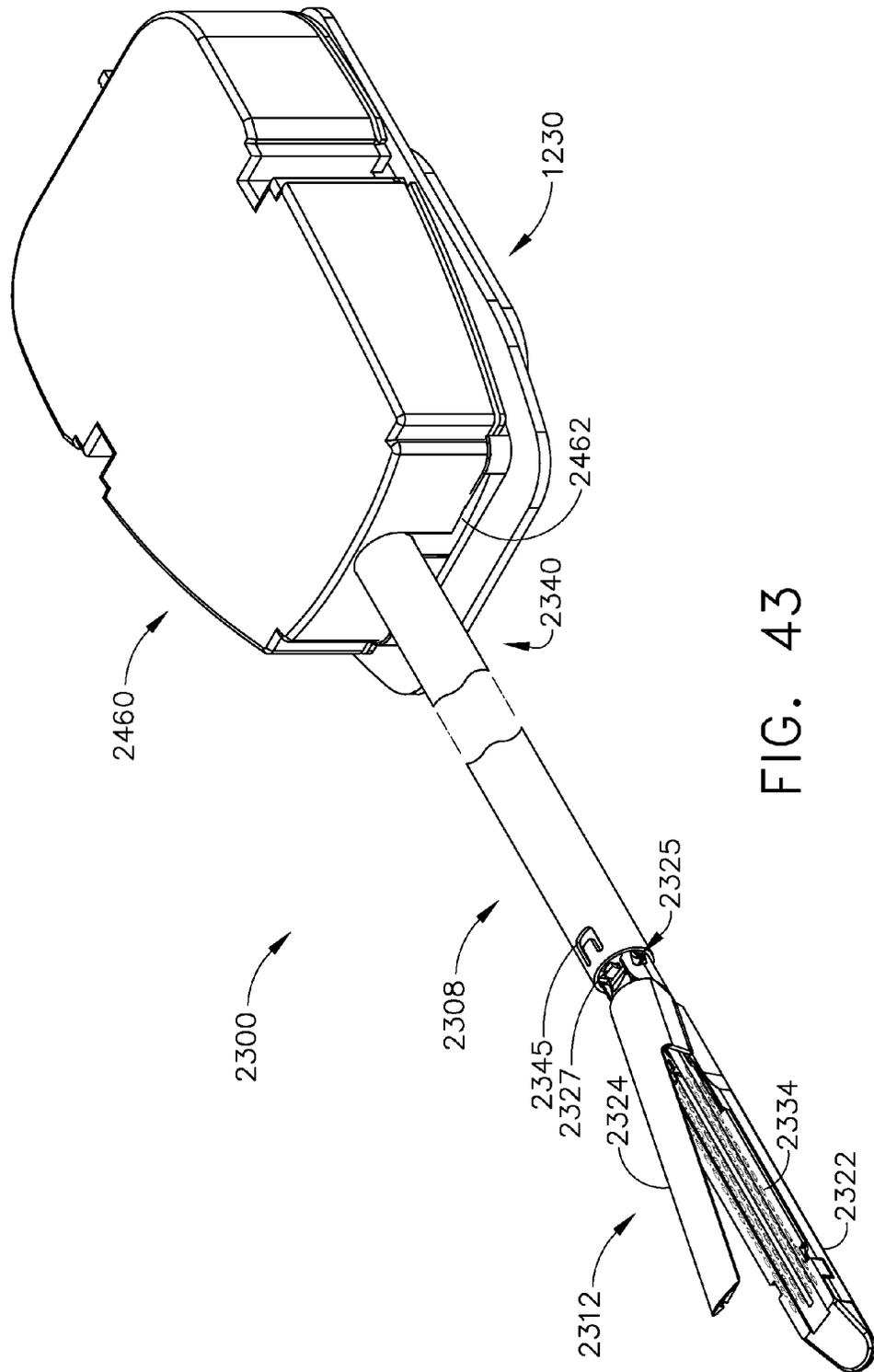


FIG. 43

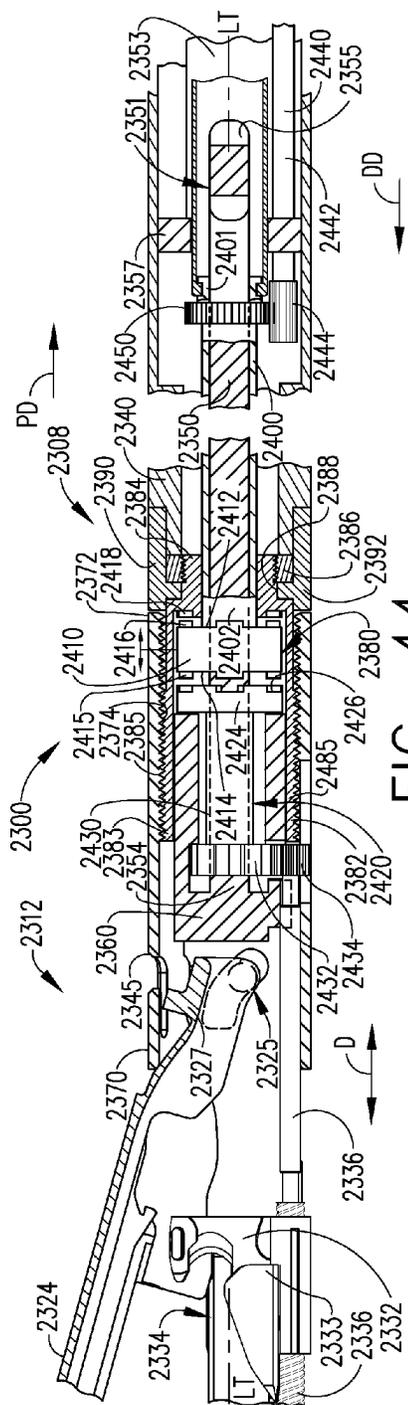


FIG. 44

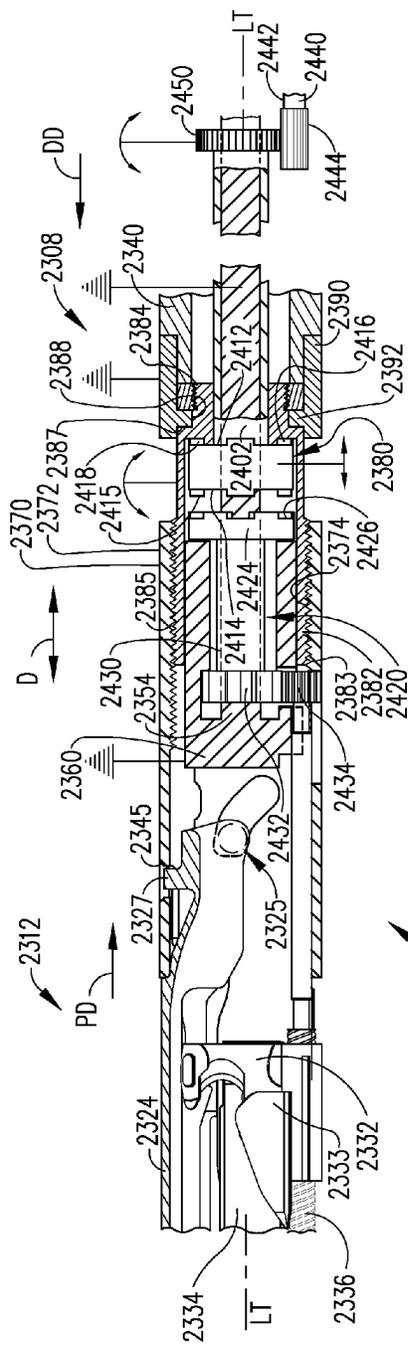


FIG. 45

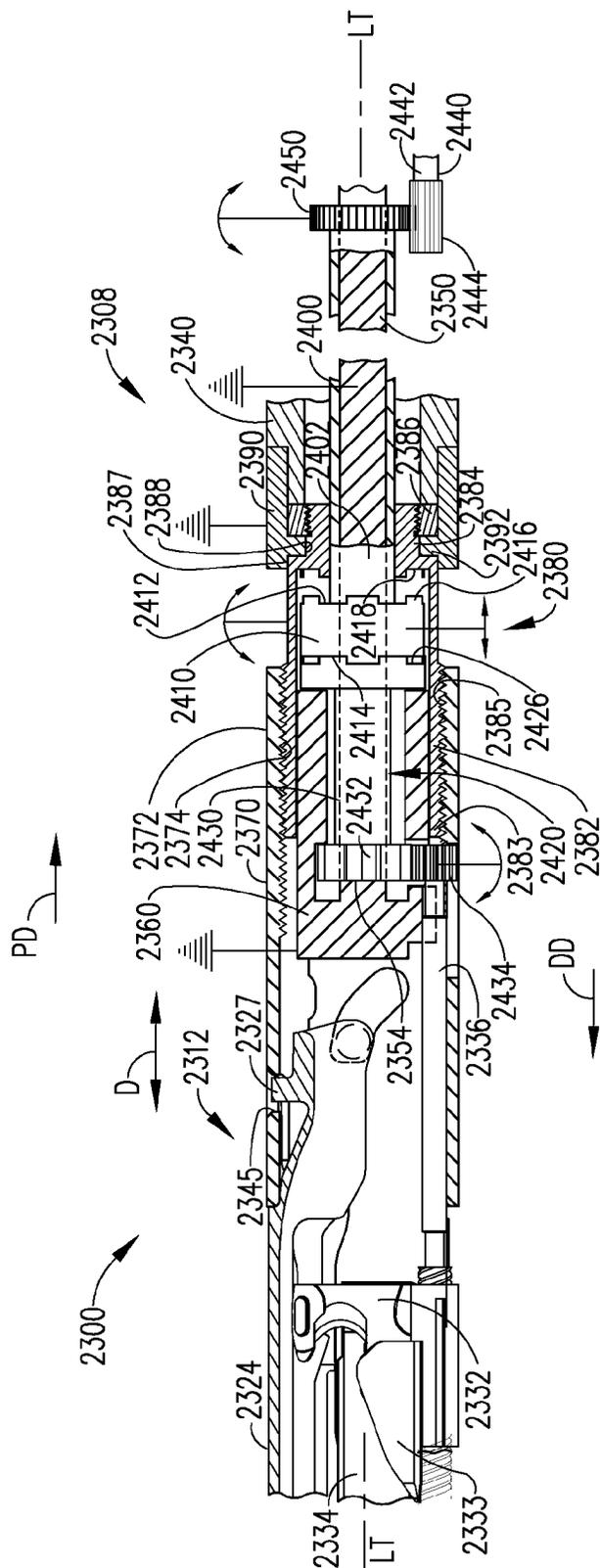


FIG. 46

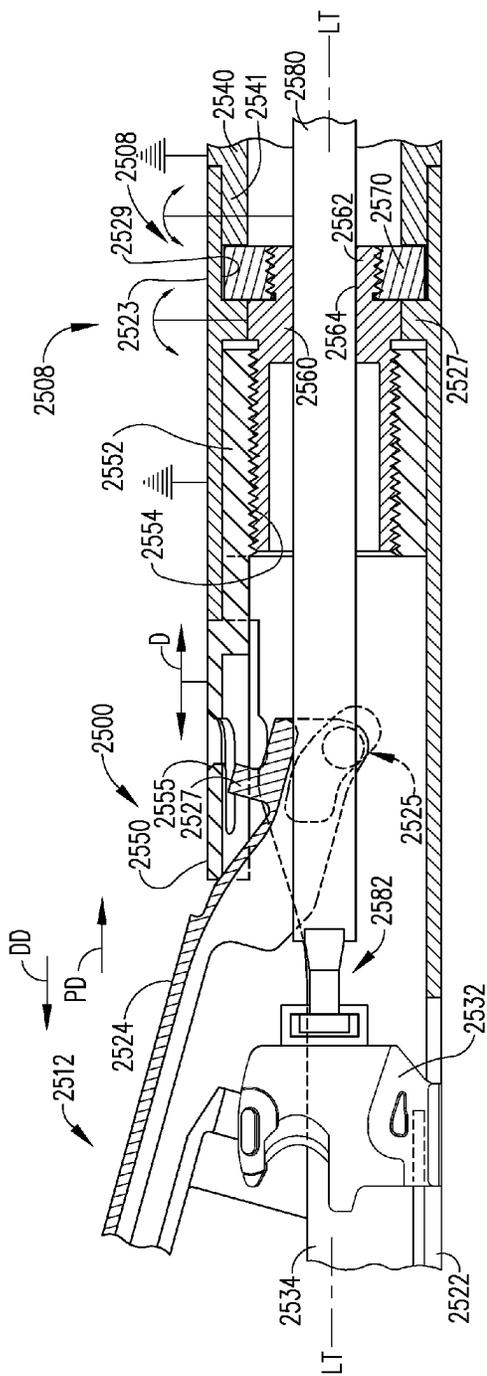


FIG. 49

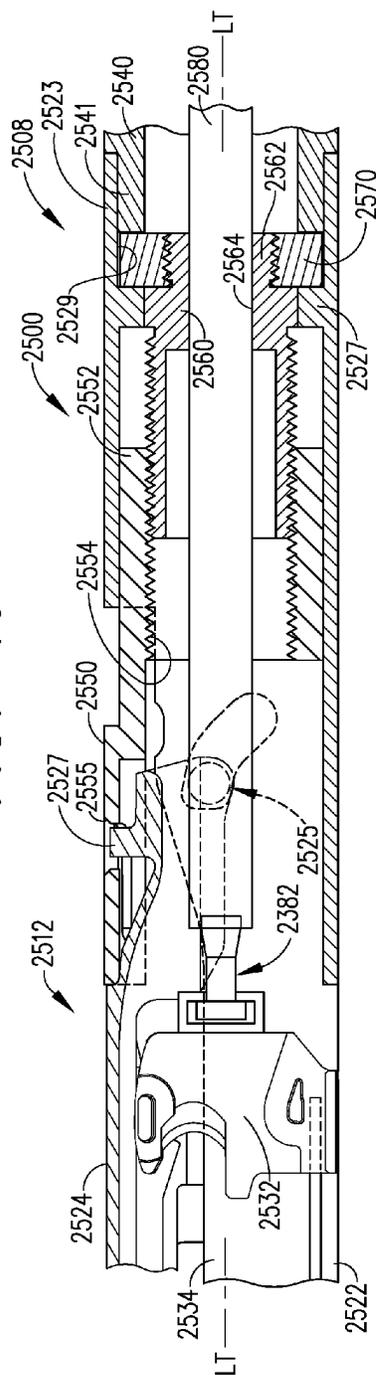


FIG. 50

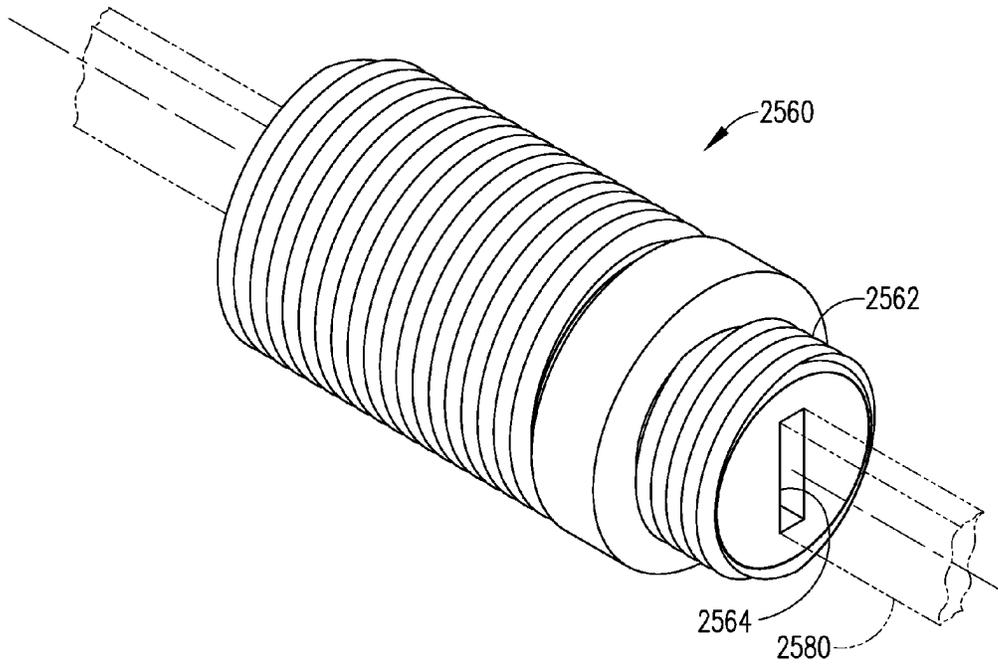


FIG. 51

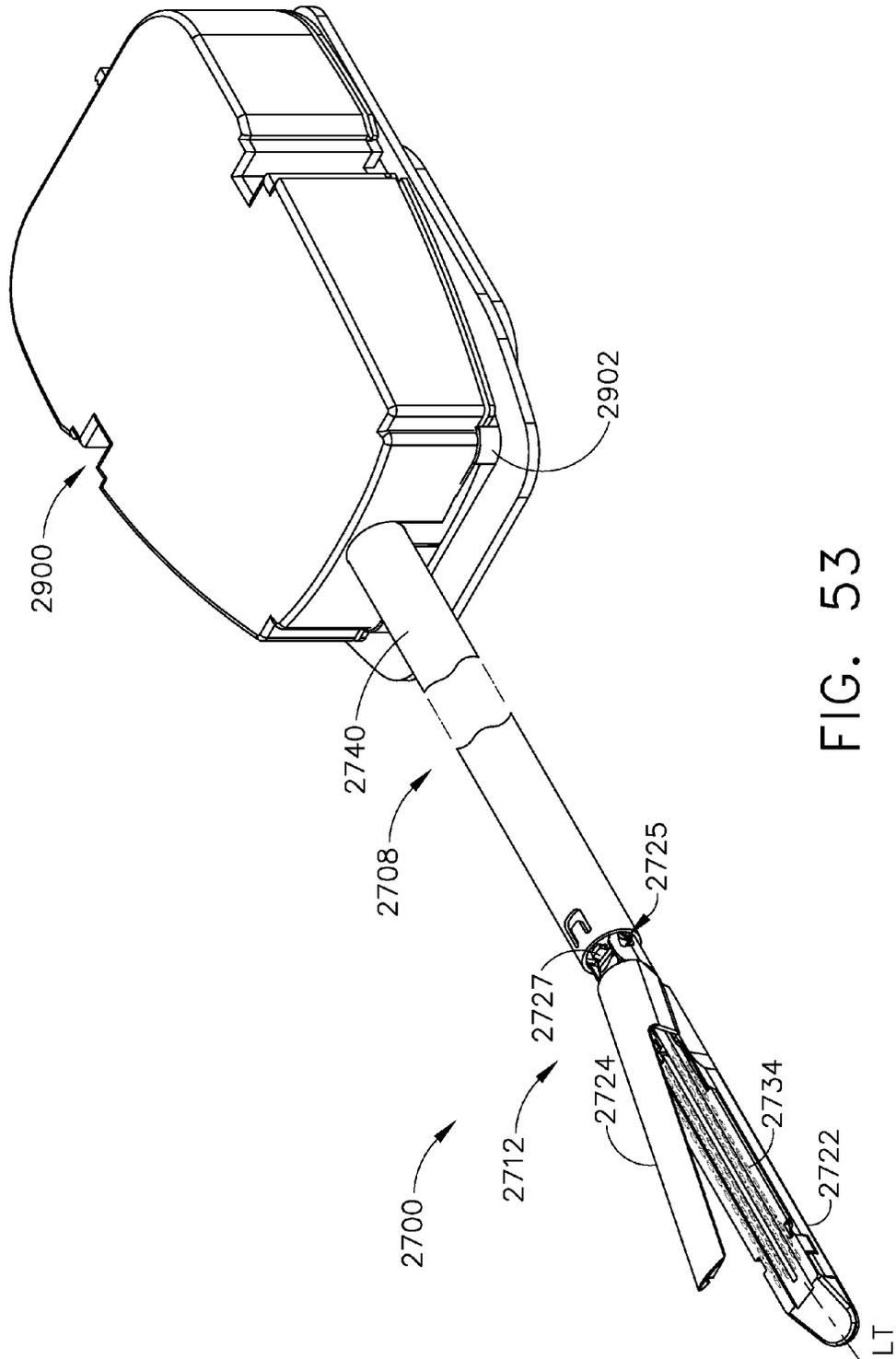


FIG. 53

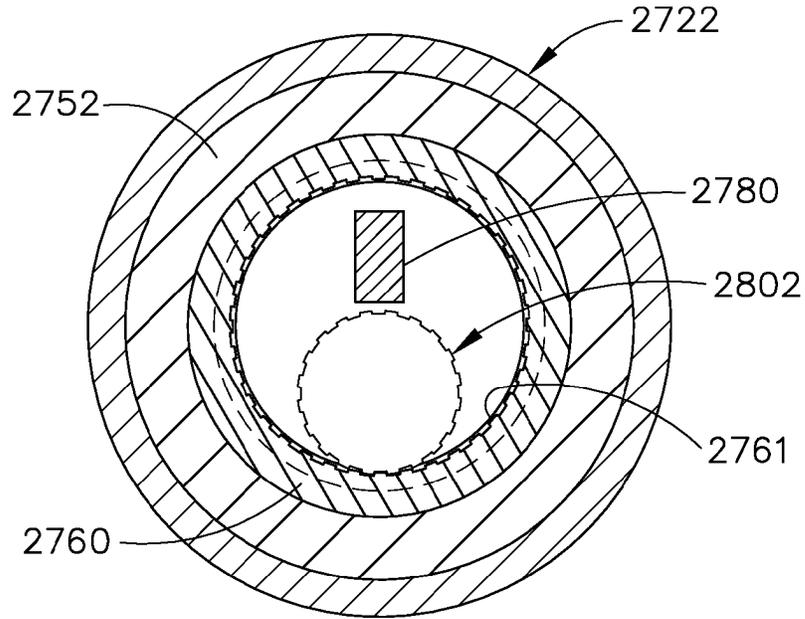


FIG. 56

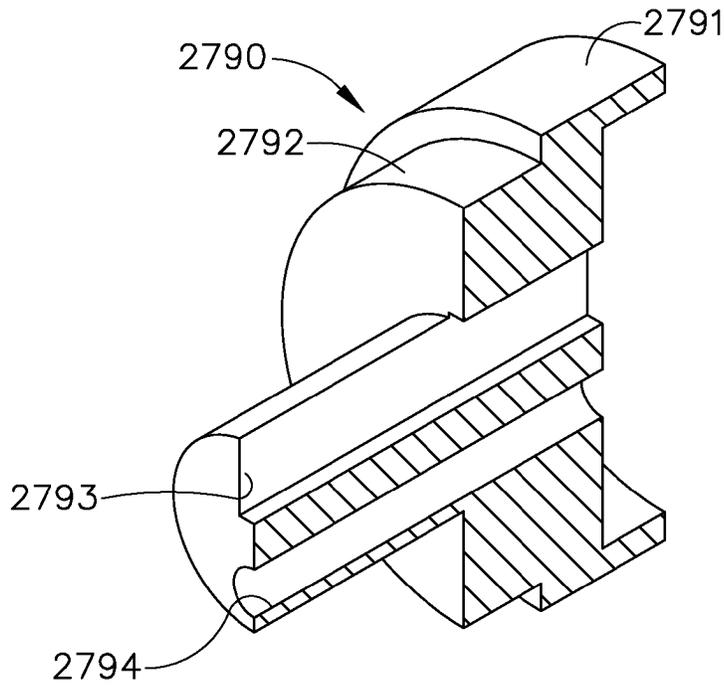


FIG. 57

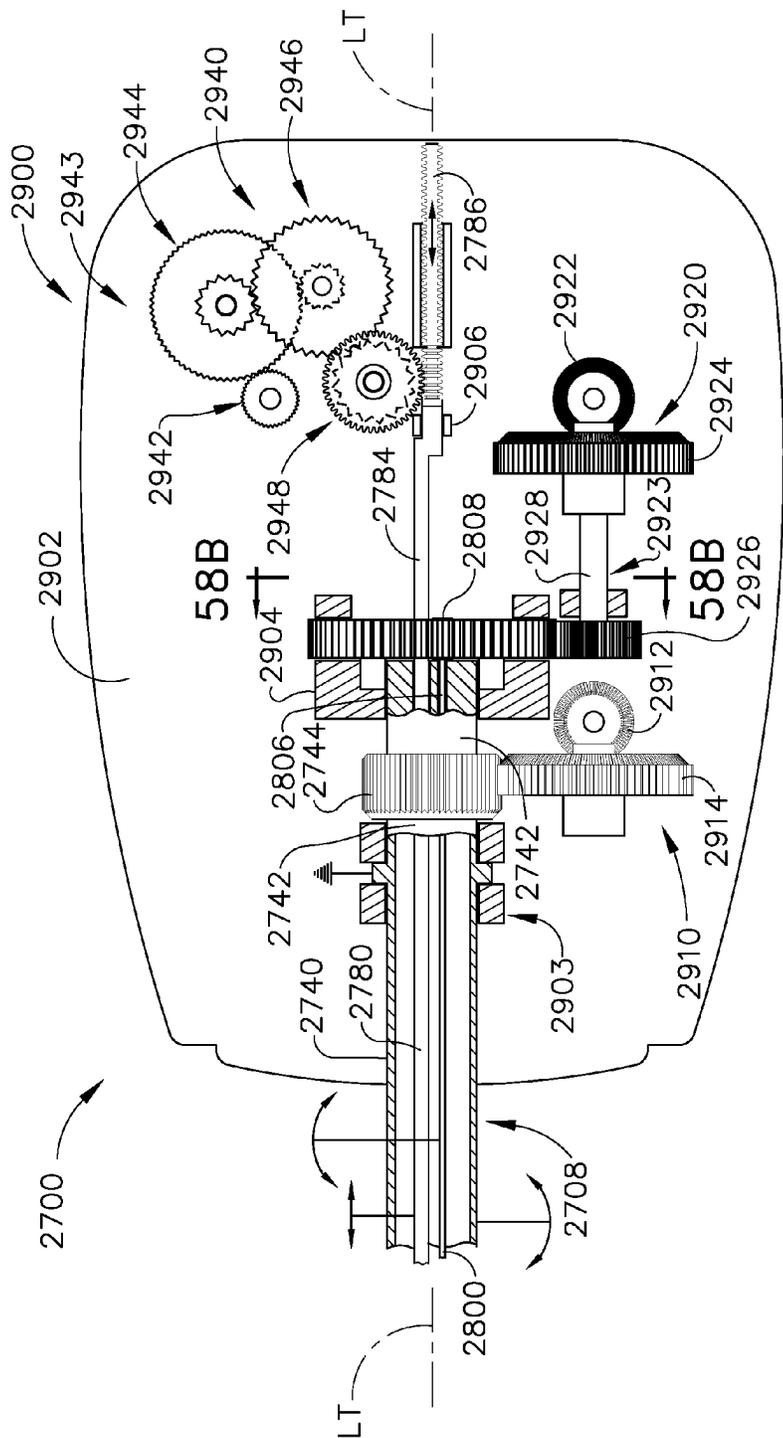


FIG. 58

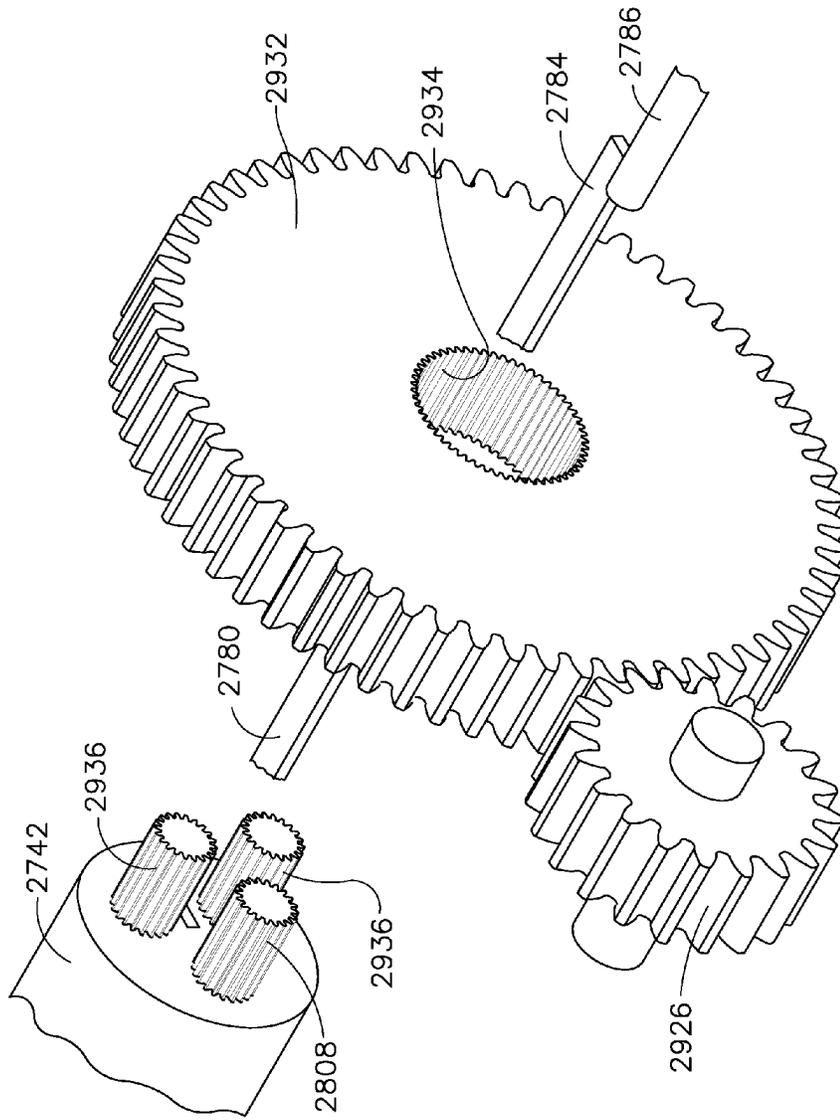


FIG. 58A

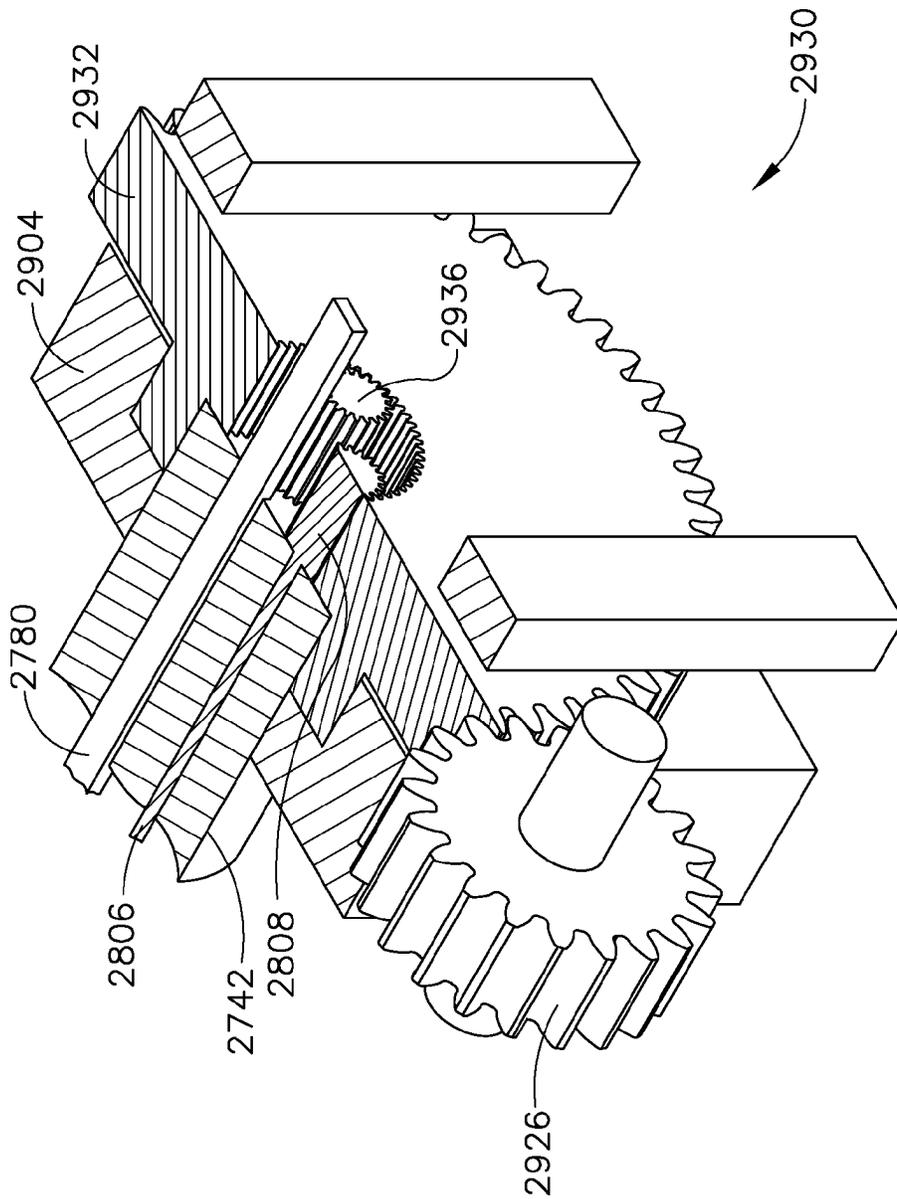


FIG. 58B

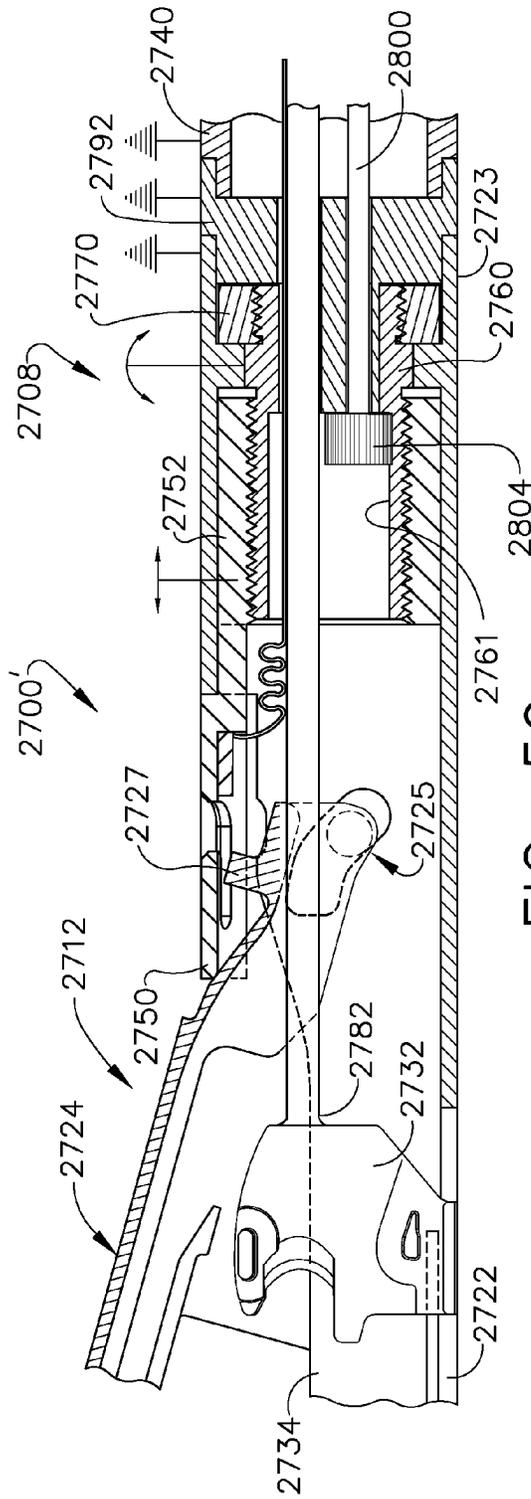


FIG. 59

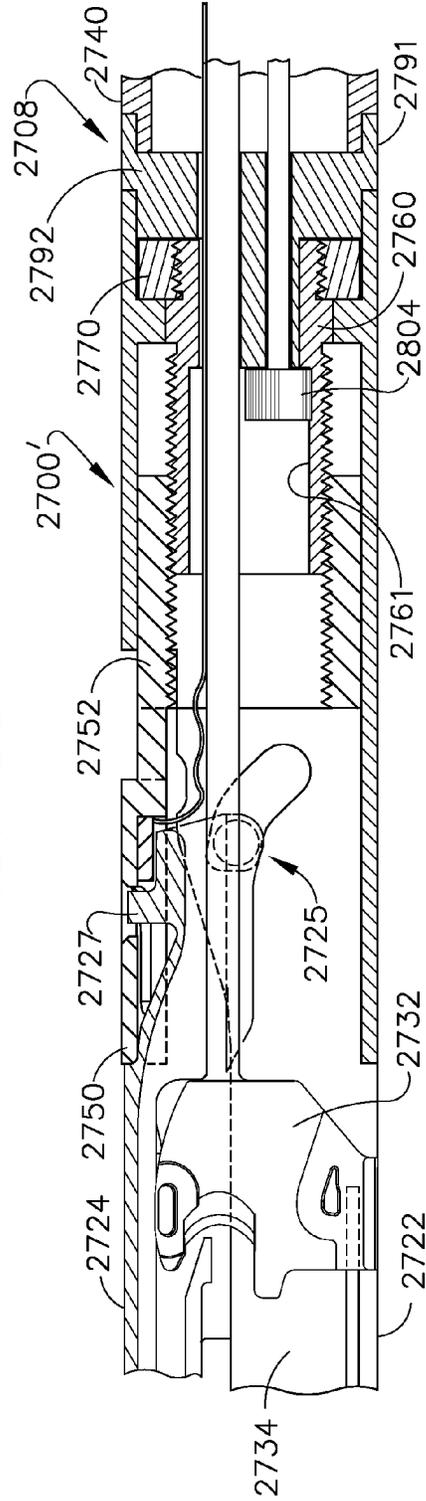


FIG. 60

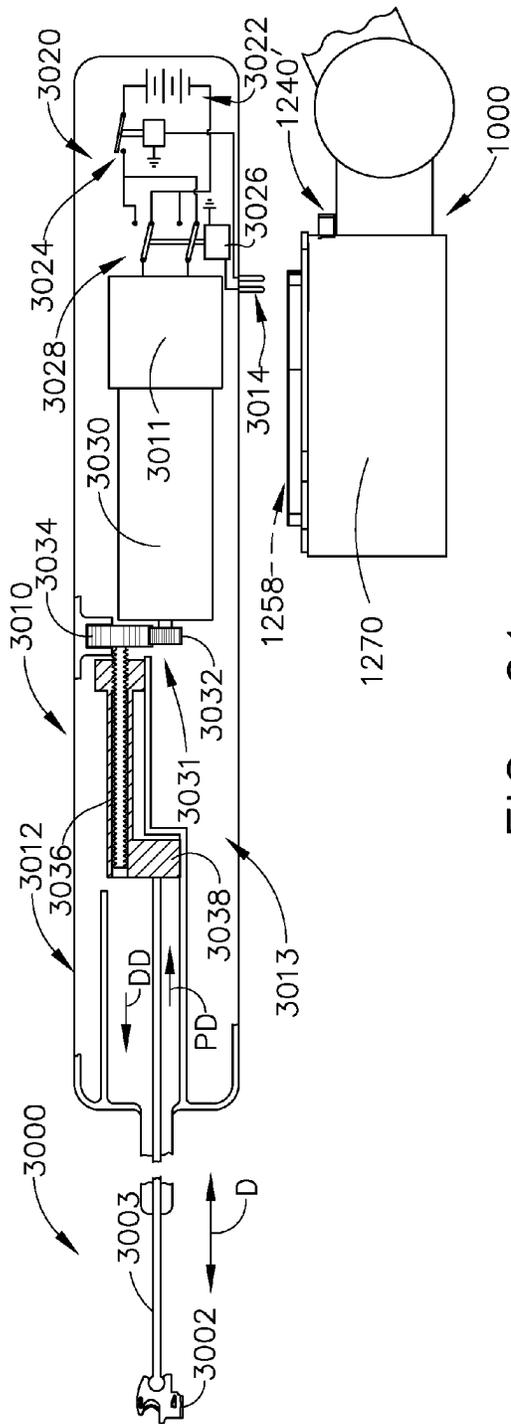


FIG. 61

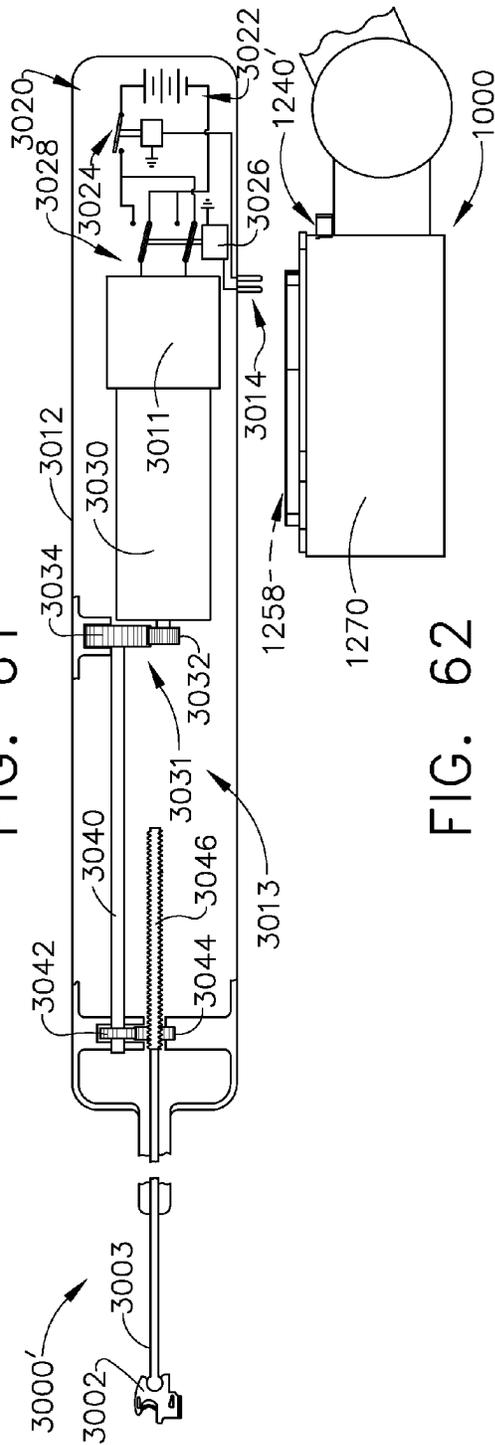


FIG. 62

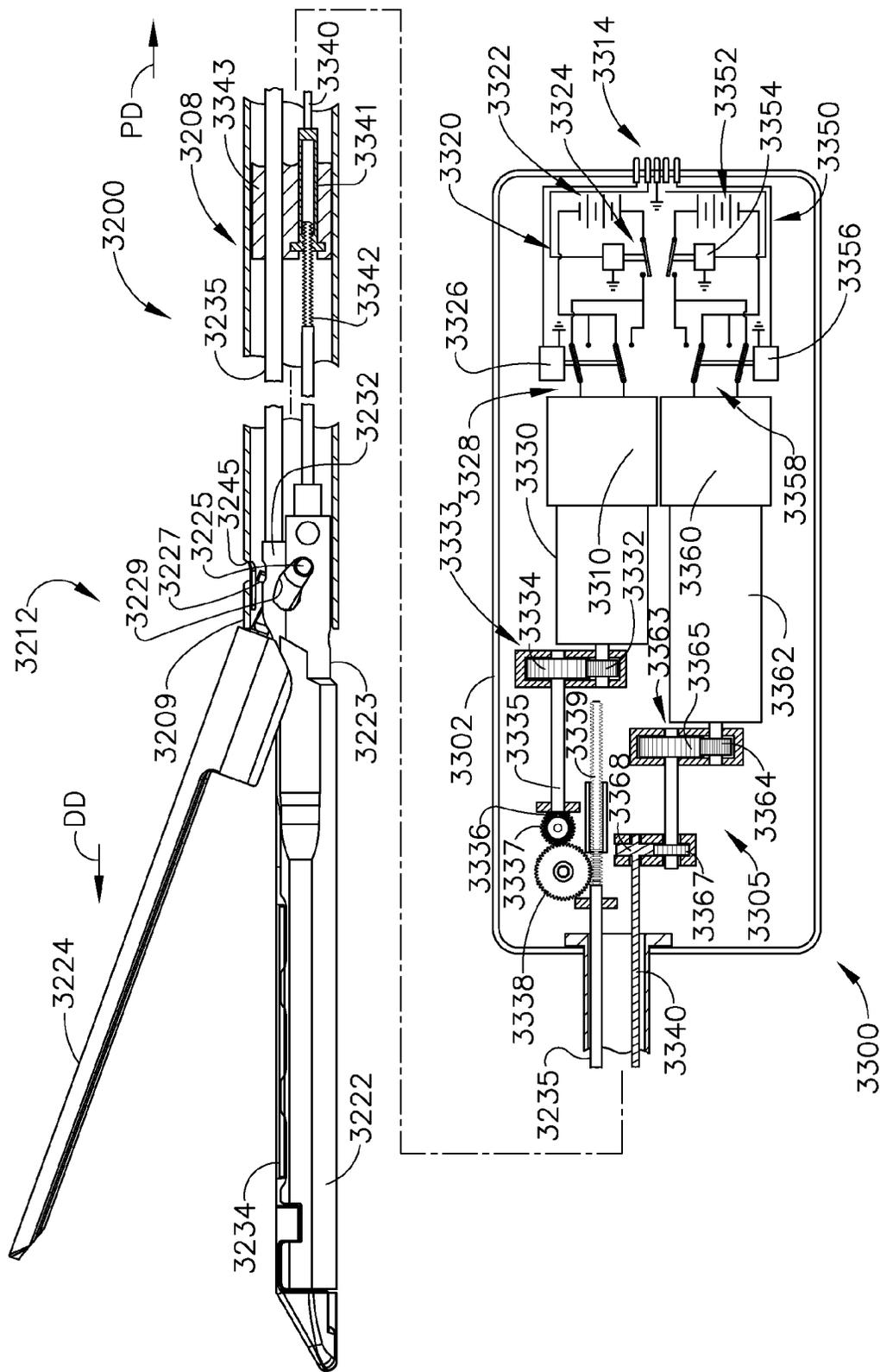


FIG. 63

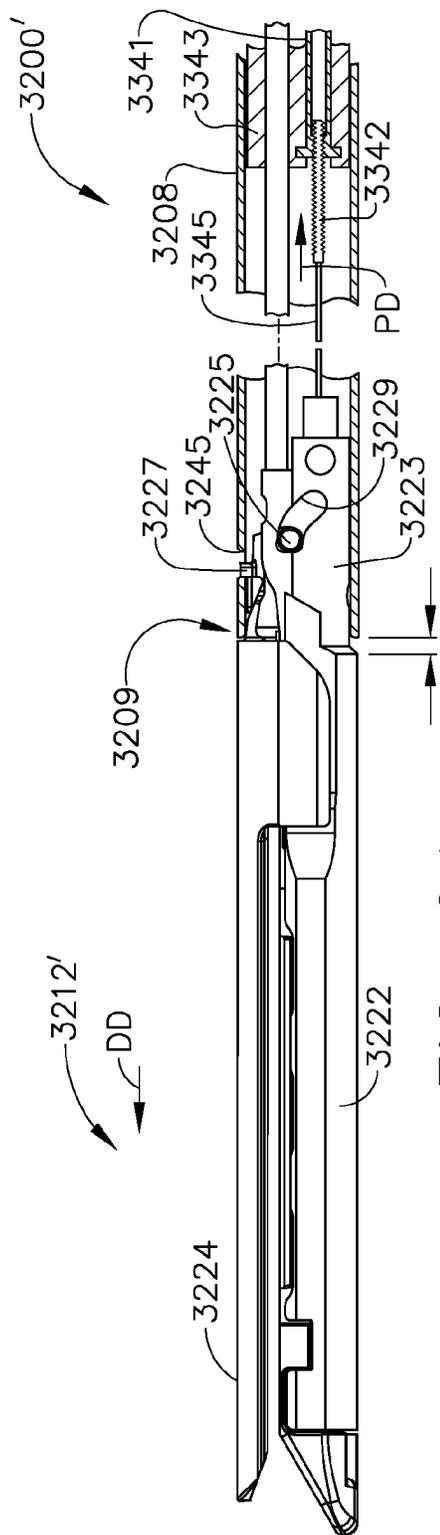


FIG. 64

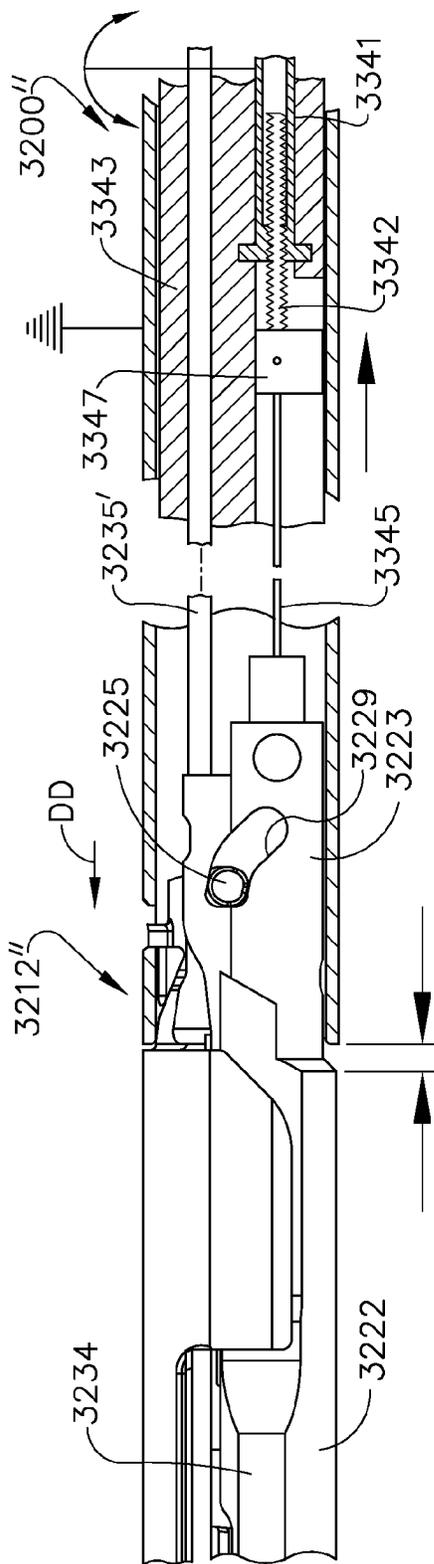


FIG. 65

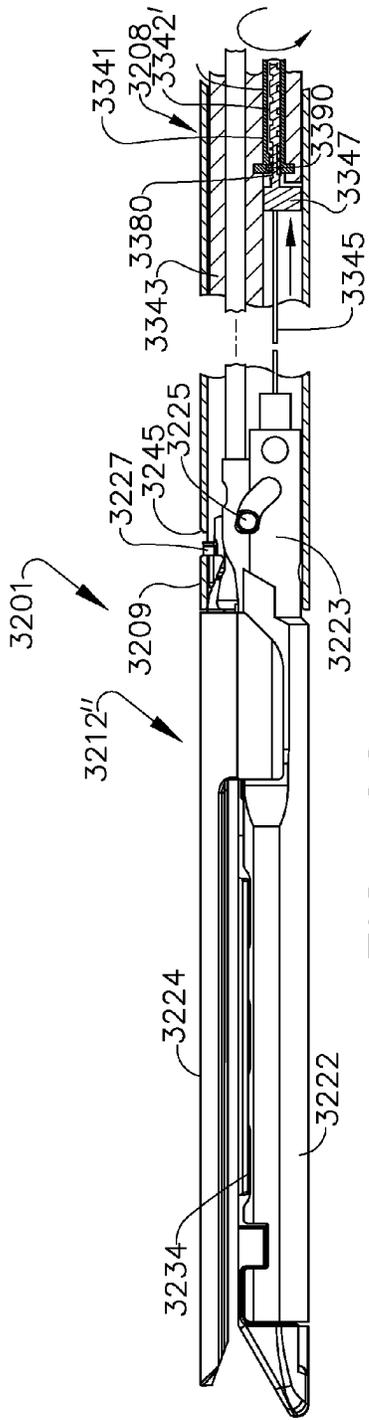


FIG. 66

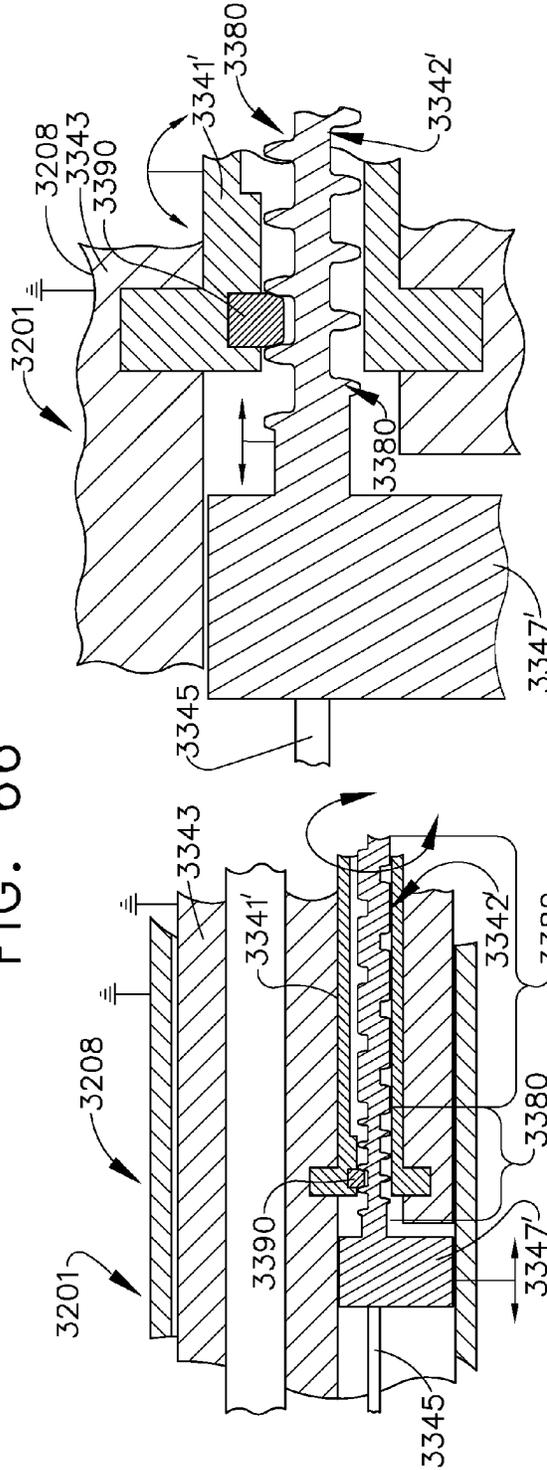


FIG. 68

FIG. 67

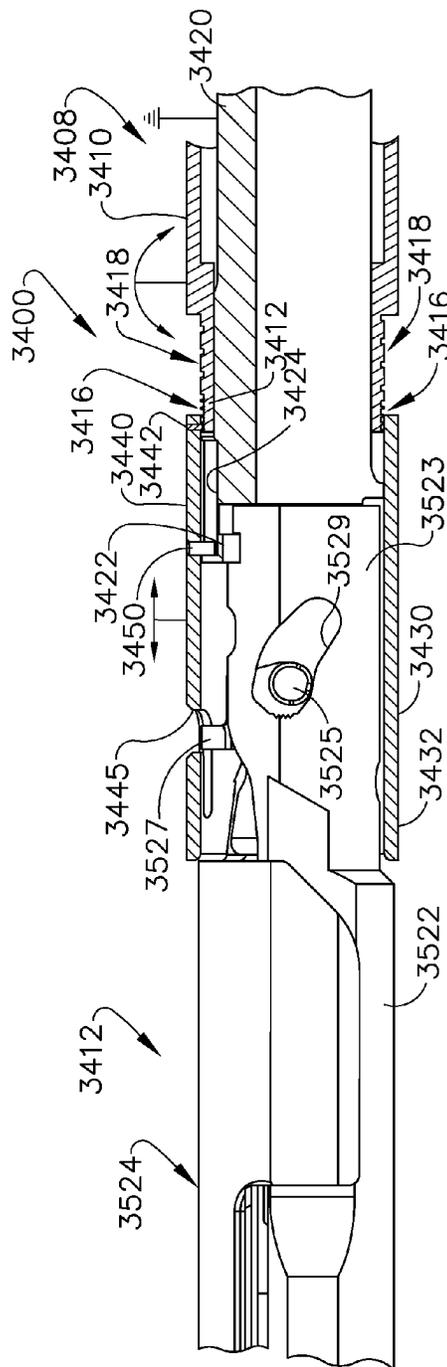


FIG. 71

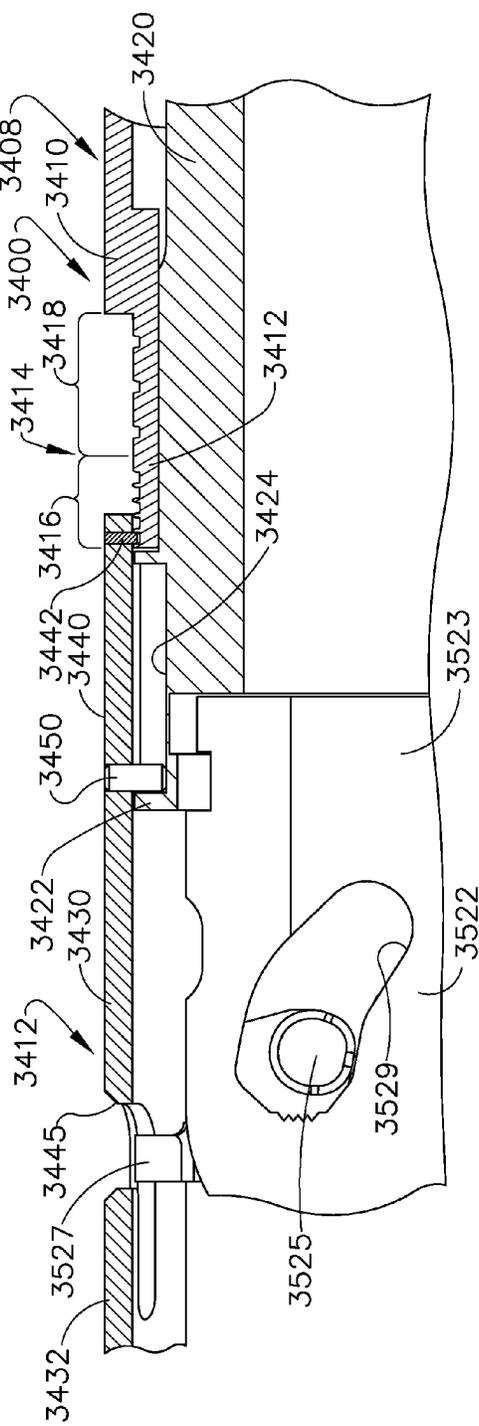


FIG. 72

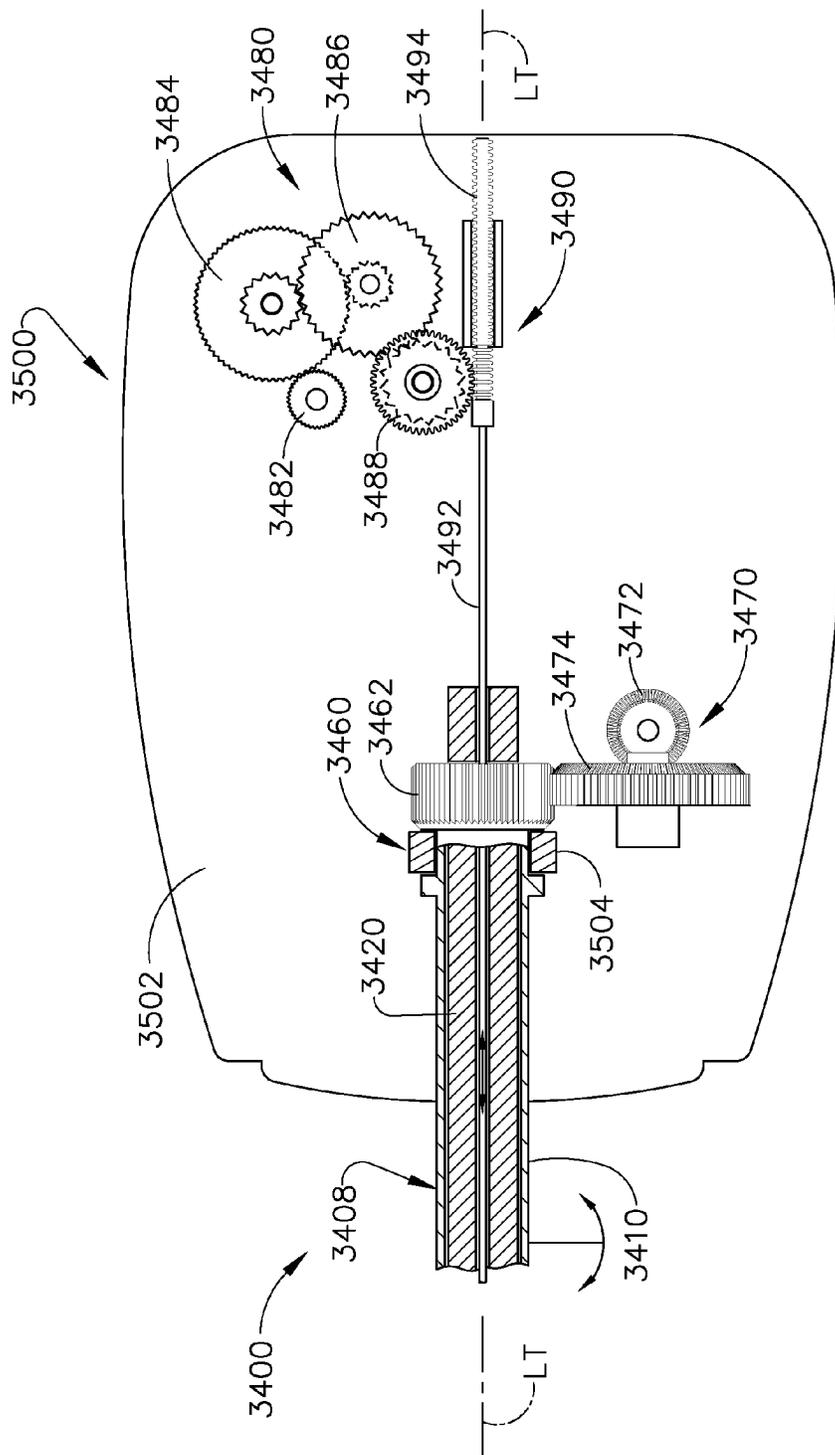


FIG. 73

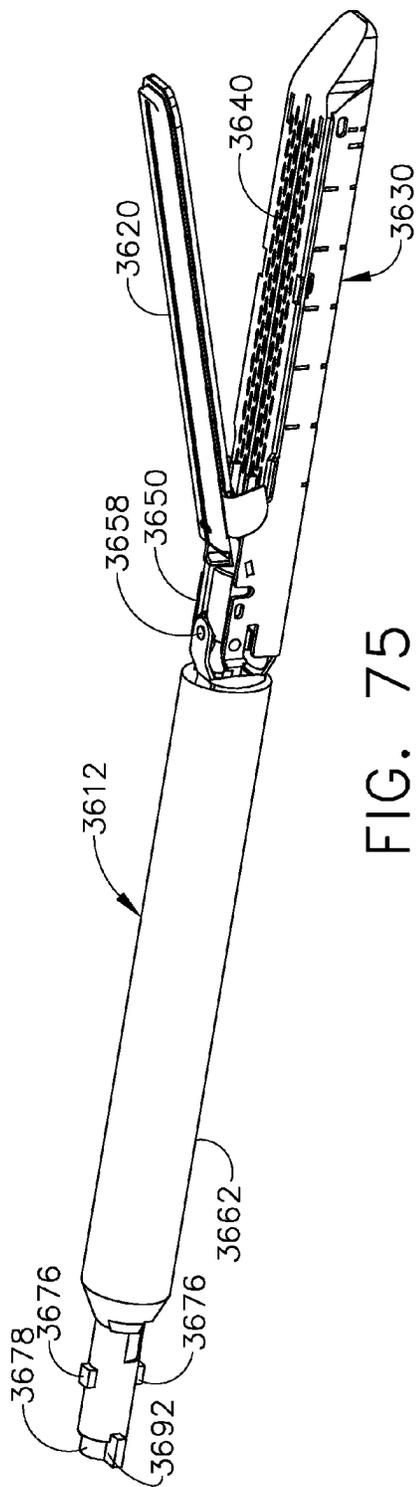


FIG. 75

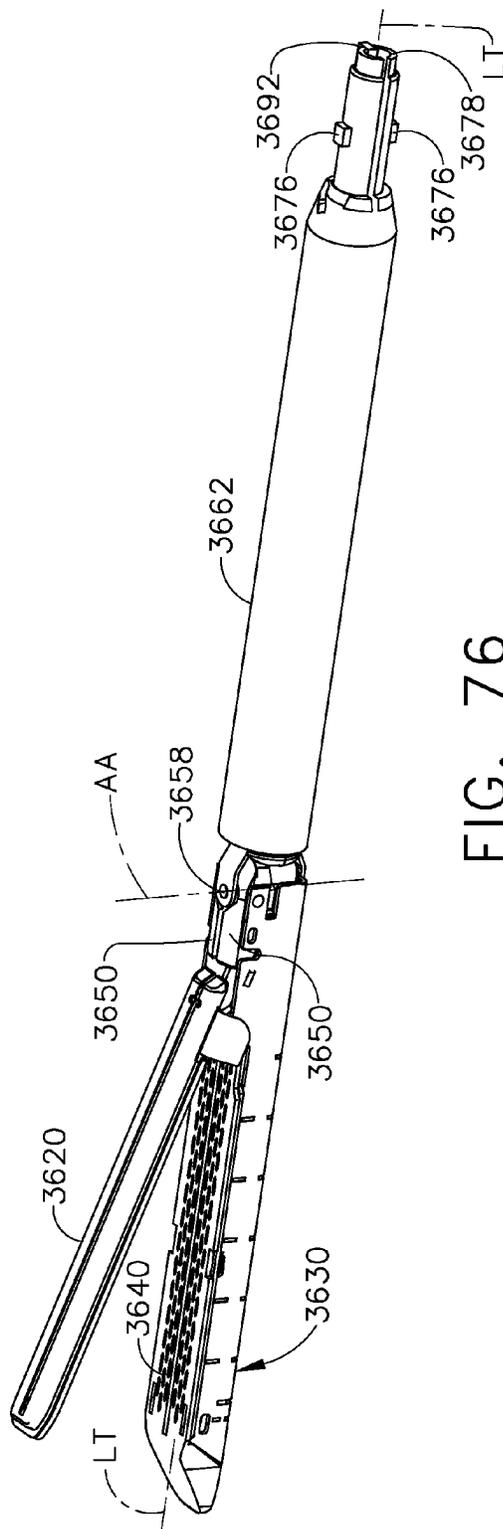


FIG. 76

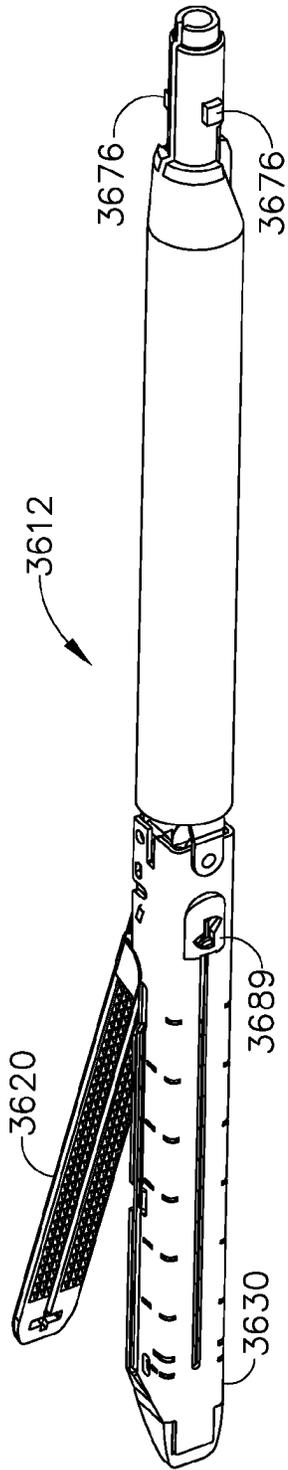


FIG. 77

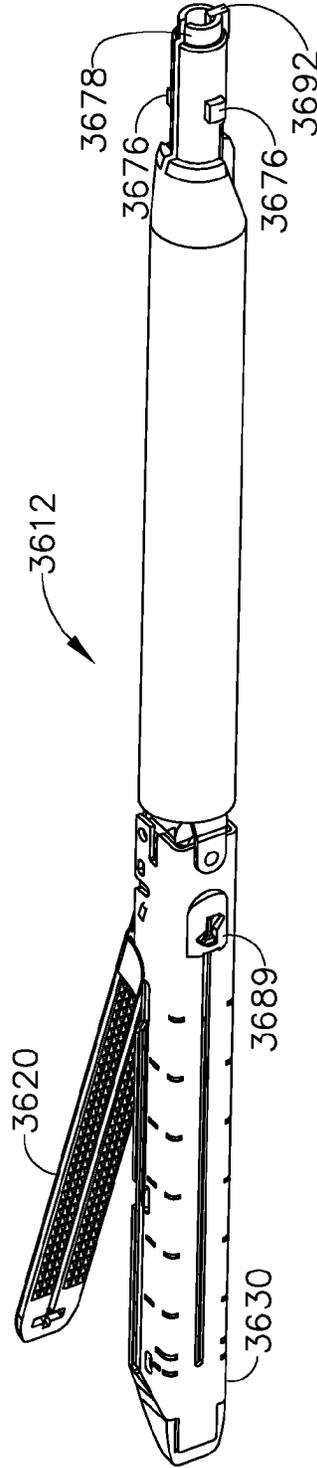


FIG. 78

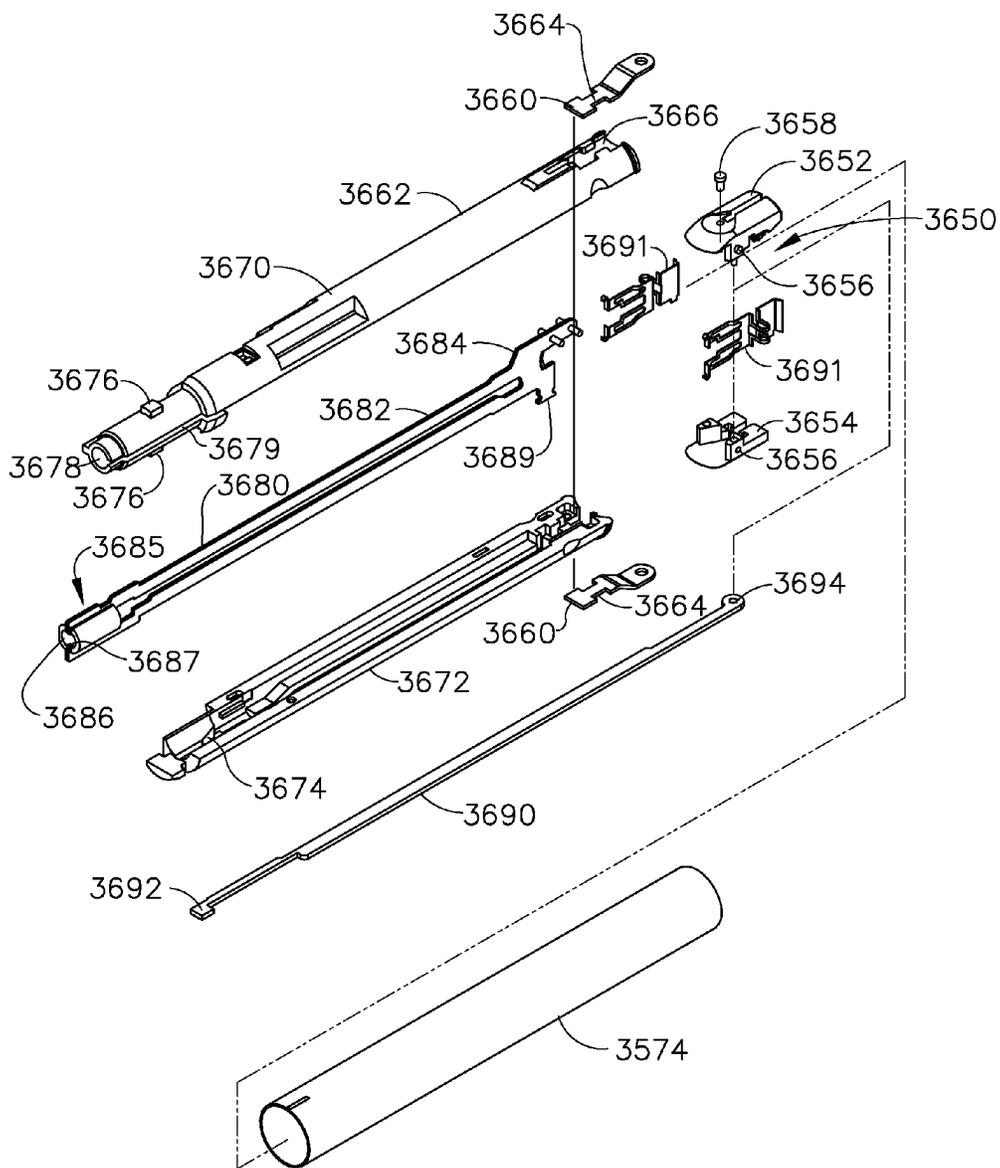


FIG. 79

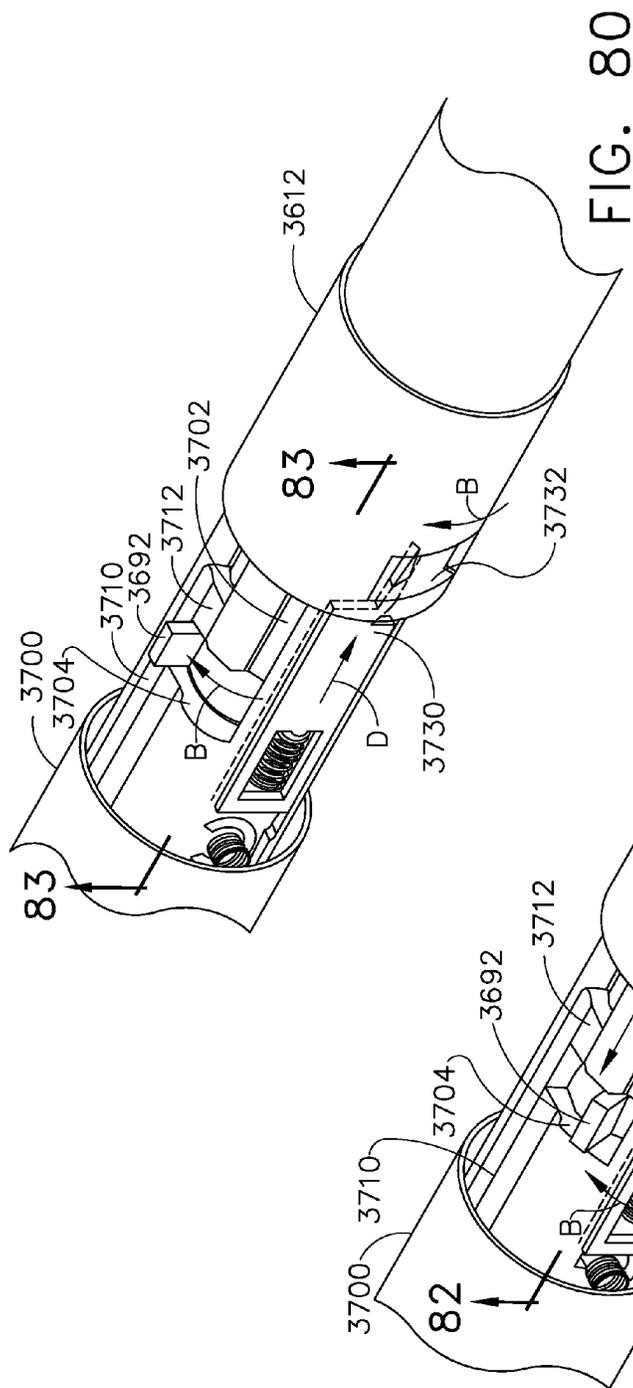


FIG. 80

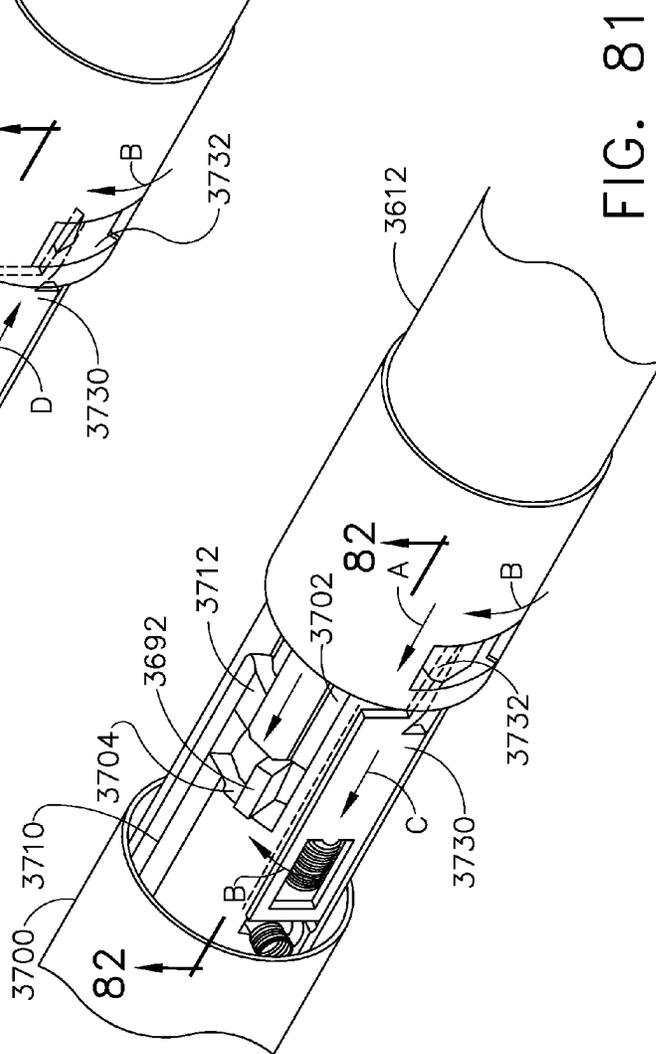


FIG. 81

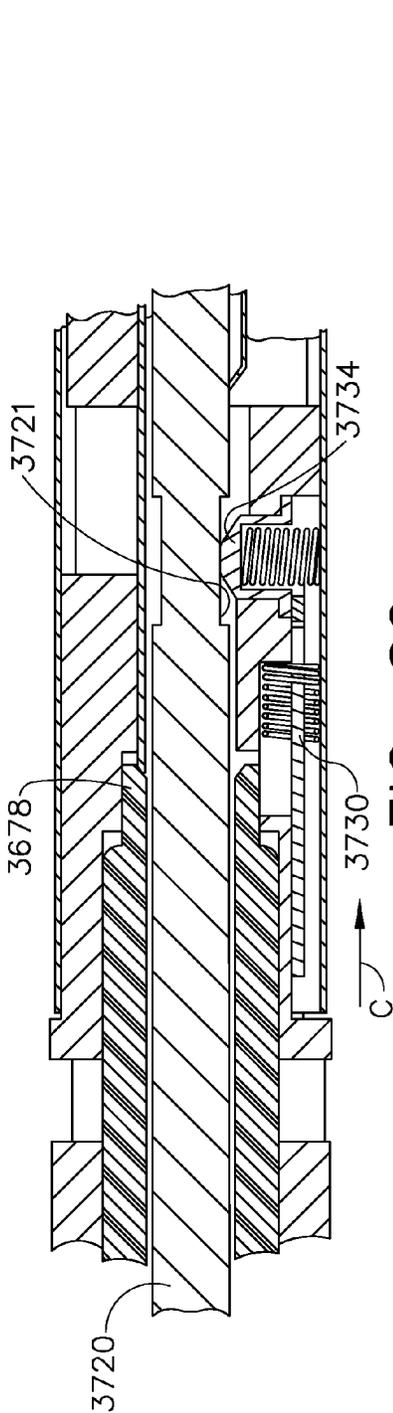


FIG. 82

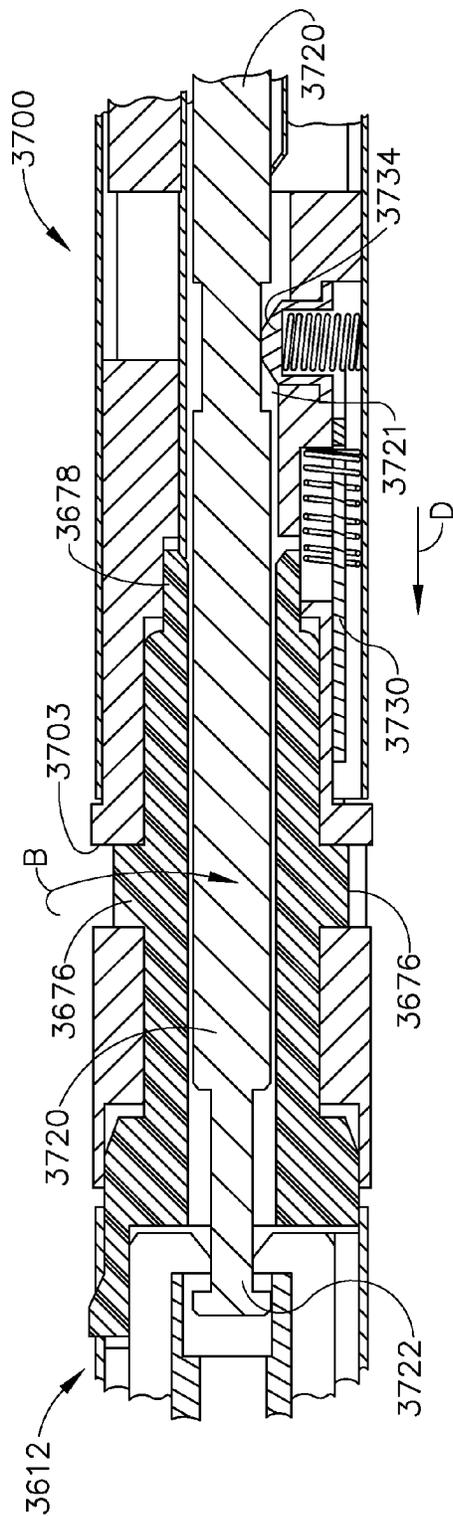


FIG. 83

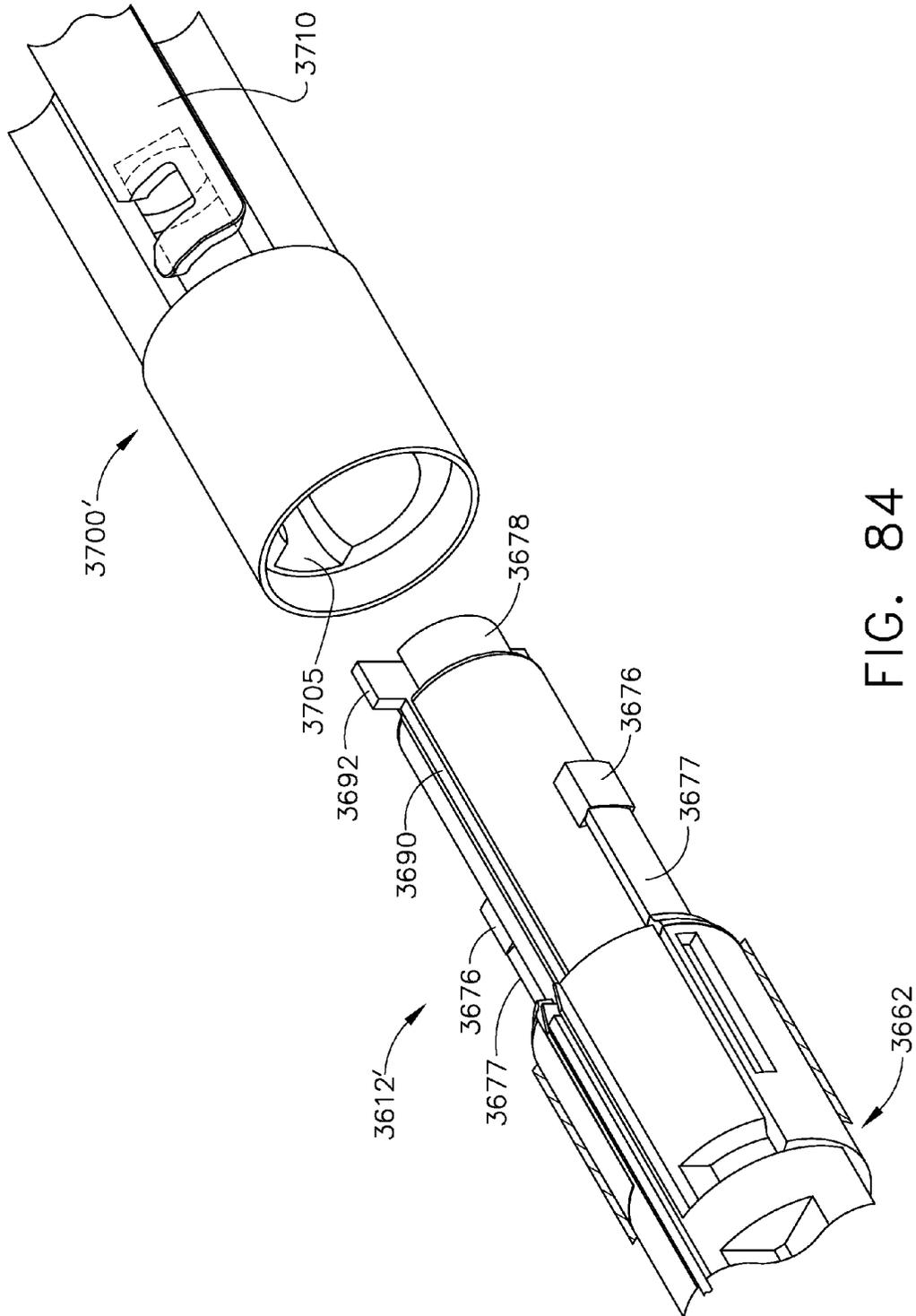
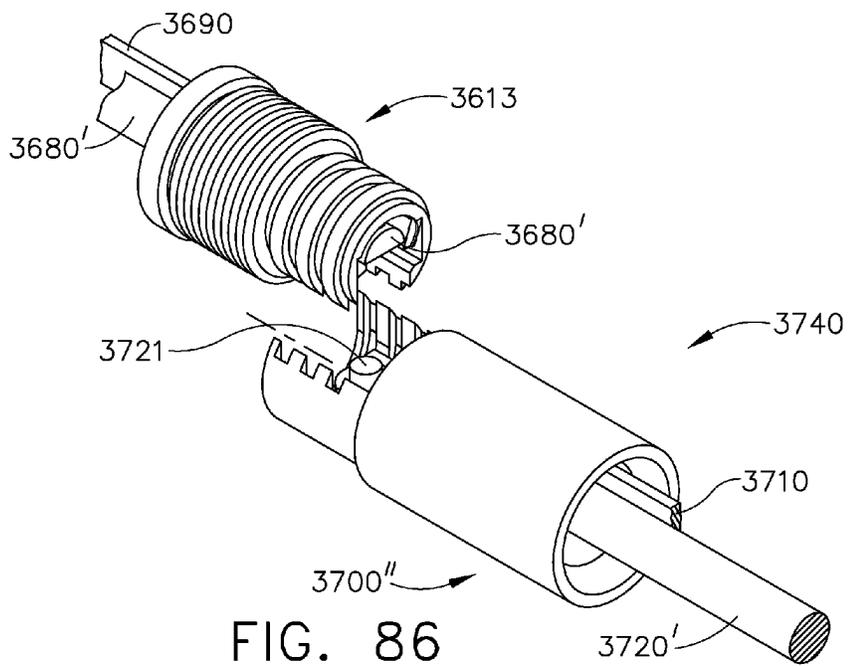
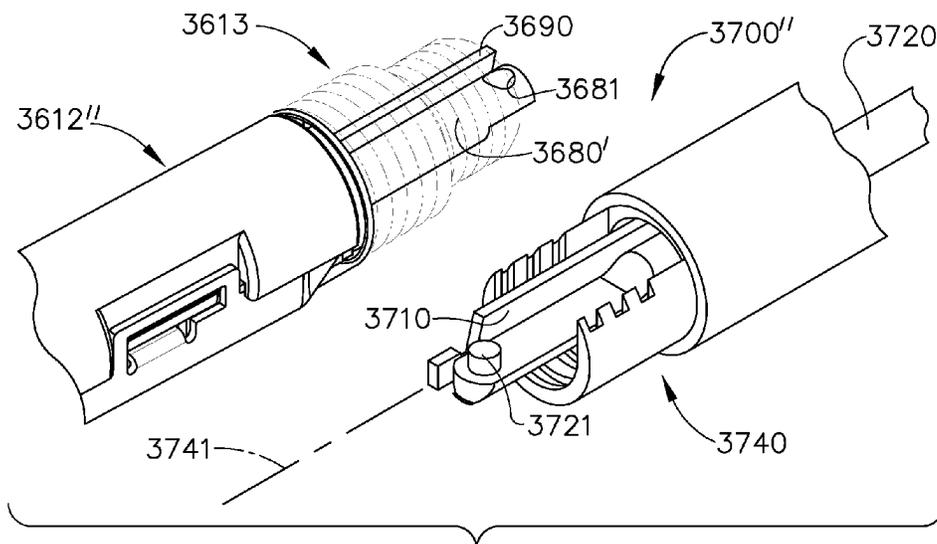


FIG. 84



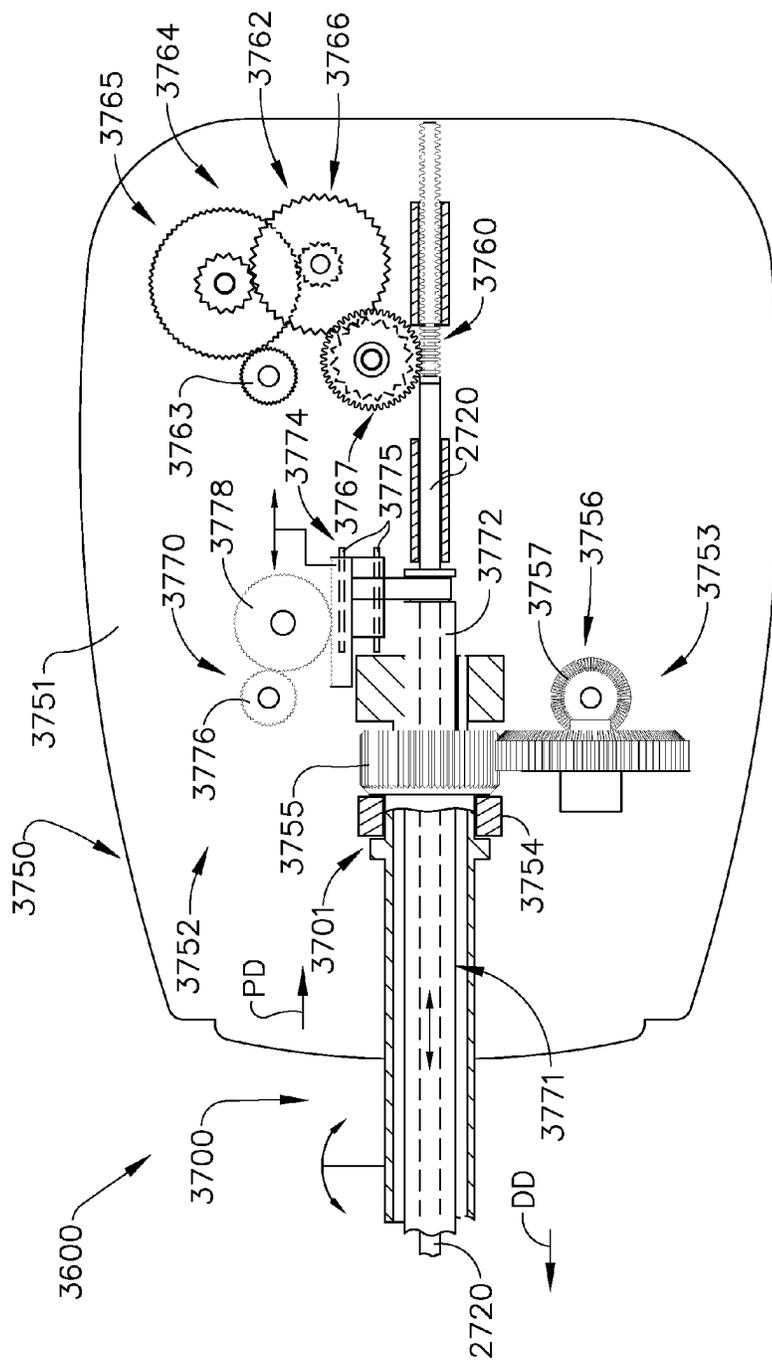


FIG. 87

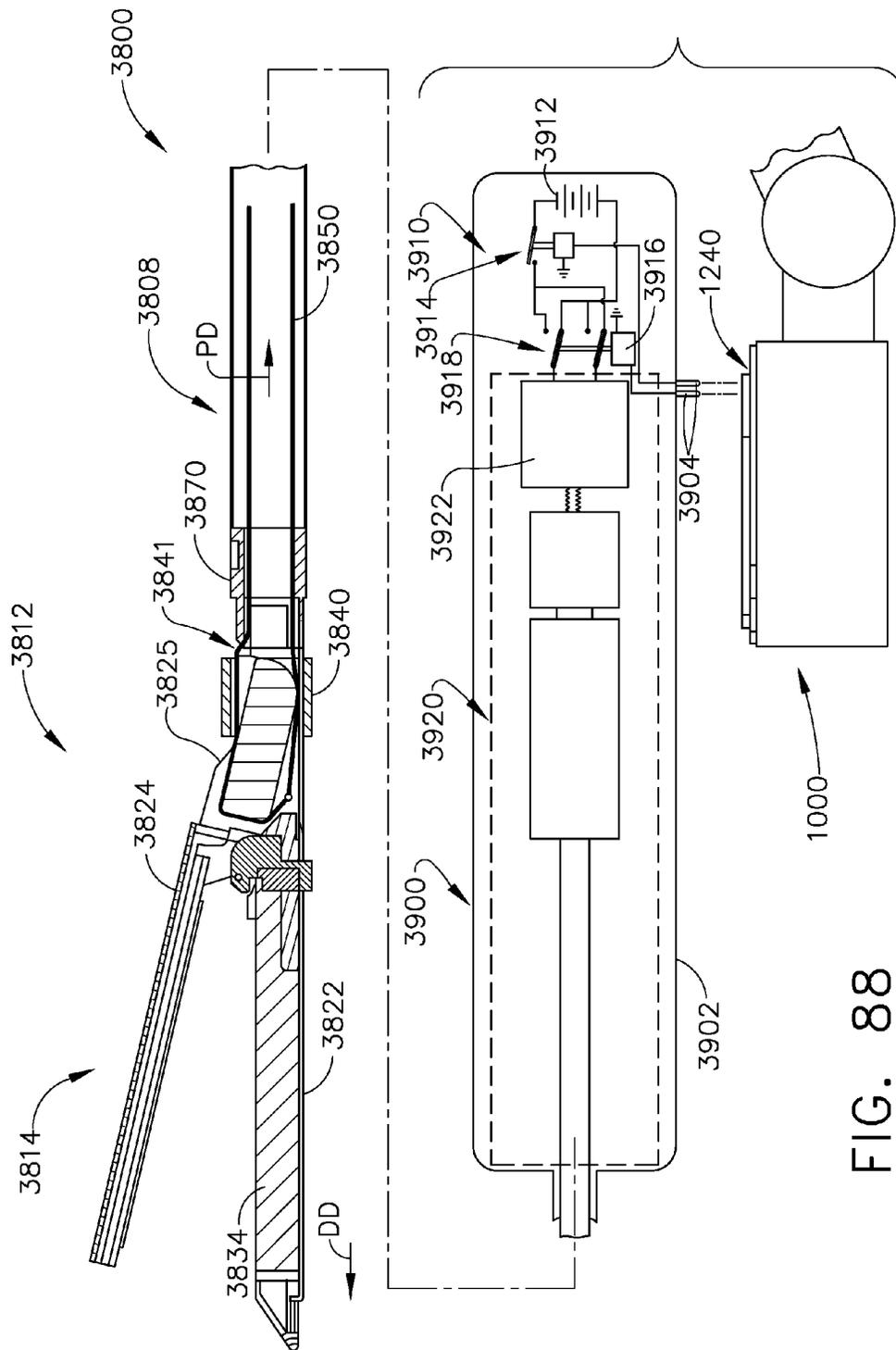


FIG. 88

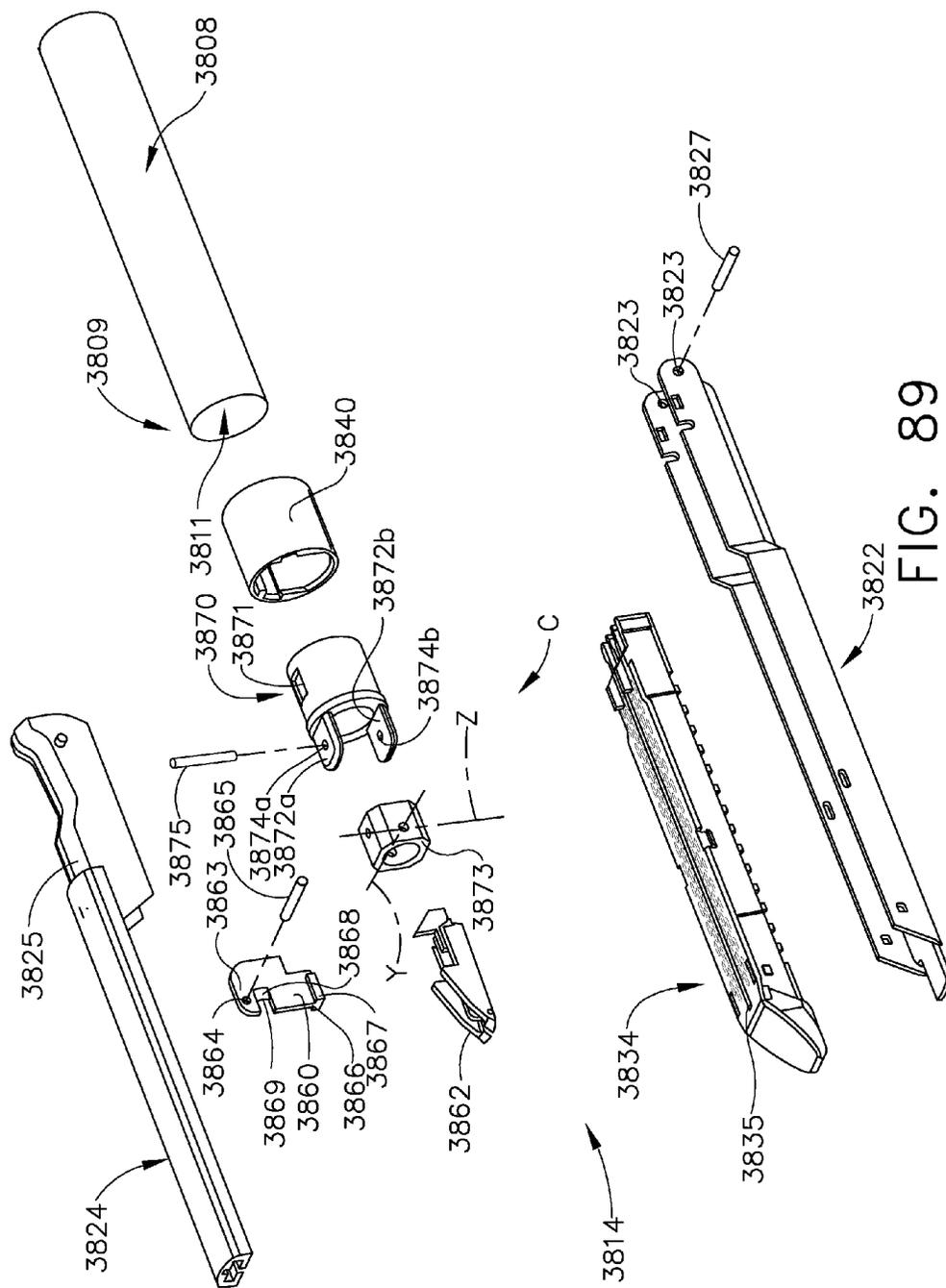
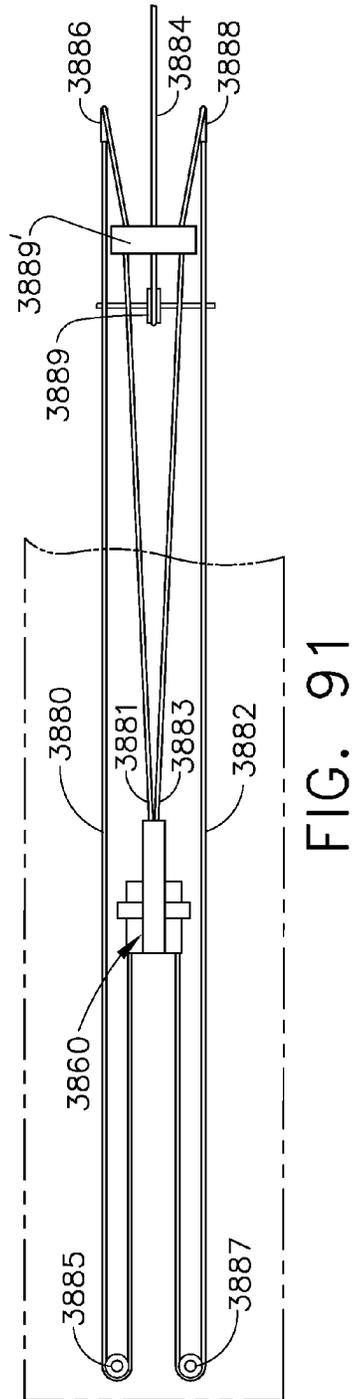
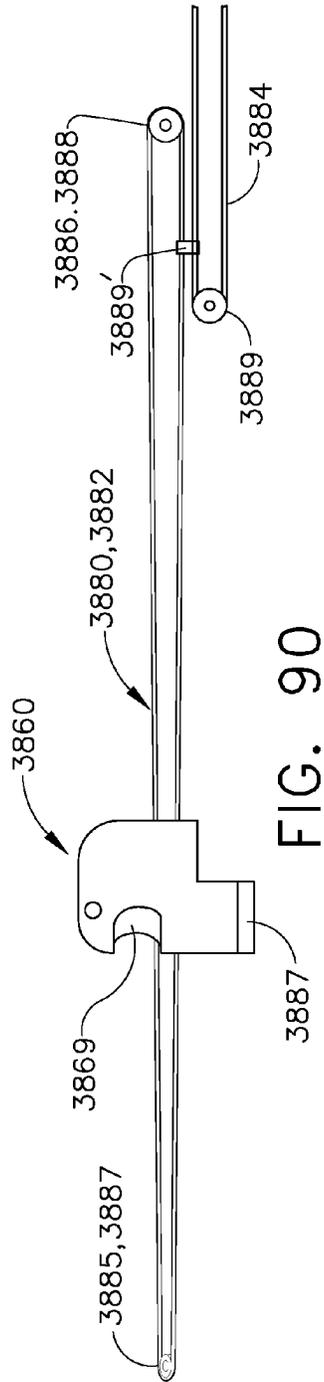


FIG. 89



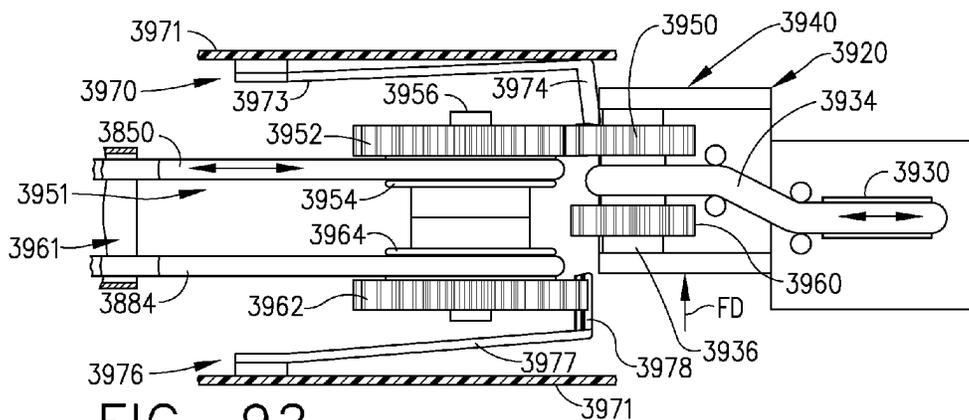


FIG. 92

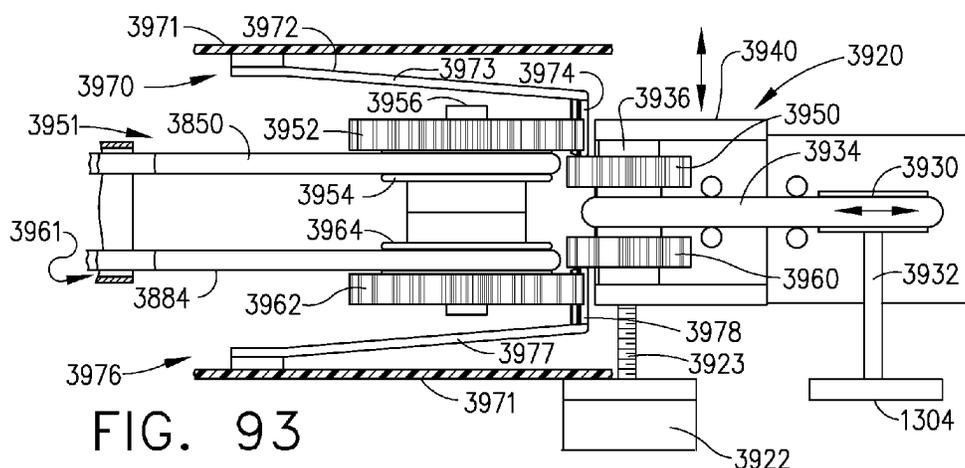


FIG. 93

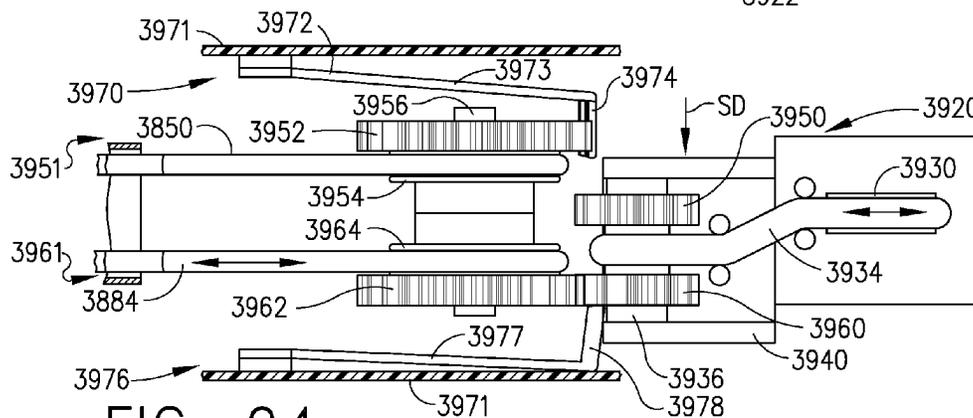


FIG. 94

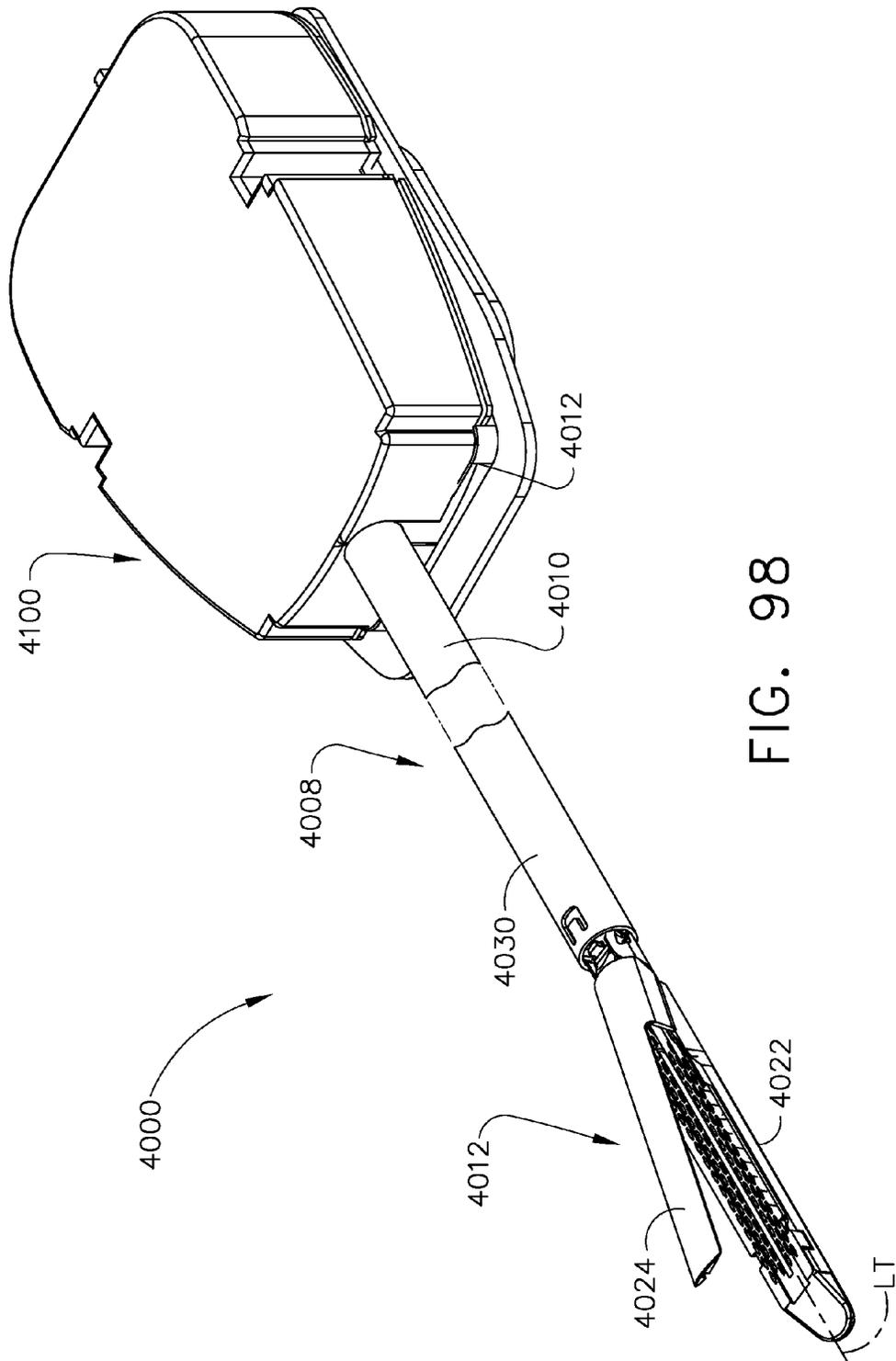


FIG. 98

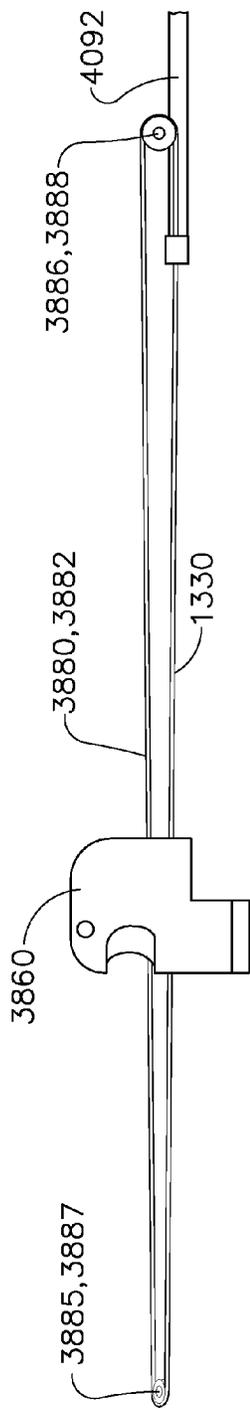


FIG. 99

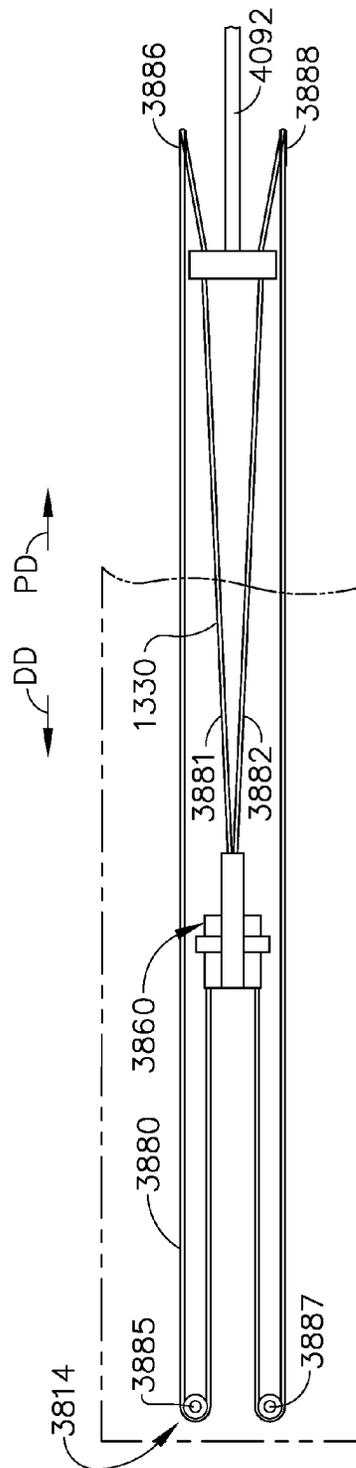
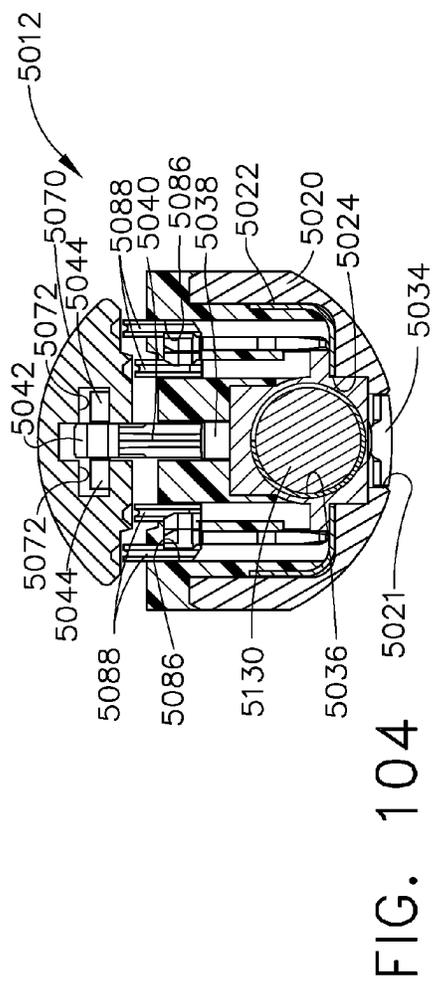
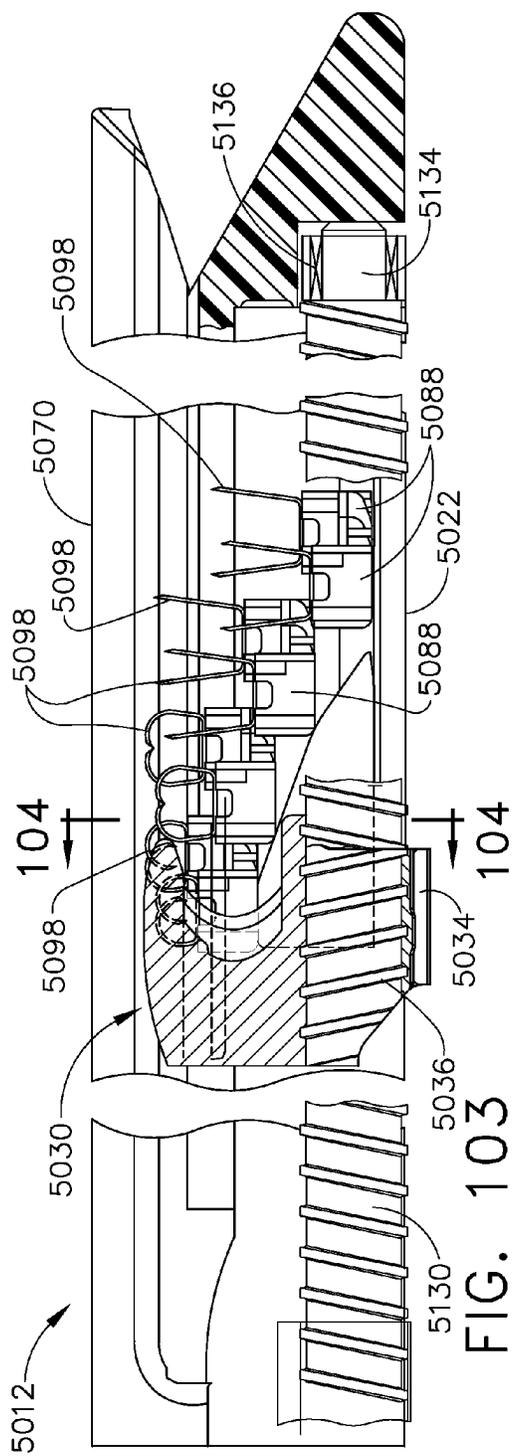


FIG. 100



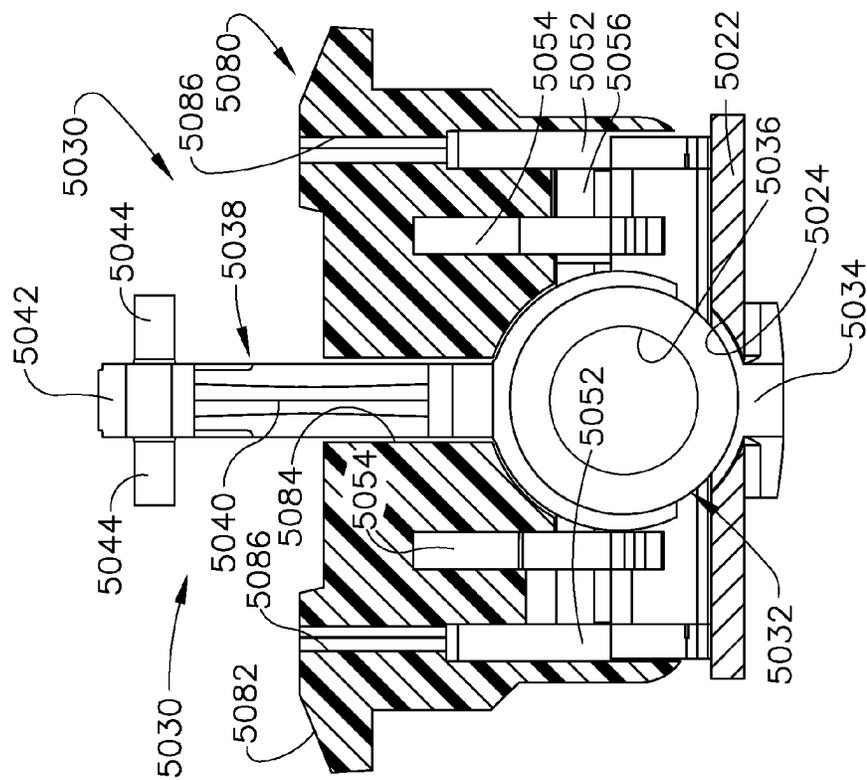


FIG. 108

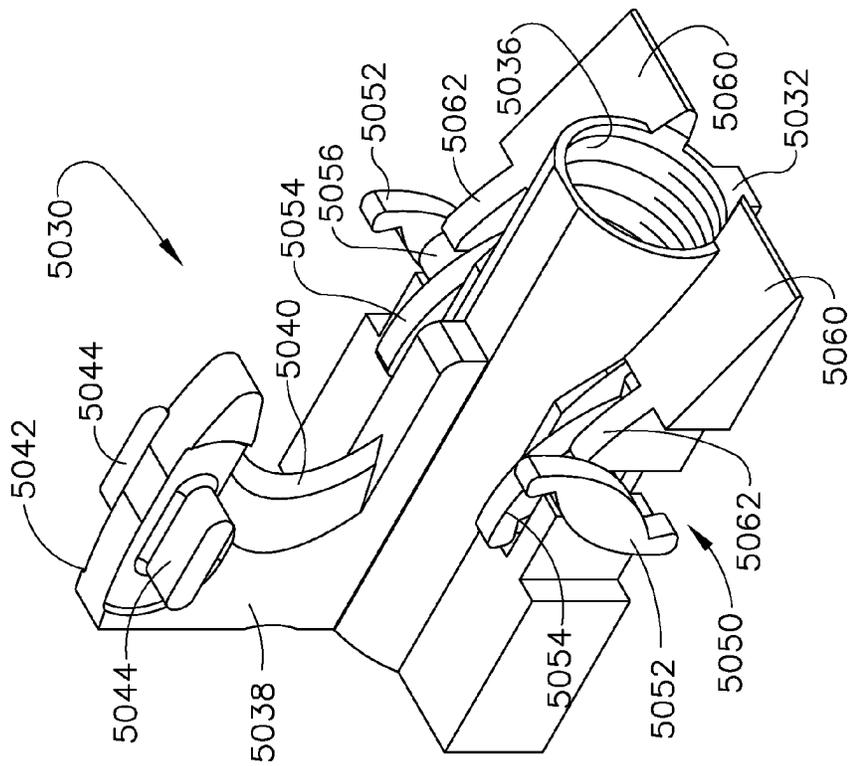


FIG. 107

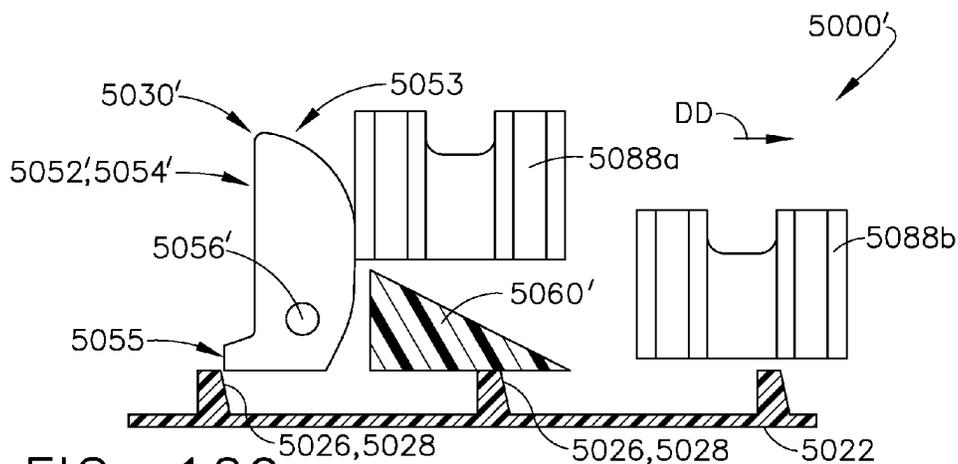


FIG. 109

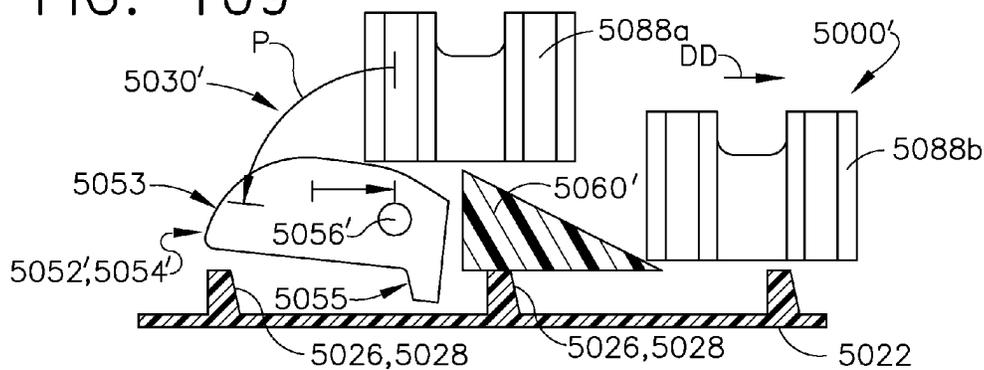


FIG. 110

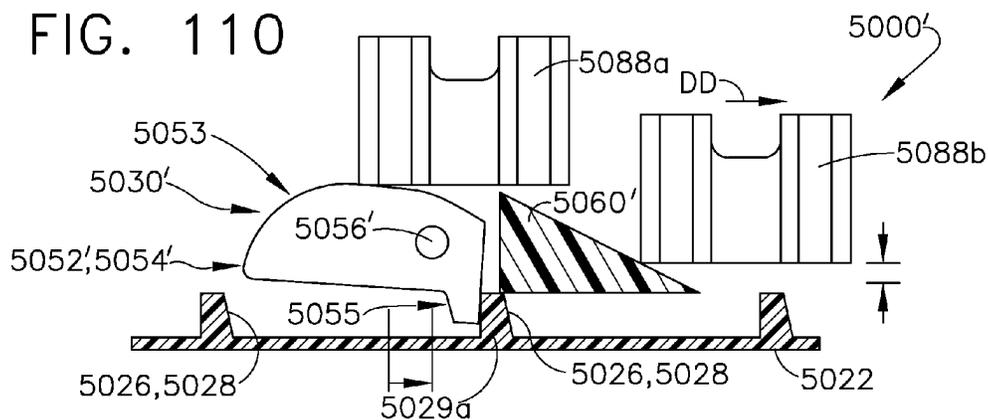


FIG. 111

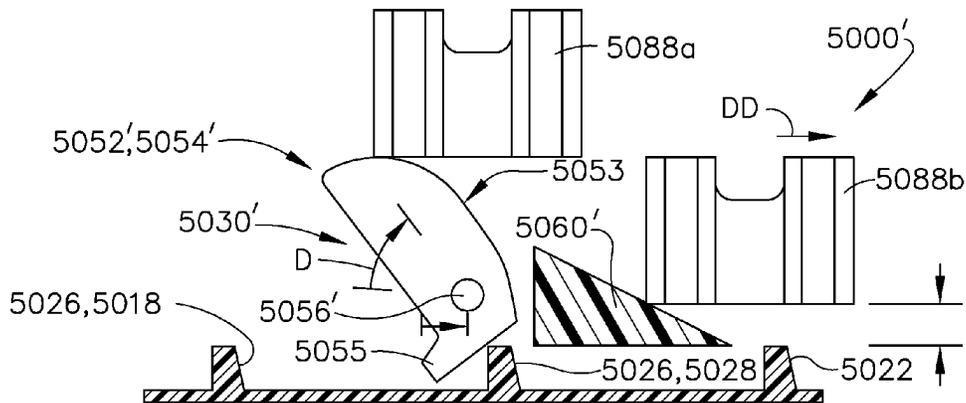


FIG. 112

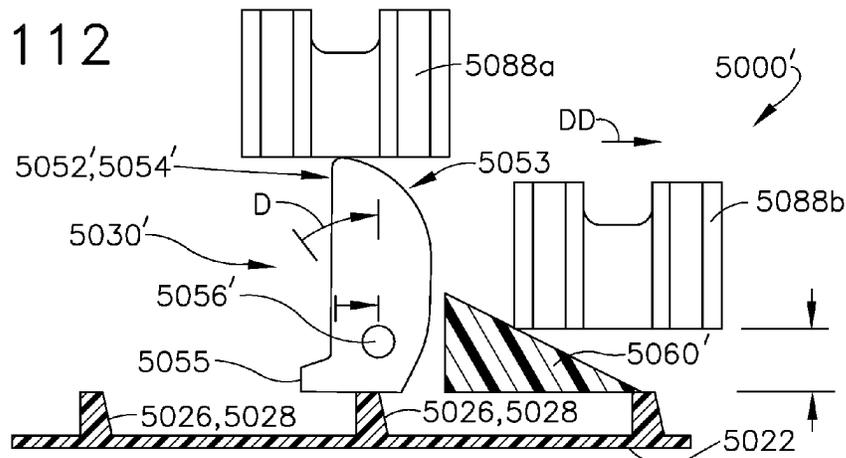


FIG. 113

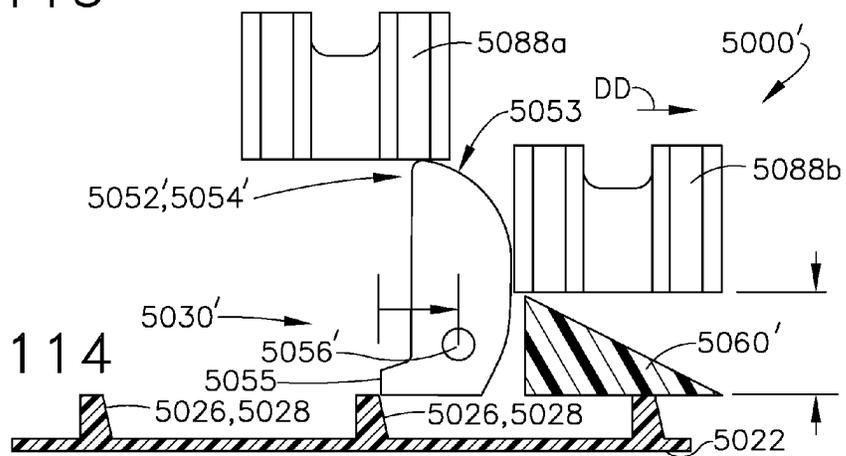


FIG. 114

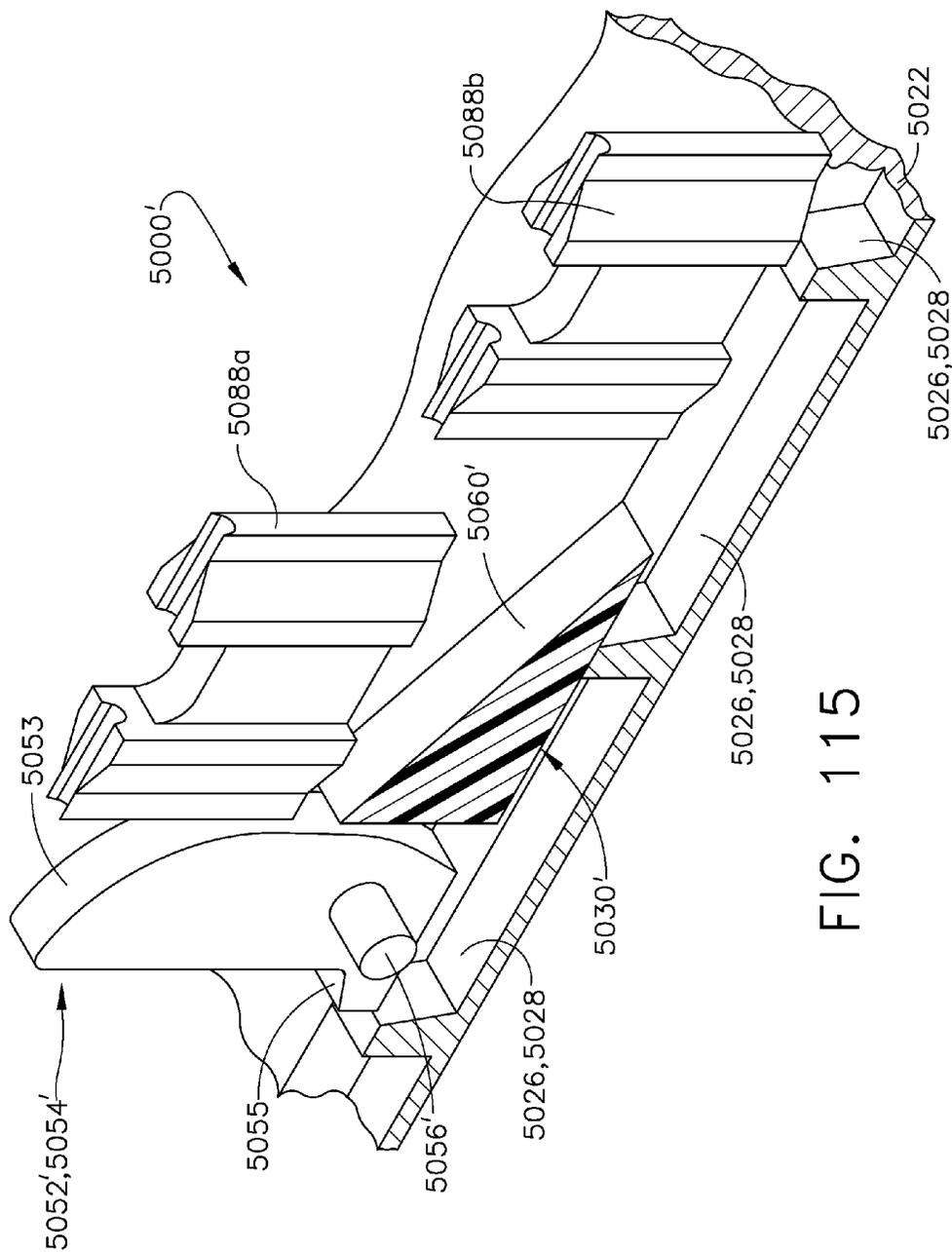


FIG. 115

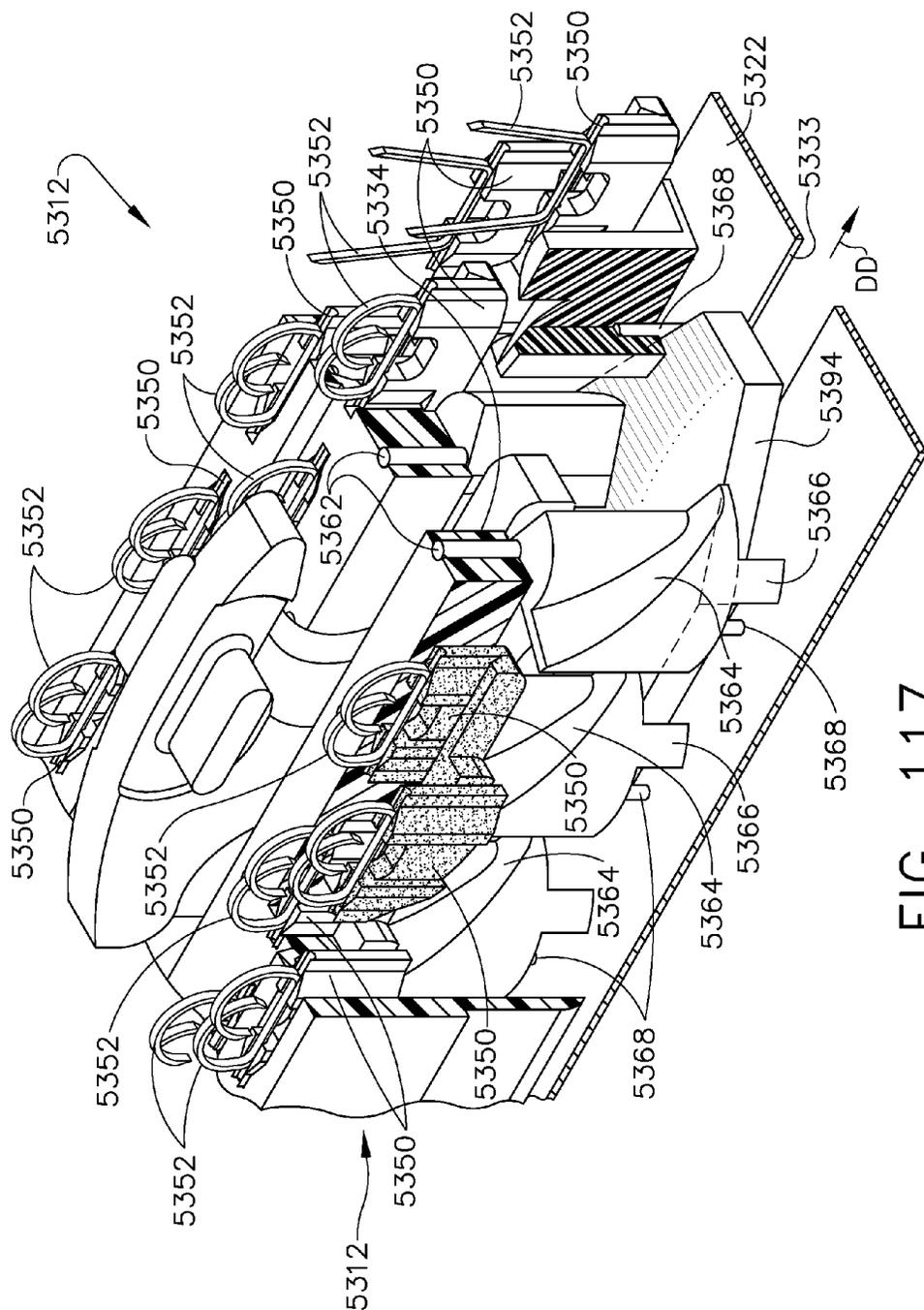


FIG. 117

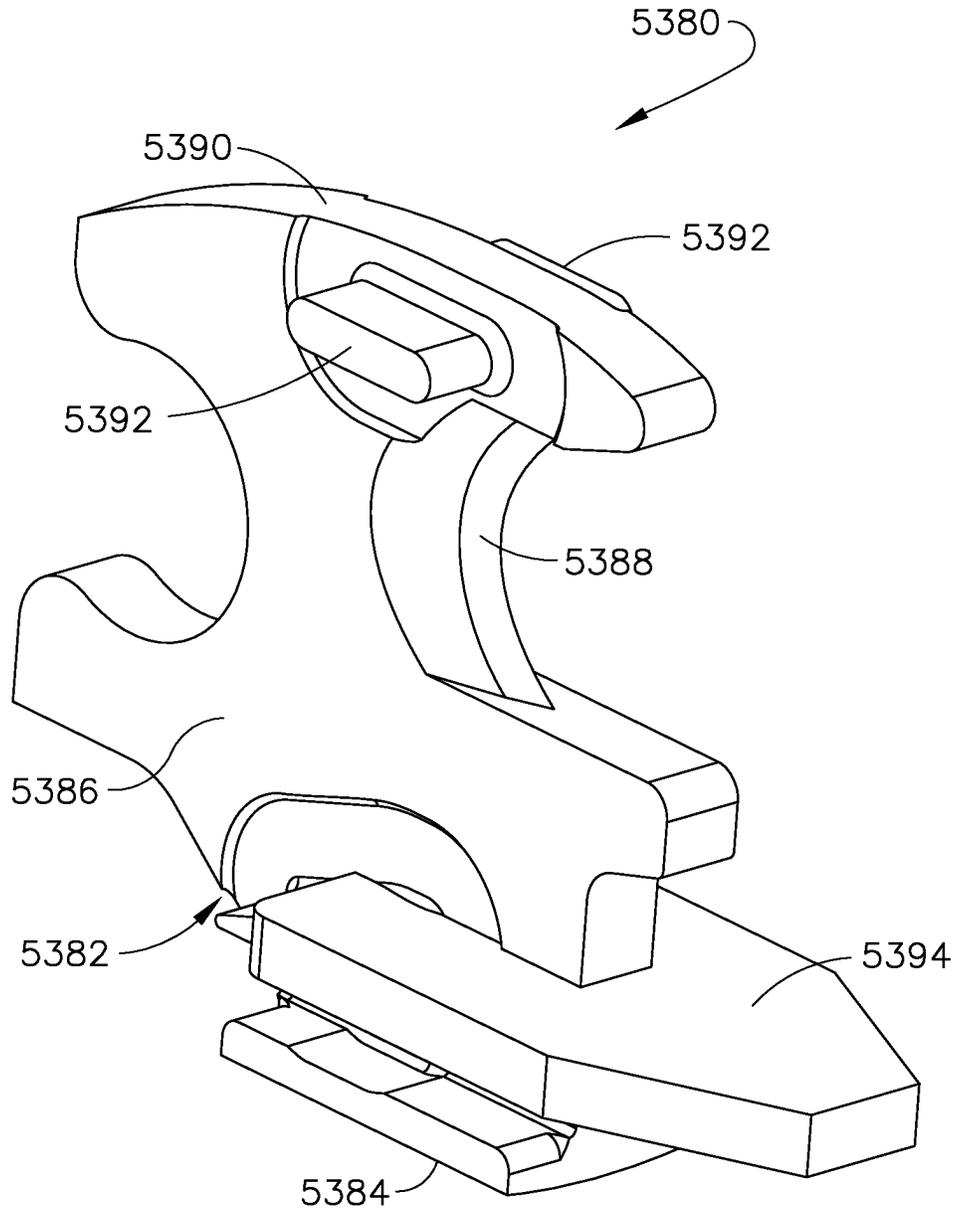


FIG. 118

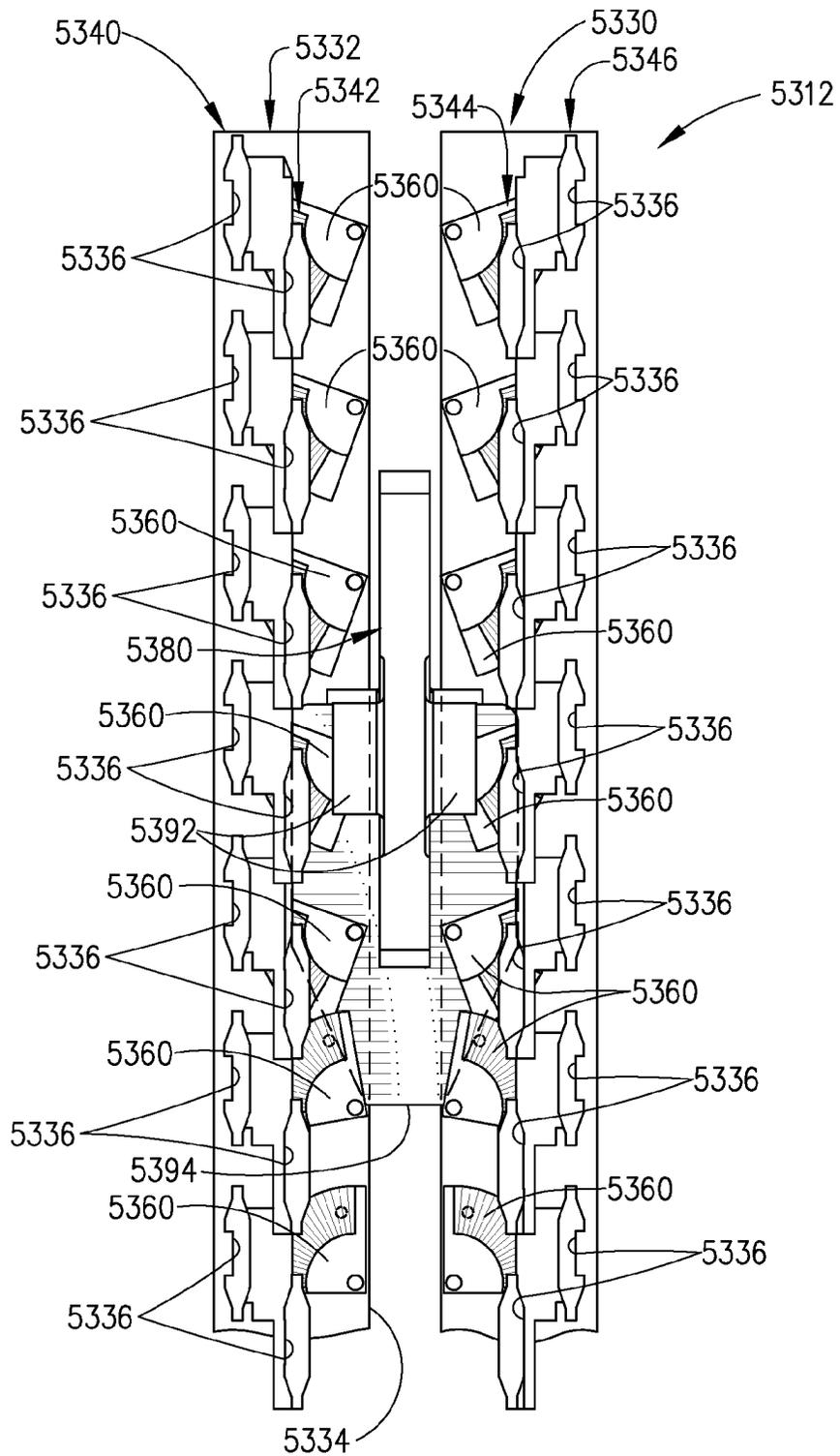


FIG. 119

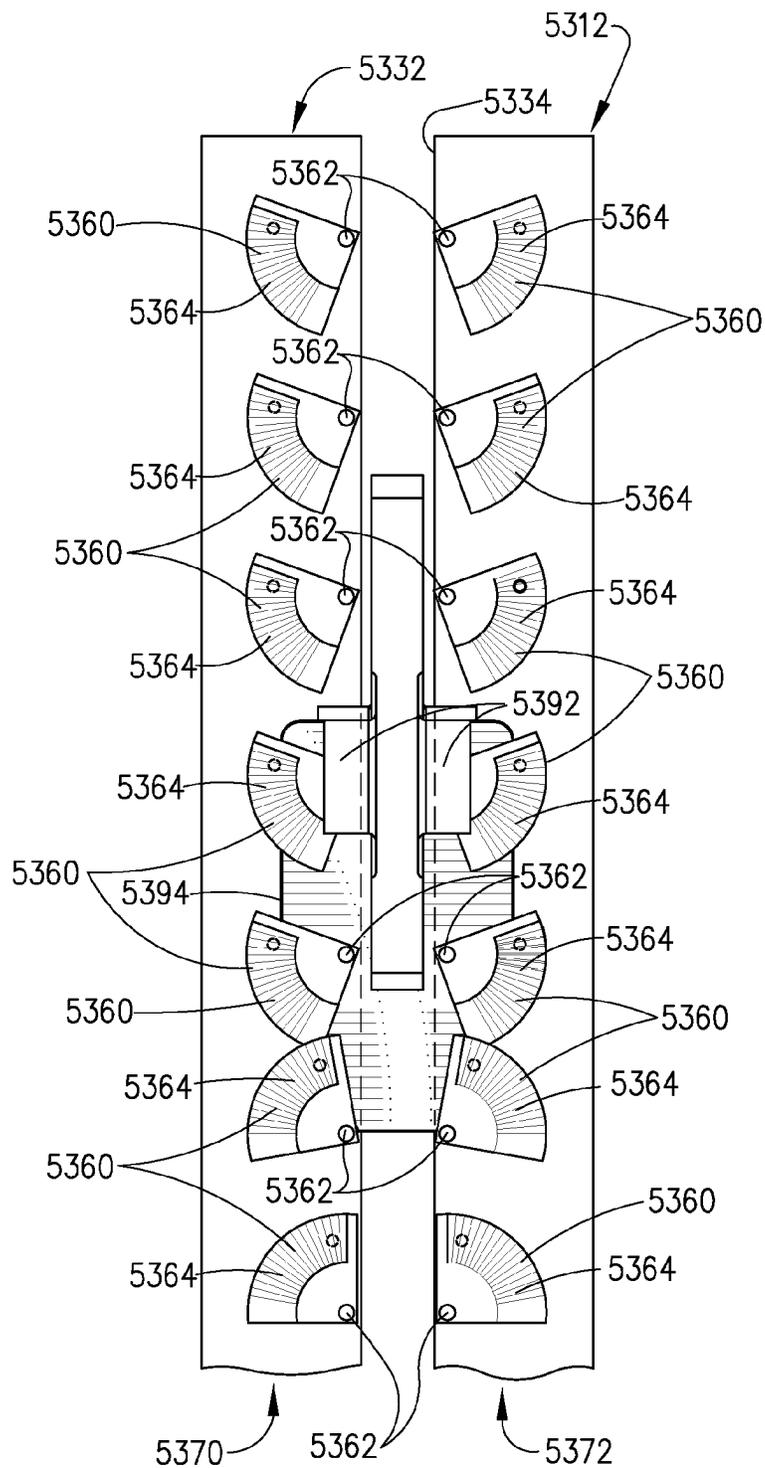


FIG. 120

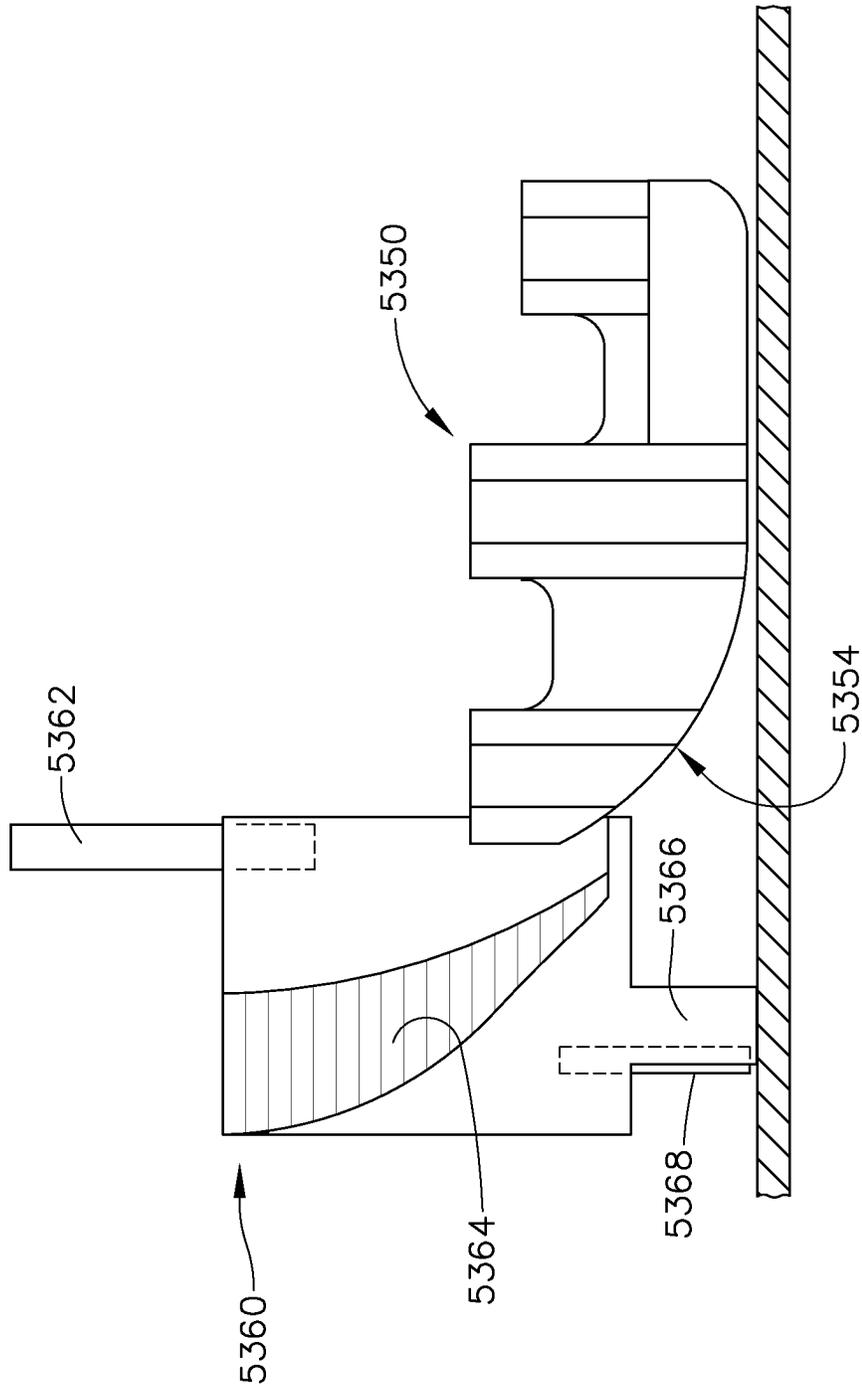


FIG. 121

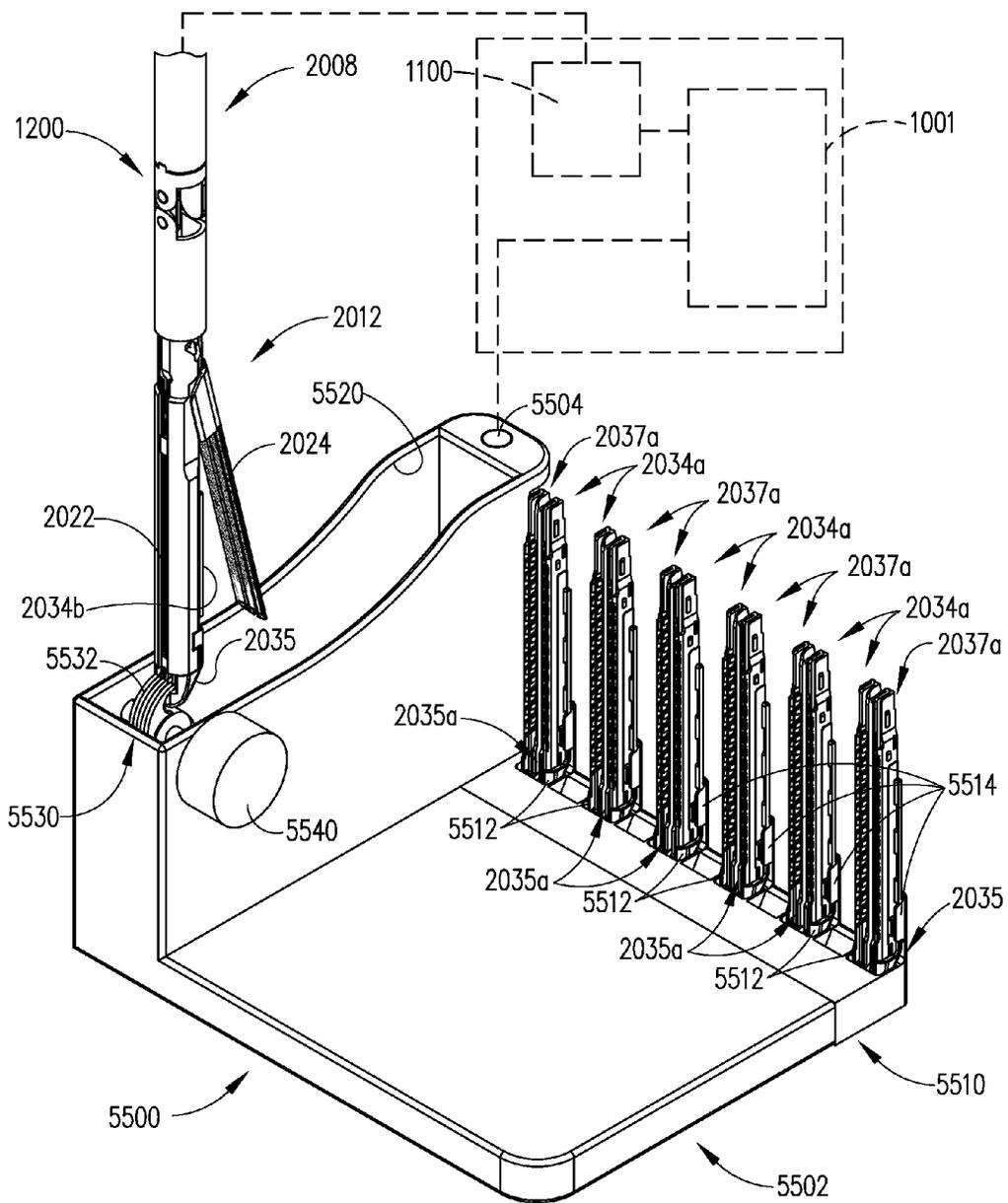


FIG. 122

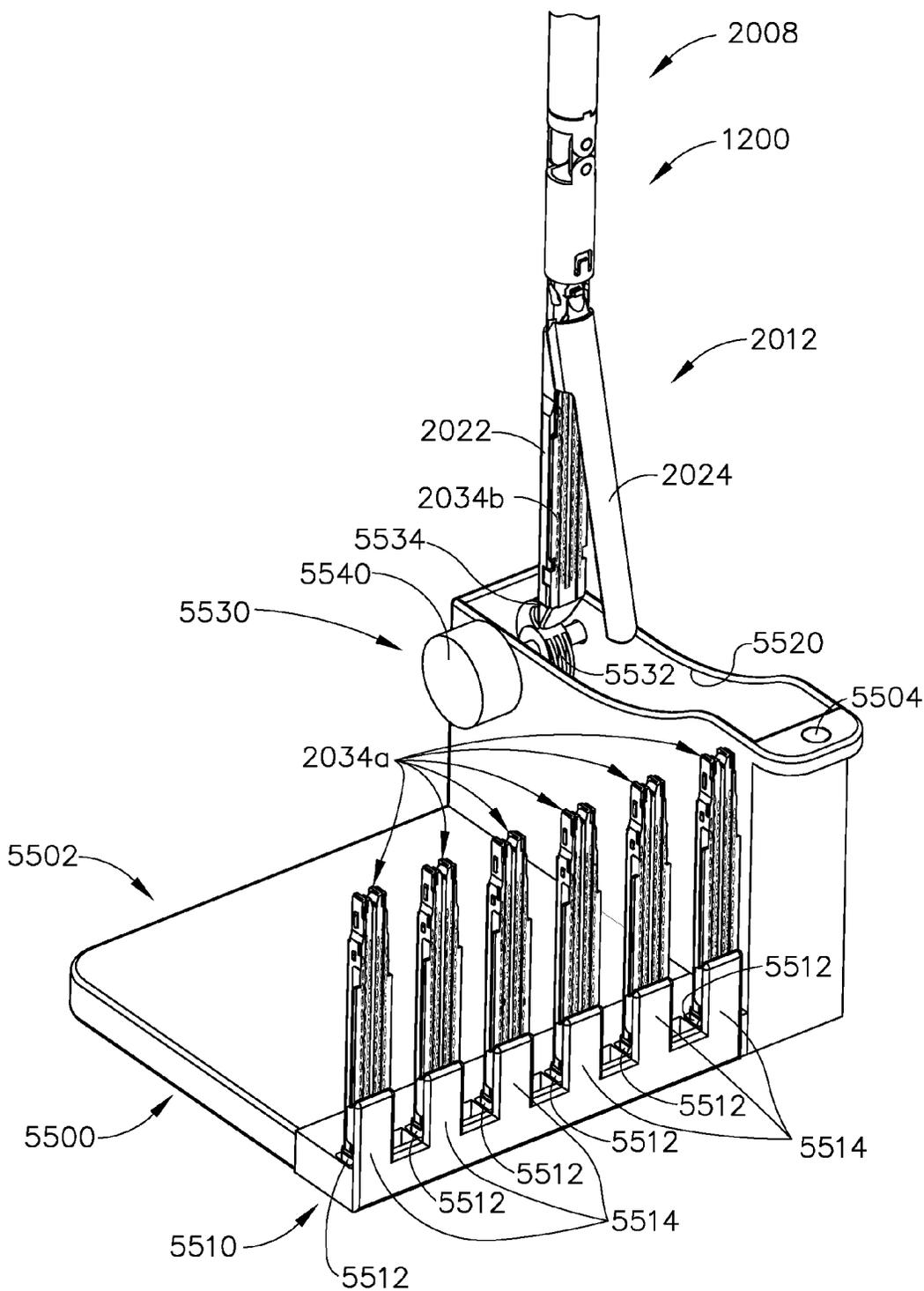
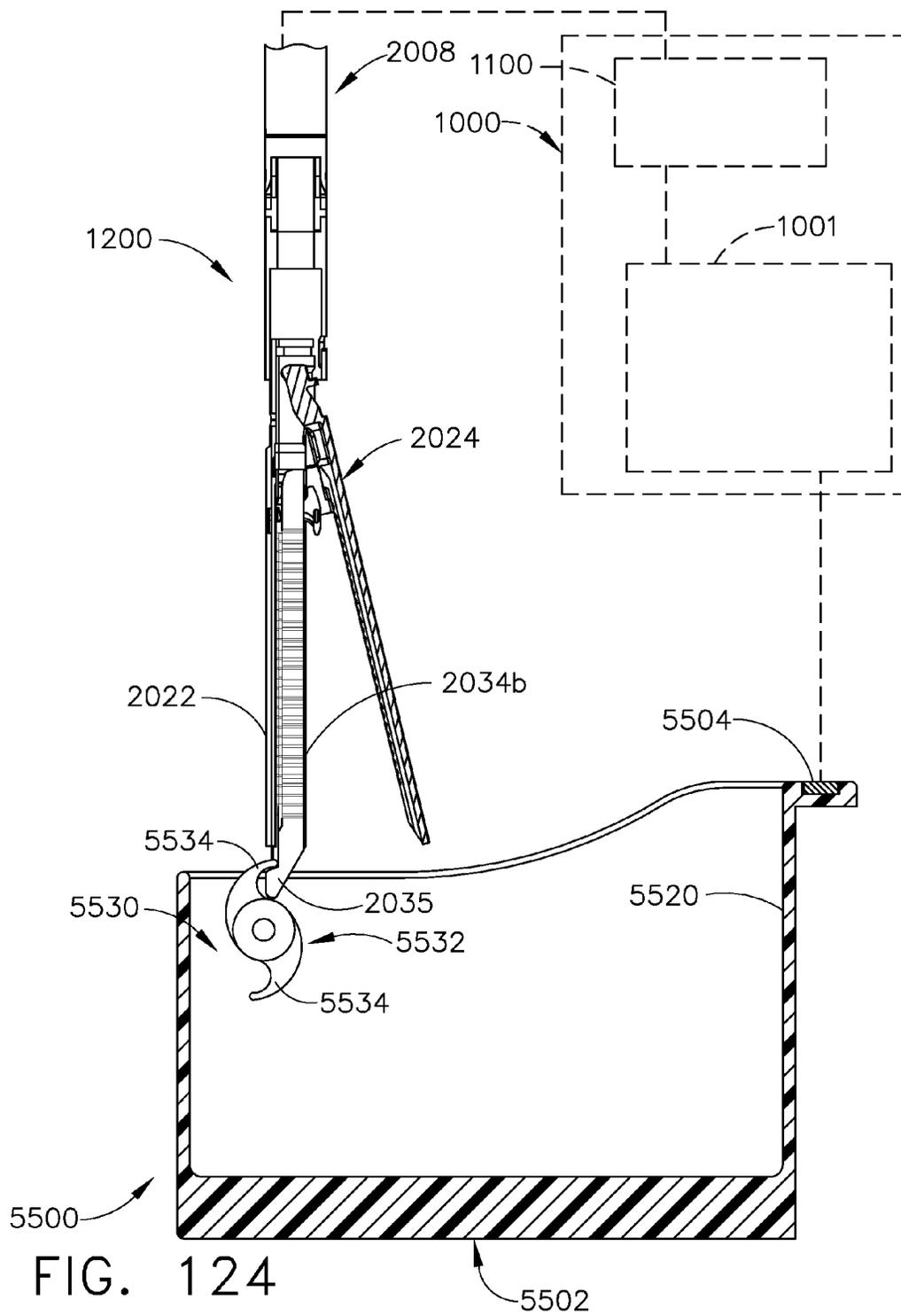
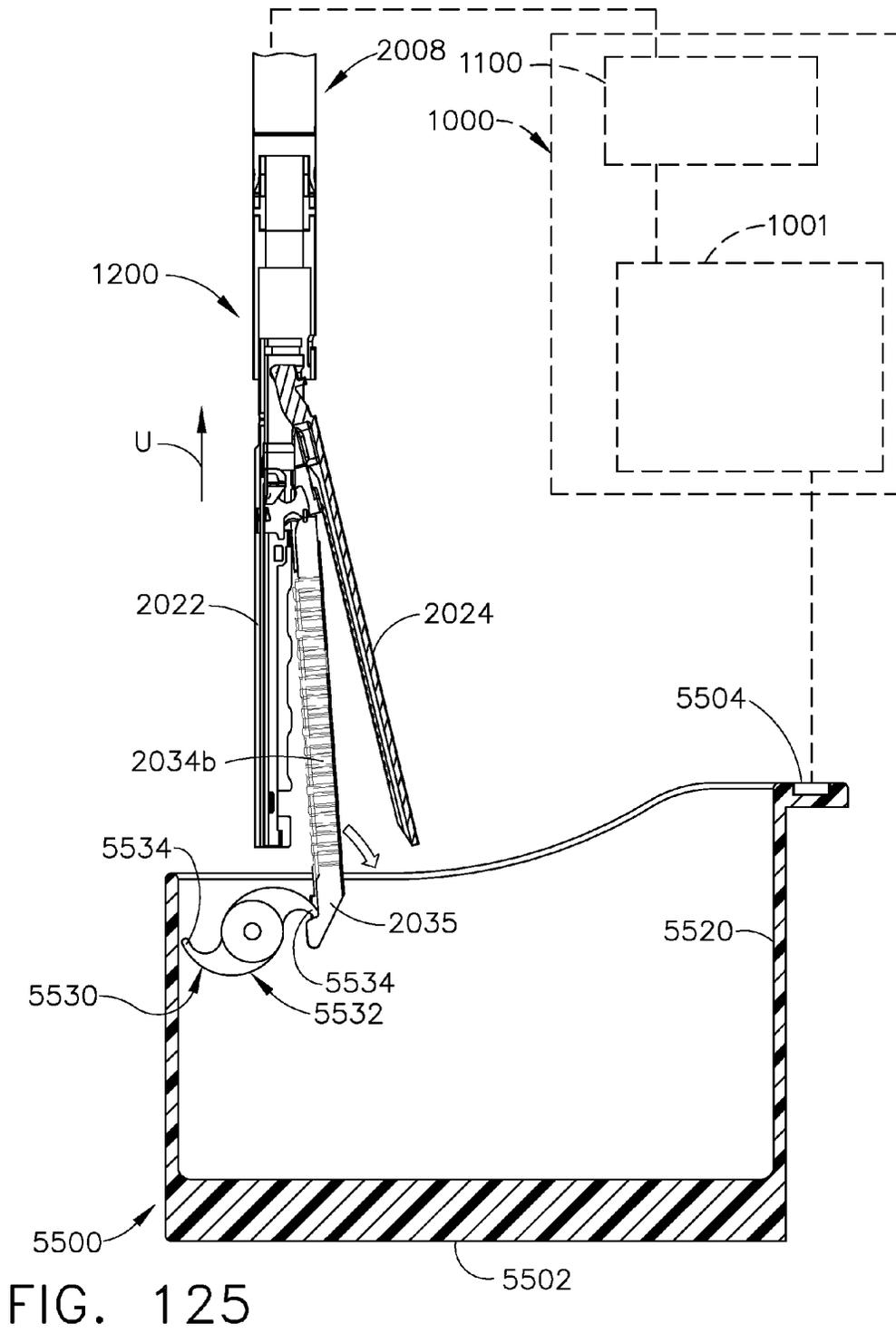
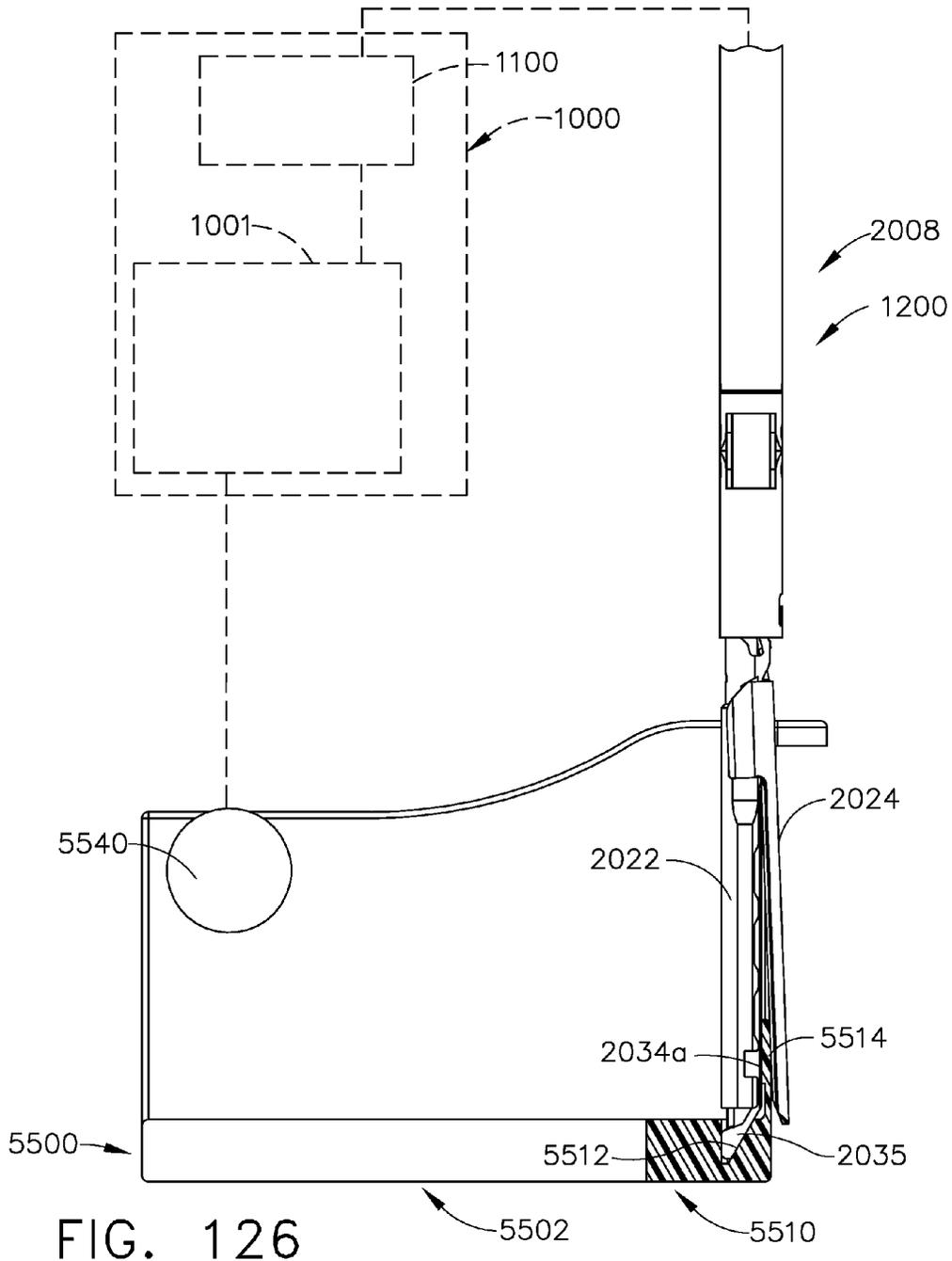
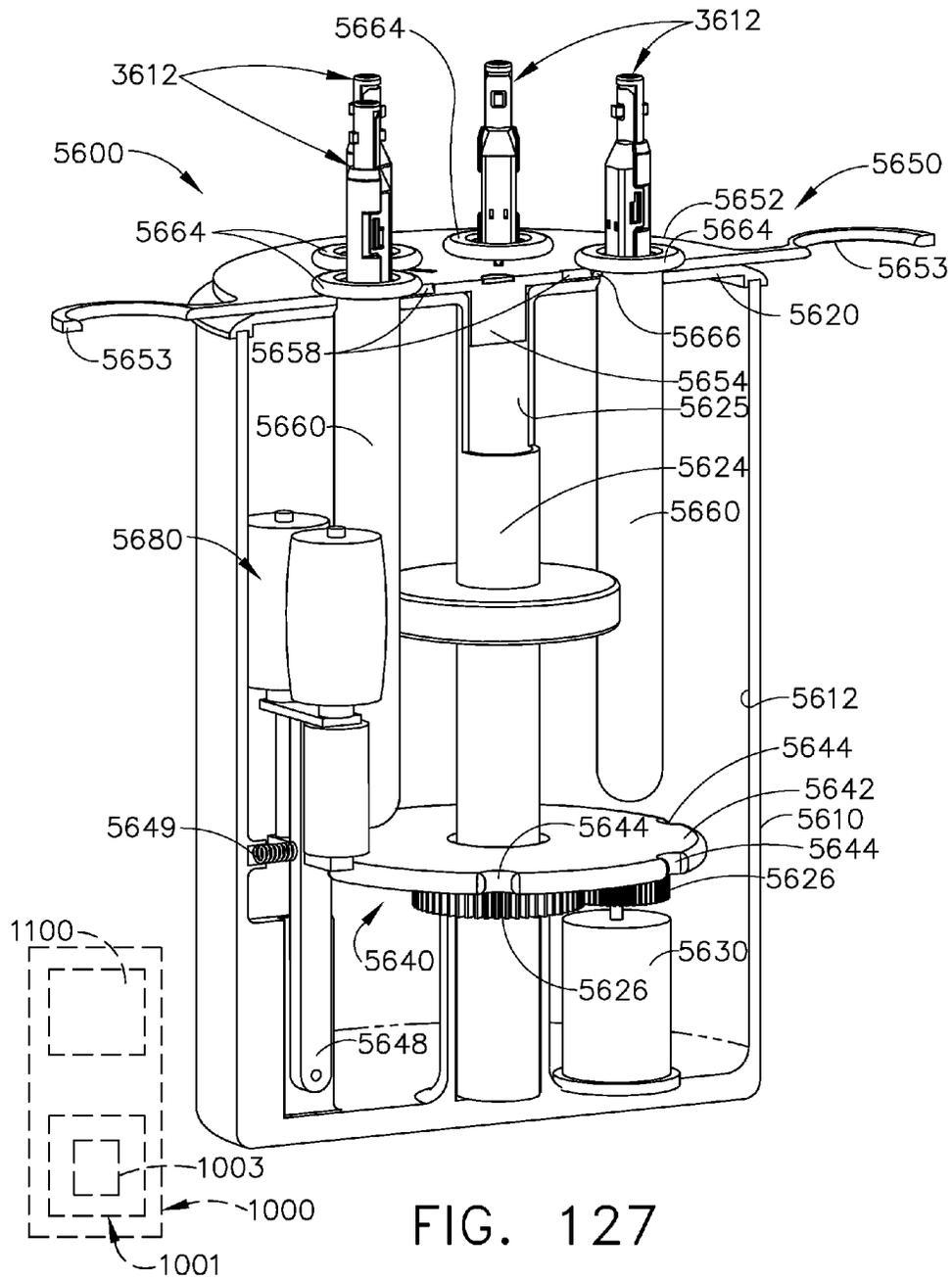


FIG. 123









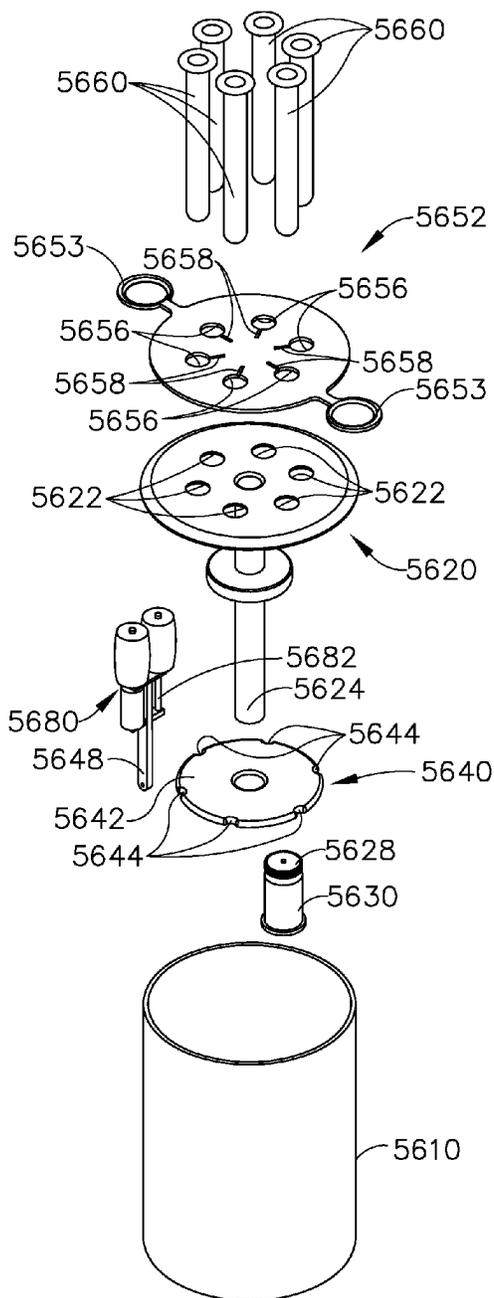


FIG. 128

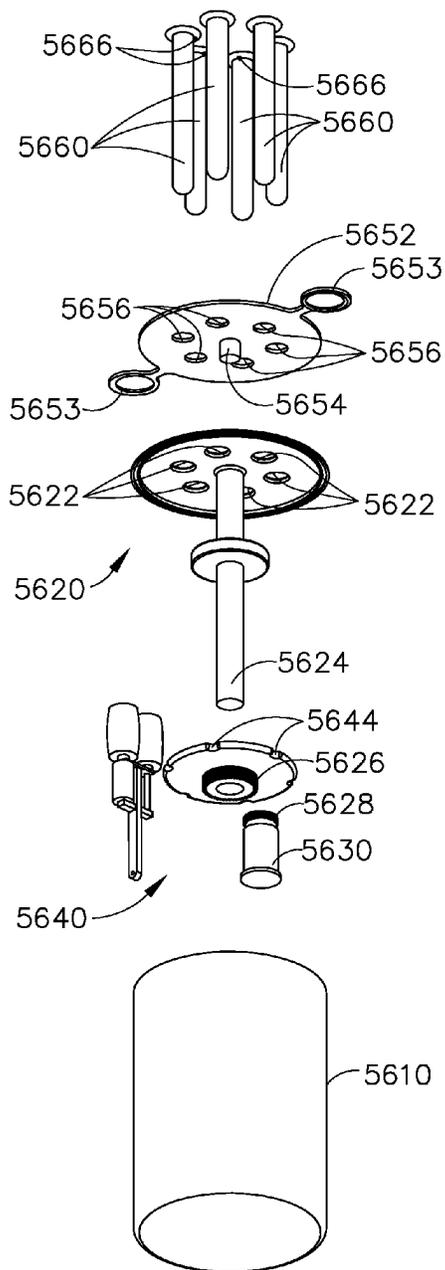


FIG. 129

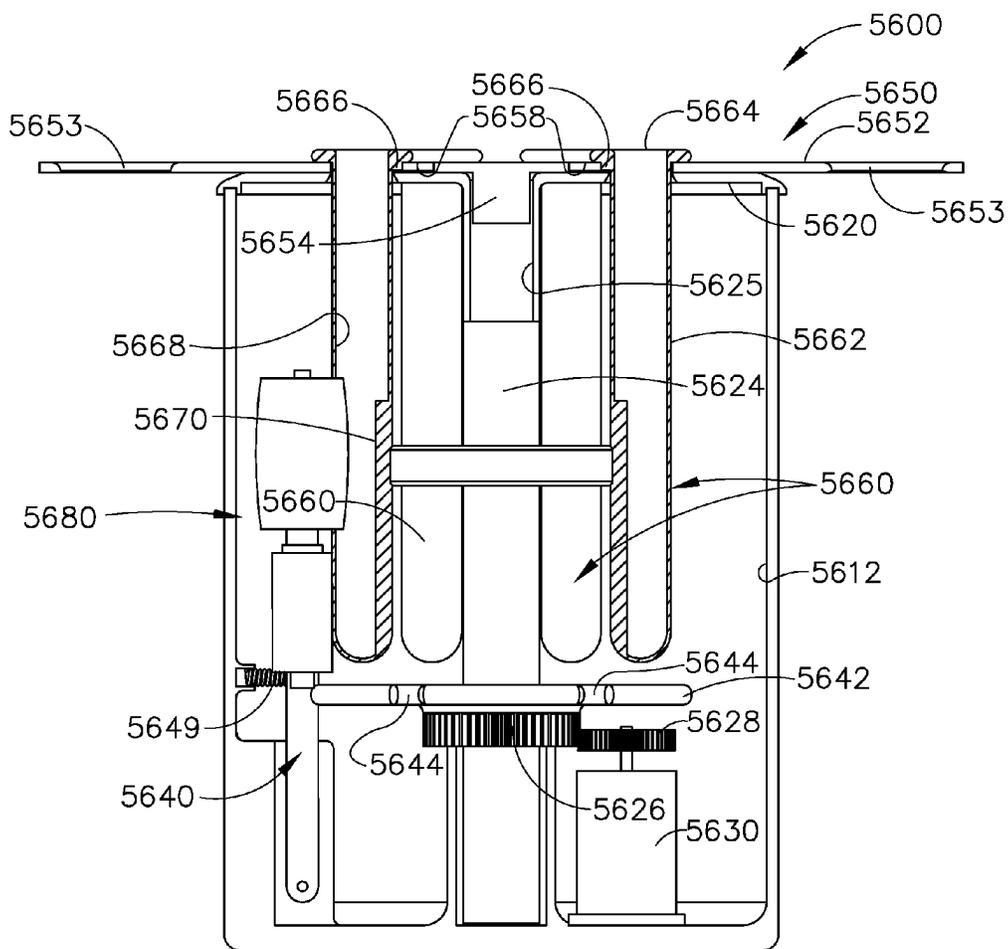


FIG. 130

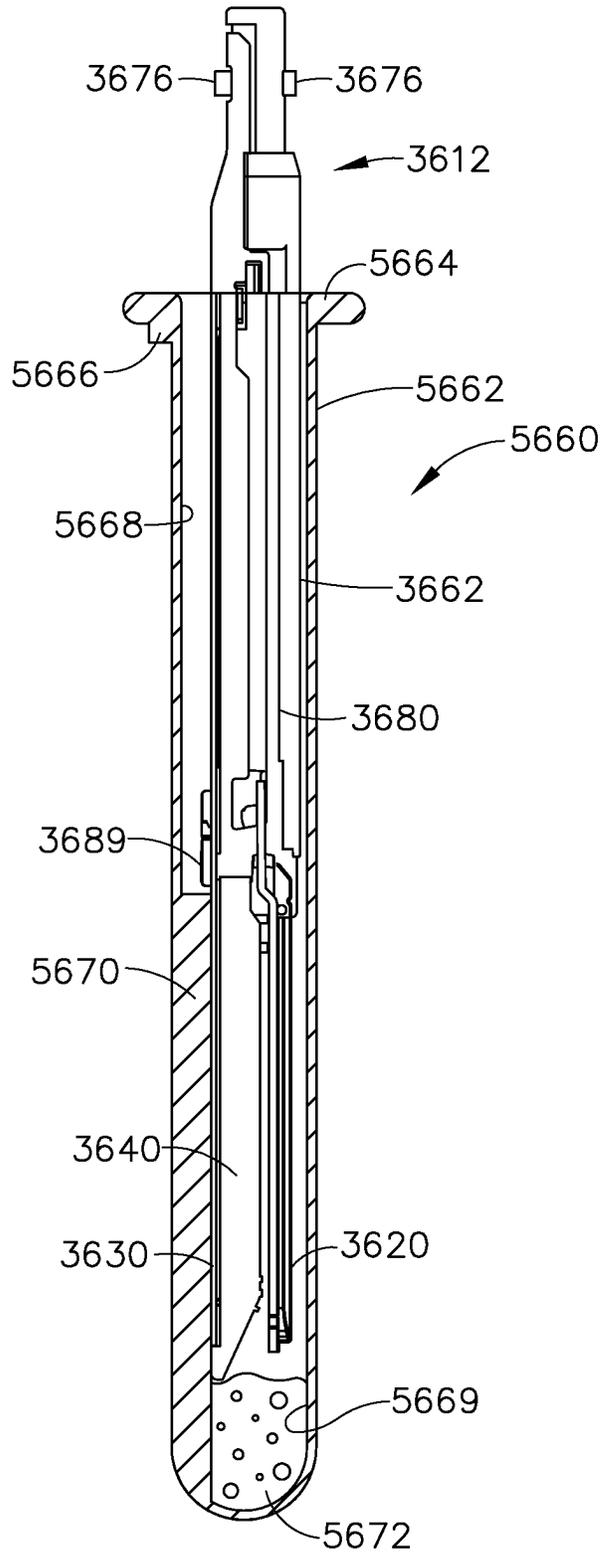


FIG. 131

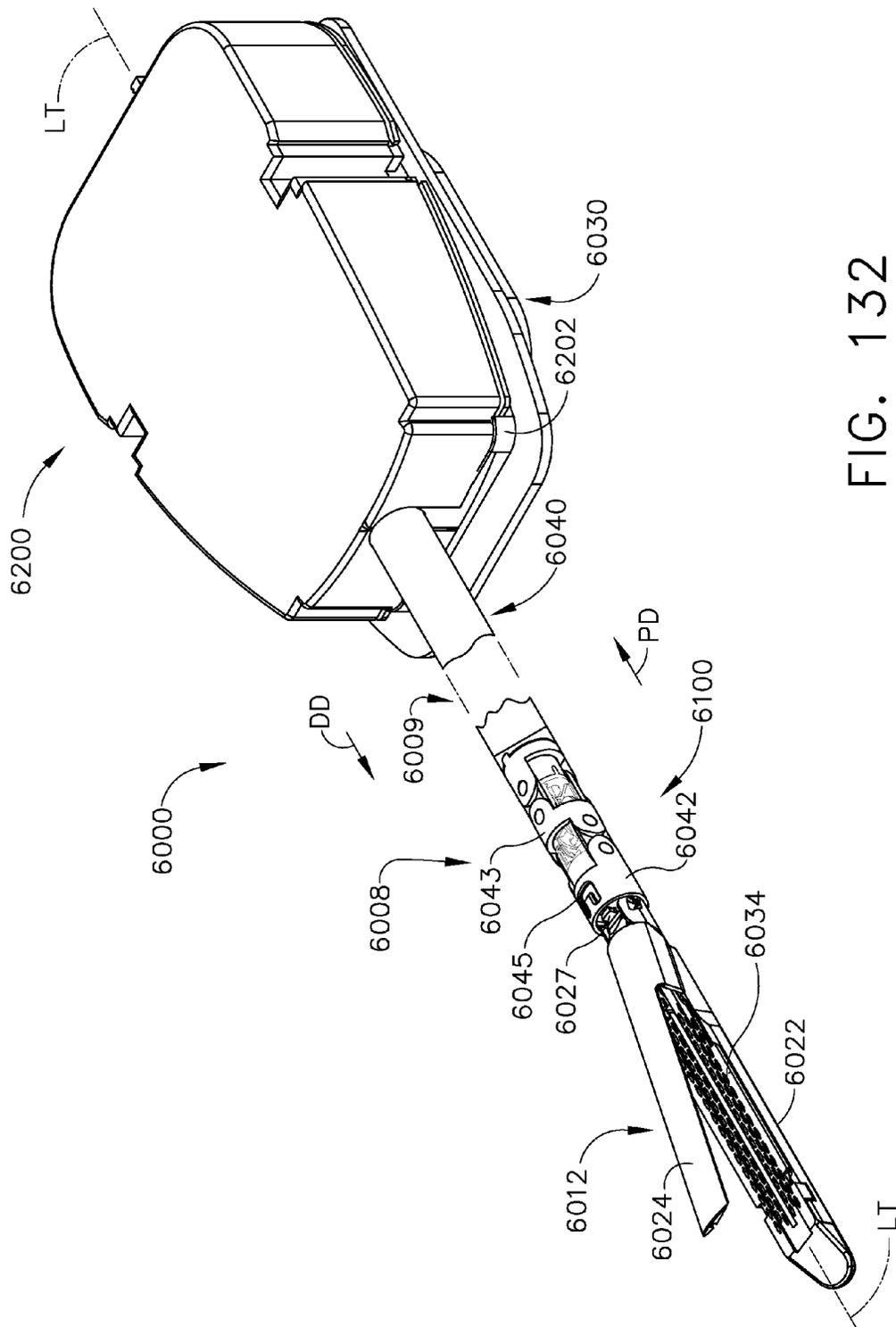


FIG. 132

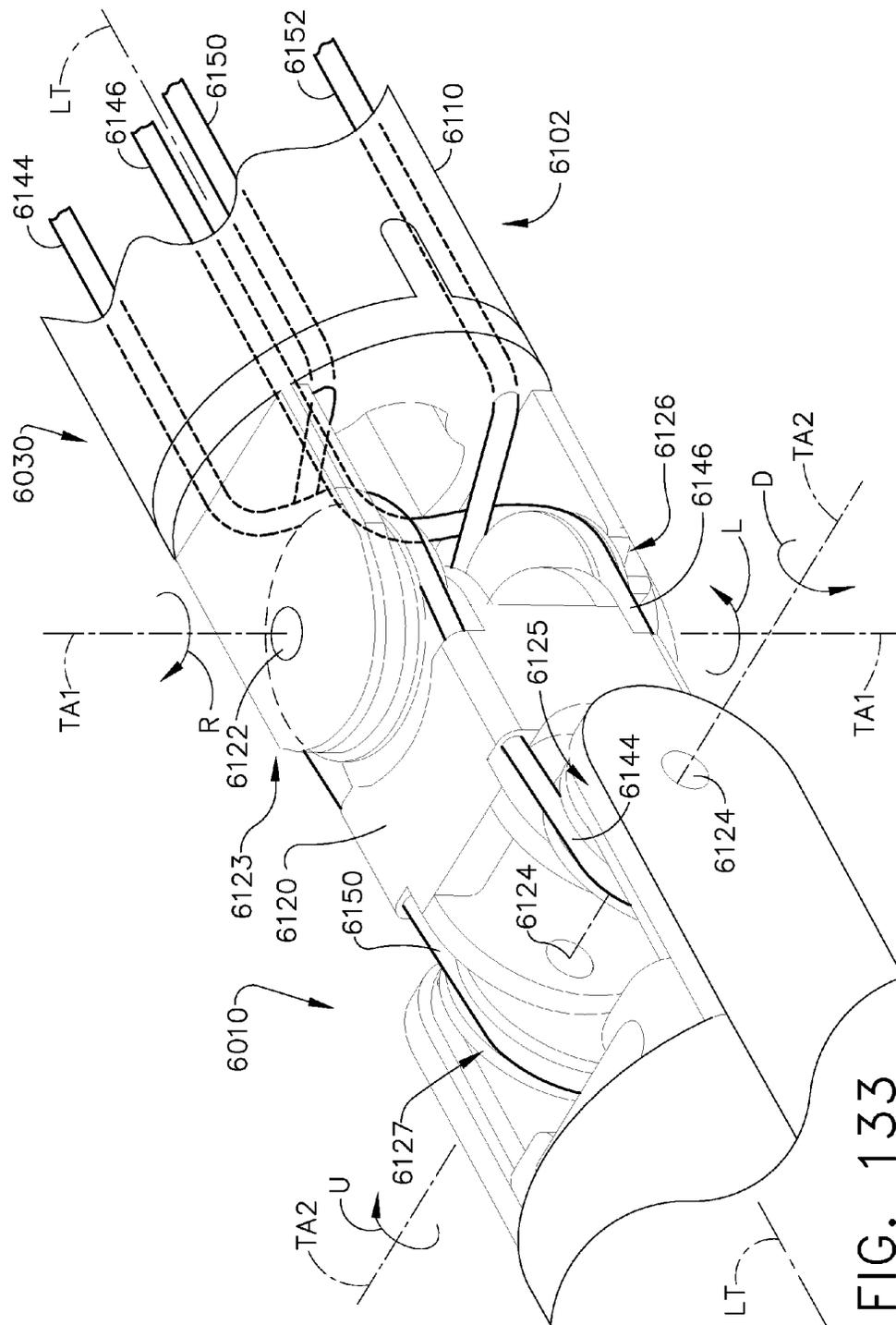


FIG. 133

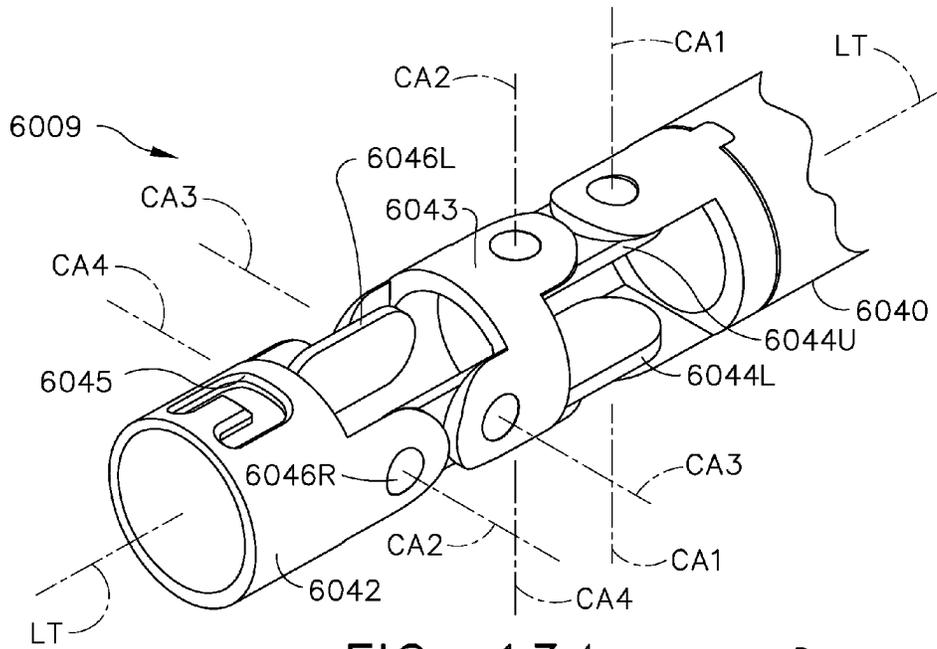


FIG. 134

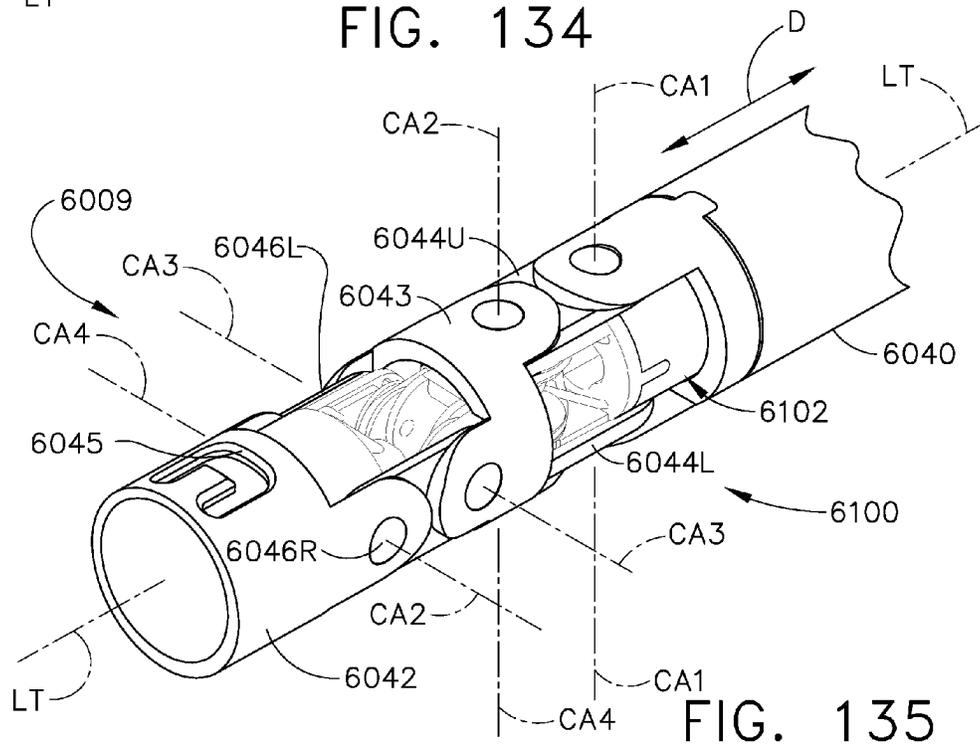


FIG. 135

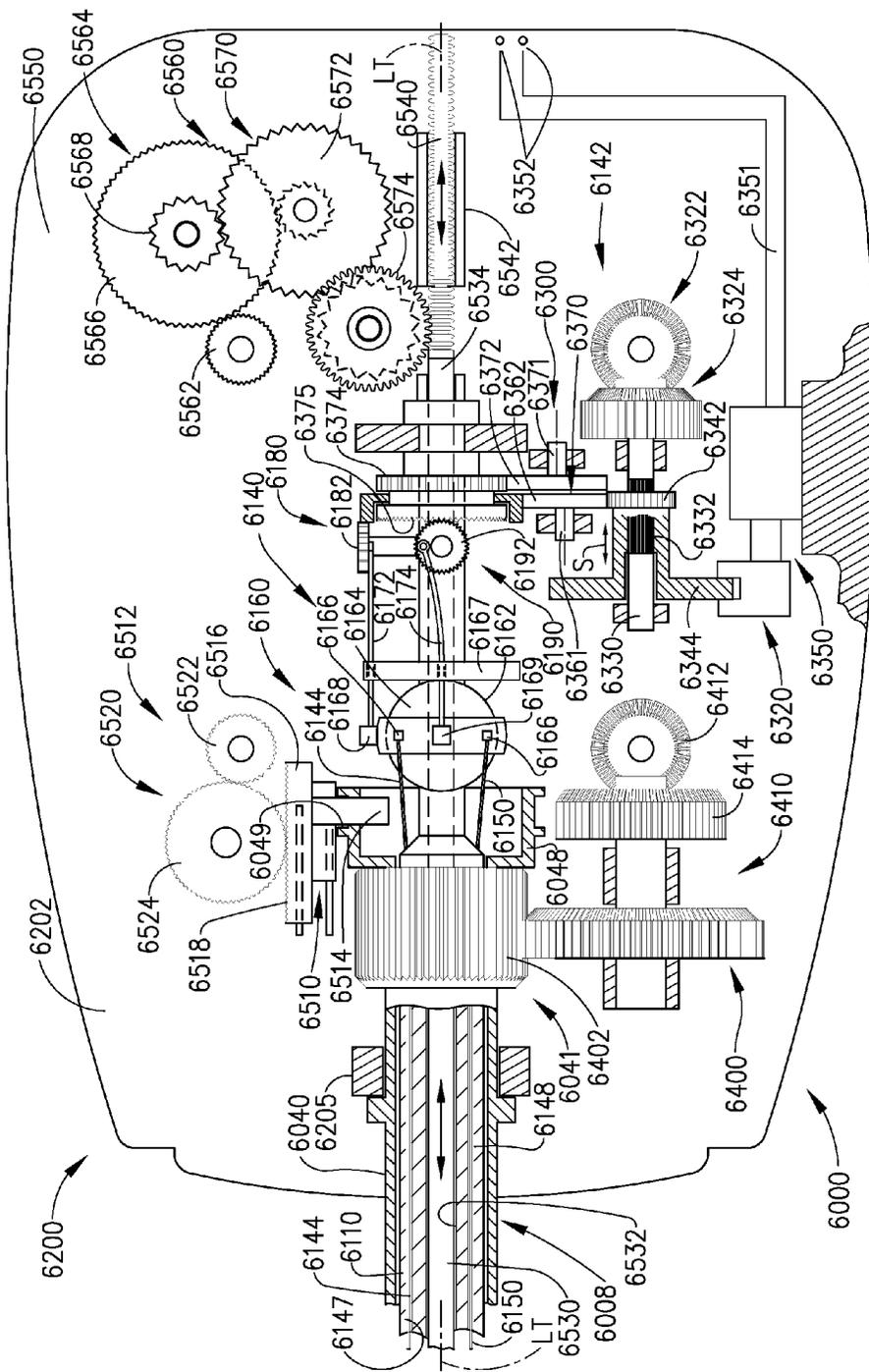


FIG. 136

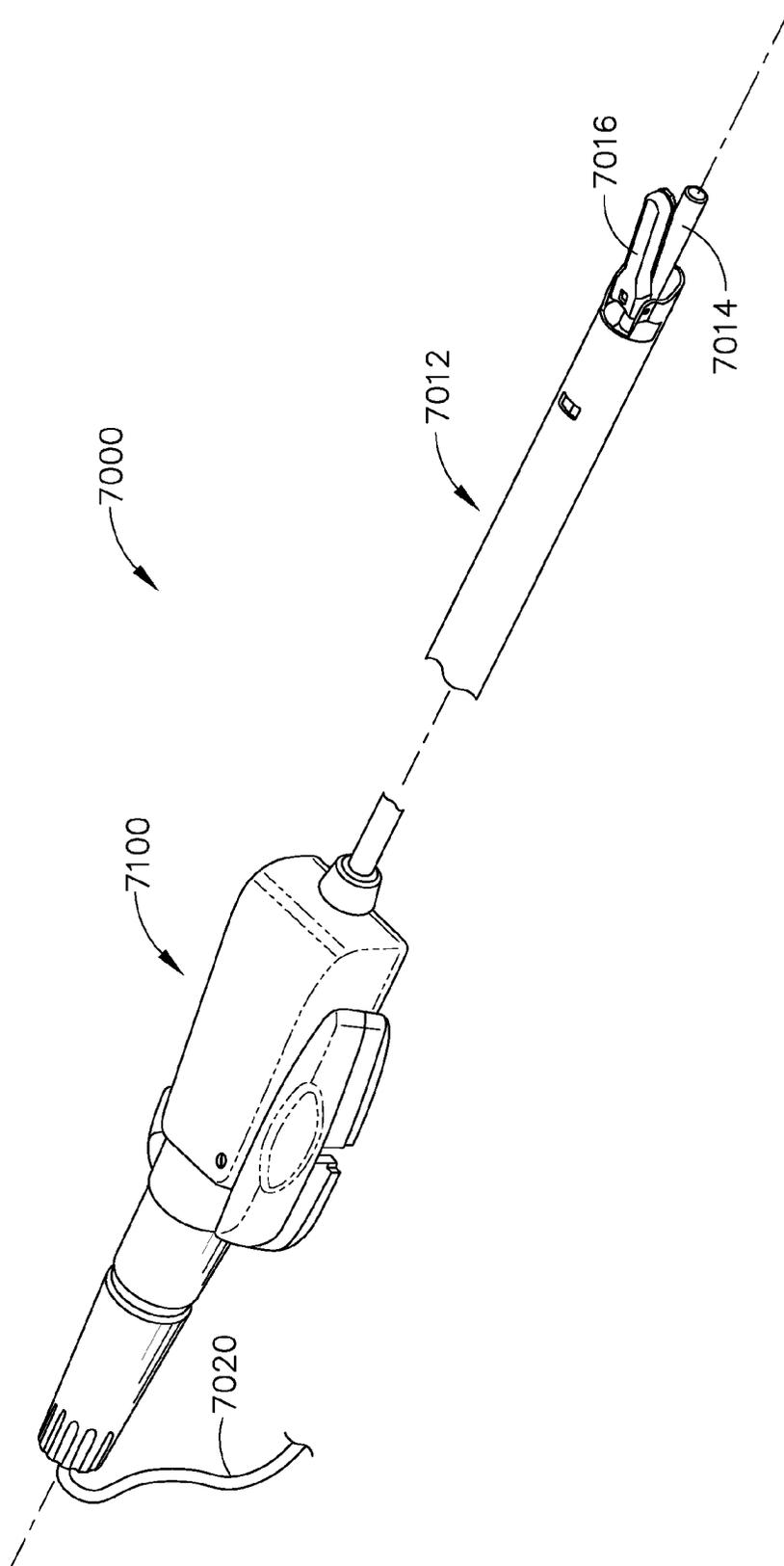


FIG. 138

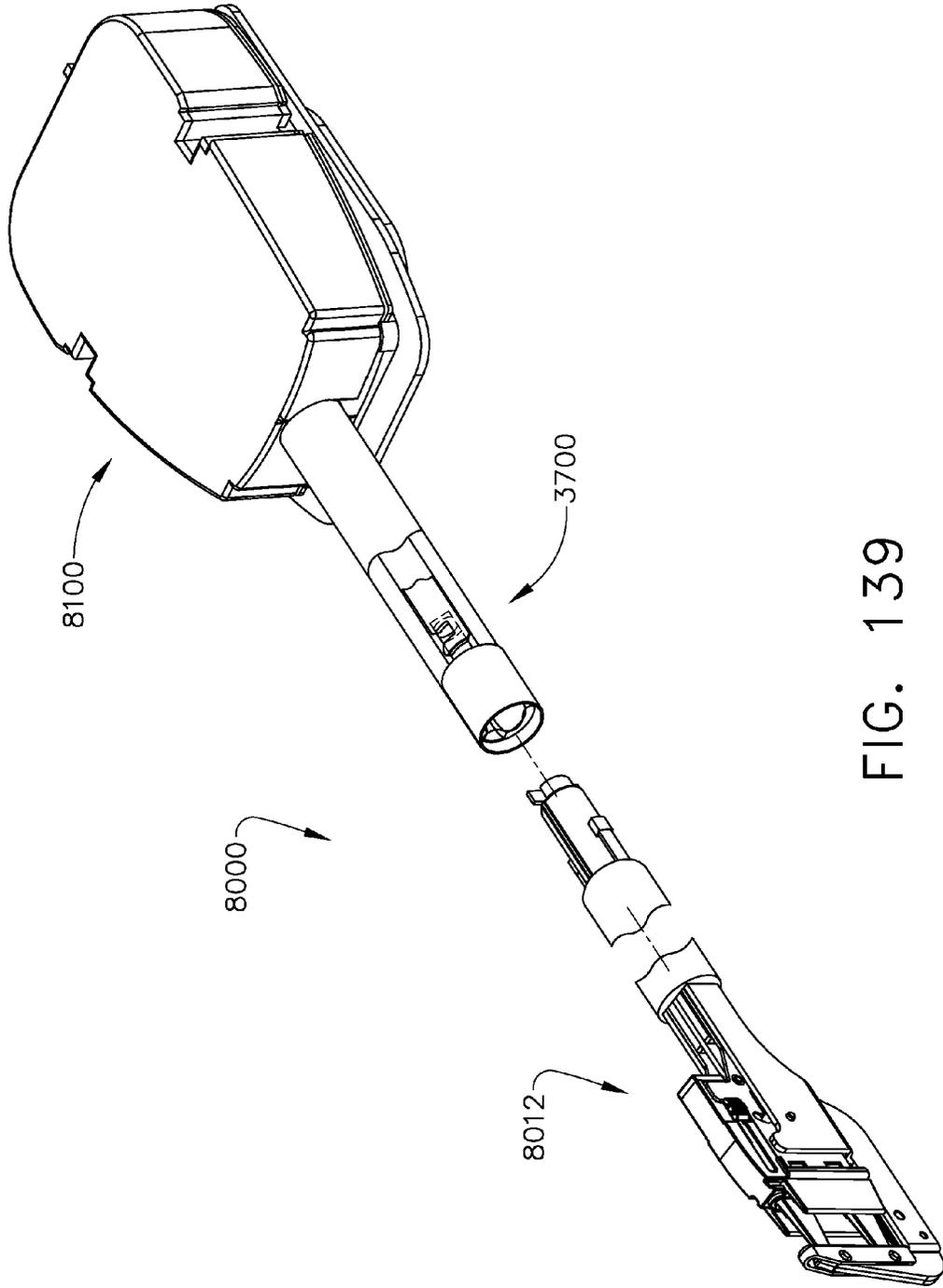


FIG. 139

1

**DRIVE INTERFACE FOR OPERABLY
COUPLING A MANIPULATABLE SURGICAL
TOOL TO A ROBOT**

CROSS REFERENCE TO RELATED
APPLICATIONS

The present application is a continuation patent application of and claims the benefit from U.S. patent application Ser. No. 13/118,259, filed May 27, 2011, U.S. Patent Publication No. 2011/0295270, entitled "Surgical Instrument With Wireless Communication Between A Control Unit of a Robotic System and Remote Sensor", the entire disclosure of which is hereby incorporated by reference and which is a continuation-in-part patent application and claims the benefit from U.S. patent application Ser. No. 11/651,807, entitled "Surgical Instrument With Wireless Communication Between Control Unit and Remote Sensor", filed Jan. 10, 2007, U.S. Patent Publication No. US 2008/0167672 A1, the disclosure of which is hereby incorporated by reference in its entirety and which is related to the following U.S. patent applications, which are also incorporated herein by reference in their respective entireties:

(1) U.S. patent application Ser. No. 11/651,715, filed Jan. 10, 2007, U.S. Patent Application Publication No. US-2008/0167522, entitled "SURGICAL INSTRUMENT WITH WIRELESS COMMUNICATION BETWEEN CONTROL UNIT AND SENSOR TRANSPONDERS," by J. Giordano et al.;

(2) U.S. patent application Ser. No. 11/651,806, filed Jan. 10, 2007, now U.S. Pat. No. 7,954,682, entitled "SURGICAL INSTRUMENT WITH ELEMENTS TO COMMUNICATE BETWEEN CONTROL UNIT AND END EFFECTOR," by J. Giordano et al.;

(3) U.S. patent application Ser. No. 11/651,768, filed Jan. 10, 2007, now U.S. Pat. No. 7,721,931, entitled "PREVENTION OF CARTRIDGE REUSE IN A SURGICAL INSTRUMENT," by F. Shelton et al.;

(4) U.S. patent application Ser. No. 11/651,771, filed Jan. 10, 2007, now U.S. Pat. No. 7,738,971, entitled "POST-STERILIZATION PROGRAMMING OF SURGICAL INSTRUMENTS," by J. Swayze et al.;

(5) U.S. patent application Ser. No. 11/651,788, filed Jan. 10, 2007, now U.S. Pat. No. 7,721,936, entitled "INTERLOCK AND SURGICAL INSTRUMENT INCLUDING SAME," by F. Shelton et al.; and

(6) U.S. patent application Ser. No. 11/651,785, filed Jan. 10, 2007, now U.S. Pat. No. 7,900,805, entitled "SURGICAL INSTRUMENT WITH ENHANCED BATTERY PERFORMANCE," by F. Shelton et al.

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

2

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 receives a staple cartridge having 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 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.

An example of a surgical stapler suitable for endoscopic applications is described in U.S. Pat. No. 5,465,895, which discloses an endocutter with distinct closing and firing actions. A clinician using this device is able to close the jaw members upon tissue to position the tissue prior to firing. Once the clinician has determined that the jaw members are properly gripping tissue, the clinician can then fire the surgical stapler with a single firing stroke, thereby severing and stapling the tissue. The simultaneous severing and stapling avoids complications that may arise when performing such actions sequentially with different surgical tools that respectively only sever and staple.

One specific advantage of being able to close upon tissue before firing is that the clinician is able to verify via an endoscope that the desired location for the cut has been achieved, including that a sufficient amount of tissue has been captured between opposing jaws. Otherwise, opposing jaws may be drawn too close together, especially pinching at their distal ends, and thus not effectively forming closed staples in the severed tissue. At the other extreme, an excessive amount of clamped tissue may cause binding and an incomplete firing.

Endoscopic staplers/cutters continue to increase in complexity and function with each generation. One of the main reasons for this is the quest to lower force-to-fire (FTF) to a level that all or a great majority of surgeons can handle. One known solution to lower FTF it use CO₂ or electrical motors. These devices have not fared much better than traditional hand-powered devices, but for a different reason. Surgeons typically prefer to experience proportionate force distribution to that being experienced by the end effector in the forming of the staple to assure them that the cutting/stapling cycle is complete, with the upper limit within the capabilities of most surgeons (usually around 15-30 lbs). They also typically want to maintain control of deploying the staples and being able to stop at anytime if the forces felt in the handle of the device feel too great or for some other clinical reason.

To address this need, so-called "power-assist" endoscopic surgical instruments have been developed in which a supplemental power source aids in the firing of the instrument. For example, in some power-assist devices, a motor provides supplemental electrical power to the power input by the user from squeezing the firing trigger. Such devices are capable of providing loading force feedback and control to the operator to reduce the firing force required to be exerted by the operator in order to complete the cutting operation. One such power-assist device is described in U.S. patent application Ser. No. 11/343,573, filed Jan. 31, 2006 by Shelton et al., entitled "Motor-driven surgical cutting and fastening instrument with loading force feedback," ("the '573 application") which is incorporated herein by reference.

These power-assist devices often include other components that purely mechanical endoscopic surgical instruments do not, such as sensors and control systems. One challenge in using such electronics in a surgical instrument is delivering

3

power and/or data to and from the sensors, particularly when there is a free rotating joint in the surgical instrument.

SUMMARY

In one general aspect, the present invention is directed to a surgical instrument, such as an endoscopic or laparoscopic instrument. According to one embodiment, the surgical instrument comprises an end effector comprising at least one sensor transponder that is passively powered. The surgical instrument also comprises a shaft having a distal end connected to the end effector and a handle connected to a proximate end of the shaft. The handle comprises a control unit (e.g., a microcontroller) that is in communication with the sensor transponder via at least one inductive coupling. Further, the surgical instrument may comprise a rotational joint for rotating the shaft. In such a case, the surgical instrument may comprise a first inductive element located in the shaft distally from the rotational joint and inductively coupled to the control unit, and a second inductive element located distally in the shaft and inductively coupled to the at least one sensor transponder. The first and second inductive elements may be connected by a wired, physical connection.

That way, the control unit may communicate with the transponder in the end effector without a direct wired connection through complex mechanical joints like the rotating joint where it may be difficult to maintain such a wired connection. In addition, because the distances between the inductive elements may be fixed and known, the couplings could be optimized for inductive transfer of energy. Also, the distances could be relatively short so that relatively low power signals could be used to thereby minimize interference with other systems in the use environment of the instrument.

In another general aspect of the present invention, the electrically conductive shaft of the surgical instrument may serve as an antenna for the control unit to wirelessly communicate signals to and from the sensor transponder. For example, the sensor transponder could be located on or disposed in a nonconductive component of the end effector, such as a plastic cartridge, thereby insulating the sensor from conductive components of the end effector and the shaft. In addition, the control unit in the handle may be electrically coupled to the shaft. In that way, the shaft and/or the end effector may serve as an antenna for the control unit by radiating signals from the control unit to the sensor and/or by receiving radiated signals from the sensor. Such a design is particularly useful in surgical instruments having complex mechanical joints (such as rotary joints), which make it difficult to use a direct wired connection between the sensor and control unit for communicating data signals.

In another embodiment, the shaft and/or components of the end effector could serve as the antenna for the sensor by radiating signals to the control unit and receiving radiated signals from the control unit. According to such an embodiment, the control unit is electrically insulated from the shaft and the end effector.

In another general aspect, the present invention is directed to a surgical instrument comprising a programmable control unit that can be programmed by a programming device after the instrument has been packaged and sterilized. In one such embodiment, the programming device may wirelessly program the control unit. The control unit may be passively powered by the wireless signals from the programming device during the programming operation. In another embodiment, the sterile container may comprise a connection

4

interface so that the programming unit can be connected to the surgical instrument while the surgical instrument is in its sterilized container.

In another general aspect, an embodiment of the present invention is directed to a surgical instrument for use with a robotic system that has a control unit and a shaft portion. An electrically conductive elongated member is attached to a portion of the robotic system and is configured to transmit control motions from the robotic system. In various embodiments, the surgical instrument comprises an end effector that is configured to be operably coupled to the elongated electrically conductive member to receive the control motions from the surgical tool system such that at least one sensor within the end effector is electrically insulated from the elongated electrically conductive member such that the elongated electrically conductive member can wirelessly radiate communication signals from the control unit to the at least one sensor and can receive wirelessly radiated communication signals from the at least one sensor.

In accordance with another general aspect of an embodiment of the present invention, there is provided a surgical instrument for use with a robotic system that has a control unit. A shaft portion that includes an elongated electrically conductive member is attached to a portion of the robotic system and at least partially houses a drive shaft therein. In various embodiments, the surgical instrument comprises an end effector that is configured to be operably coupled to the elongated electrically conductive member and the drive shaft for receiving control motions from the robotic system. The end effector has at least one sensor that is electrically insulated from the elongated electrically conductive member such that the elongated electrically conductive member can wirelessly radiate communication signals from the control unit to the at least one sensor and can receive wirelessly radiated communication signals from the at least one sensor.

FIGURES

Various embodiments of the present invention are described herein by way of example in conjunction with the following figures wherein:

FIGS. 1 and 2 are perspective views of a surgical instrument according to various embodiments of the present invention;

FIGS. 3-5 are exploded views of an end effector and shaft of the instrument according to various embodiments of the present invention;

FIG. 6 is a side view of the end effector according to various embodiments of the present invention;

FIG. 7 is an exploded view of the handle of the instrument according to various embodiments of the present invention;

FIGS. 8 and 9 are partial perspective views of the handle according to various embodiments of the present invention;

FIG. 10 is a side view of the handle according to various embodiments of the present invention;

FIGS. 11, 13-14, 16, and 22 are perspective views of a surgical instrument according to various embodiments of the present invention;

FIGS. 12 and 19 are block diagrams of a control unit according to various embodiments of the present invention;

FIG. 15 is a side view of an end effector including a sensor transponder according to various embodiments of the present invention;

FIGS. 17 and 18 show the instrument in a sterile container according to various embodiments of the present invention;

5

FIG. 20 is a block diagram of the remote programming device according to various embodiments of the present invention;

FIG. 21 is a diagram of a packaged instrument according to various embodiments of the present invention;

FIG. 23 is a perspective view of one robotic controller embodiment;

FIG. 23A 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. 24 is a side view of the robotic surgical arm cart/manipulator depicted in FIG. 23A;

FIG. 25 is a perspective view of an exemplary cart structure with positioning linkages for operably supporting robotic manipulators that may be used with various surgical tool embodiments of the present invention;

FIG. 26 is a perspective view of a surgical tool embodiment of the present invention;

FIG. 27 is an exploded assembly view of an adapter and tool holder arrangement for attaching various surgical tool embodiments to a robotic system;

FIG. 28 is a side view of the adapter shown in FIG. 27;

FIG. 29 is a bottom view of the adapter shown in FIG. 27;

FIG. 30 is a top view of the adapter of FIGS. 27 and 28;

FIG. 31 is a partial bottom perspective view of the surgical tool embodiment of FIG. 26;

FIG. 32 is a partial exploded view of a portion of an articulatable surgical end effector embodiment of the present invention;

FIG. 33 is a perspective view of the surgical tool embodiment of FIG. 31 with the tool mounting housing removed;

FIG. 34 is a rear perspective view of the surgical tool embodiment of FIG. 31 with the tool mounting housing removed;

FIG. 35 is a front perspective view of the surgical tool embodiment of FIG. 31 with the tool mounting housing removed;

FIG. 36 is a partial exploded perspective view of the surgical tool embodiment of FIG. 35;

FIG. 37 is a partial cross-sectional side view of the surgical tool embodiment of FIG. 31;

FIG. 38 is an enlarged cross-sectional view of a portion of the surgical tool depicted in FIG. 37;

FIG. 39 is an exploded perspective view of a portion of the tool mounting portion of the surgical tool embodiment depicted in FIG. 31;

FIG. 40 is an enlarged exploded perspective view of a portion of the tool mounting portion of FIG. 39;

FIG. 41 is a partial cross-sectional view of a portion of the elongated shaft assembly of the surgical tool of FIG. 31;

FIG. 42 is a side view of a half portion of a closure nut embodiment of a surgical tool embodiment of the present invention;

FIG. 43 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 44 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. 43 with the anvil in the open position and the closure clutch assembly in a neutral position;

FIG. 45 is another cross-sectional side view of the surgical end effector and elongated shaft assembly shown in FIG. 44 with the clutch assembly engaged in a closure position;

FIG. 46 is another cross-sectional side view of the surgical end effector and elongated shaft assembly shown in FIG. 44 with the clutch assembly engaged in a firing position;

6

FIG. 47 is a top view of a portion of a tool mounting portion embodiment of the present invention;

FIG. 48 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 49 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. 48 with the anvil in the open position;

FIG. 50 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. 48 with the anvil in the closed position;

FIG. 51 is a perspective view of a closure drive nut and portion of a knife bar embodiment of the present invention;

FIG. 52 is a top view of another tool mounting portion embodiment of the present invention;

FIG. 53 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 54 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. 53 with the anvil in the open position;

FIG. 55 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. 54 with the anvil in the closed position;

FIG. 56 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. 57 is a cross-sectional view of the mounting collar embodiment of FIG. 56;

FIG. 58 is a top view of another tool mounting portion embodiment of another surgical tool embodiment of the present invention;

FIG. 58A is an exploded perspective view of a portion of a gear arrangement of another surgical tool embodiment of the present invention;

FIG. 58B is a cross-sectional perspective view of the gear arrangement shown in FIG. 58A;

FIG. 59 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. 60 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. 59 with the anvil in the closed position;

FIG. 61 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. 62 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. 63 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. 64 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;

7

FIG. 65 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. 66 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. 67 is an enlarged cross-sectional view of a portion of the end effector of FIG. 66;

FIG. 68 is another cross-sectional view of a portion of the end effector of FIGS. 66 and 67;

FIG. 69 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. 70 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. 69;

FIG. 71 is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of FIGS. 69 and 70 with the anvil thereof in the closed position;

FIG. 72 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. 69-71;

FIG. 73 is a top view of a tool mounting portion embodiment of a surgical tool embodiment of the present invention;

FIG. 74 is a perspective assembly view of another surgical tool embodiment of the present invention;

FIG. 75 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. 76 is a rear perspective view of the disposable loading unit of FIG. 75;

FIG. 77 is a bottom perspective view of the disposable loading unit of FIGS. 75 and 76;

FIG. 78 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. 79 is an exploded perspective view of a mounting portion of a disposable loading unit depicted in FIGS. 75-77;

FIG. 80 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. 81 is another perspective view of a portion of the disposable loading unit and elongated shaft assembly of FIG. 80 with the disposable loading unit in a second position;

FIG. 82 is a cross-sectional view of a portion of the disposable loading unit and elongated shaft assembly embodiment depicted in FIGS. 80 and 81;

FIG. 83 is another cross-sectional view of the disposable loading unit and elongated shaft assembly embodiment depicted in FIGS. 80-82;

FIG. 84 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. 85 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. 86 is another partial exploded perspective view of the disposable loading unit embodiment and an elongated shaft assembly embodiment of FIG. 85;

8

FIG. 87 is a top view of another tool mounting portion embodiment of a surgical tool embodiment of the present invention;

FIG. 88 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. 89 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. 90 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. 91 is a top view of the cable-driven system and cutting instrument of FIG. 90;

FIG. 92 is a top view of a cable drive transmission embodiment of the present invention in a closure position;

FIG. 93 is another top view of the cable drive transmission embodiment of FIG. 92 in a neutral position;

FIG. 94 is another top view of the cable drive transmission embodiment of FIGS. 92 and 93 in a firing position;

FIG. 95 is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. 92;

FIG. 96 is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. 93;

FIG. 97 is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. 94;

FIG. 98 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 99 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. 100 is a top view of the cable-driven system embodiment of FIG. 99;

FIG. 101 is a top view of a tool mounting portion embodiment of another surgical tool embodiment of the present invention;

FIG. 102 is a top cross-sectional view of another surgical tool embodiment of the present invention;

FIG. 103 is a cross-sectional view of a portion of a surgical end effector embodiment of a surgical tool embodiment of the present invention;

FIG. 104 is a cross-sectional end view of the surgical end effector of FIG. 103 taken along line 104-104 in FIG. 103;

FIG. 105 is a perspective view of the surgical end effector of FIGS. 103 and 104 with portions thereof shown in cross-section;

FIG. 106 is a side view of a portion of the surgical end effector of FIGS. 103-105;

FIG. 107 is a perspective view of a sled assembly embodiment of various surgical tool embodiments of the present invention;

FIG. 108 is a cross-sectional view of the sled assembly embodiment of FIG. 107 and a portion of the elongated channel of FIG. 106;

FIGS. 109-114 diagrammatically depict the sequential firing of staples in a surgical tool embodiment of the present invention;

FIG. 115 is a partial perspective view of a portion of a surgical end effector embodiment of the present invention;

FIG. 116 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. 117 is another partial cross-sectional perspective view of the surgical end effector embodiment of FIG. 116 with a sled assembly axially advancing therethrough;

FIG. 118 is a perspective view of another sled assembly embodiment of another surgical tool embodiment of the present invention;

FIG. 119 is a partial top view of a portion of the surgical end effector embodiment depicted in FIGS. 116 and 117 with the sled assembly axially advancing therethrough;

FIG. 120 is another partial top view of the surgical end effector embodiment of FIG. 119 with the top surface of the surgical staple cartridge omitted for clarity;

FIG. 121 is a partial cross-sectional side view of a rotary driver embodiment and staple pusher embodiment of the surgical end effector depicted in FIGS. 116 and 117;

FIG. 122 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. 123 is another perspective view of the automated reloading system embodiment depicted in FIG. 122;

FIG. 124 is a cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. 122 and 123;

FIG. 125 is another cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. 122-124 with the extraction system thereof removing a spent surgical staple cartridge from the surgical end effector;

FIG. 126 is another cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. 122-125 illustrating the loading of a new surgical staple cartridge into a surgical end effector;

FIG. 127 is a perspective view of another automated reloading system embodiment of the present invention with some components shown in cross-section;

FIG. 128 is an exploded perspective view of a portion of the automated reloading system embodiment of FIG. 127;

FIG. 129 is another exploded perspective view of the portion of the automated reloading system embodiment depicted in FIG. 128;

FIG. 130 is a cross-sectional elevational view of the automated reloading system embodiment of FIGS. 127-129;

FIG. 131 is a cross-sectional view of an orientation tube embodiment supporting a disposable loading unit therein;

FIG. 132 is a perspective view of another surgical tool embodiment of the present invention;

FIG. 133 is a partial perspective view of an articulation joint embodiment of a surgical tool embodiment of the present invention;

FIG. 134 is a perspective view of a closure tube embodiment of a surgical tool embodiment of the present invention;

FIG. 135 is a perspective view of the closure tube embodiment of FIG. 134 assembled on the articulation joint embodiment of FIG. 133;

FIG. 136 is a top view of a portion of a tool mounting portion embodiment of a surgical tool embodiment of the present invention;

FIG. 137 is a perspective view of an articulation drive assembly embodiment employed in the tool mounting portion embodiment of FIG. 136;

FIG. 138 is a perspective view of another surgical tool embodiment of the present invention; and

FIG. 139 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 were filed on May 27, 2011 and which are each herein incorporated by reference in their respective entireties:

U.S. patent application Ser. No. 13/118,210, U.S. Patent Application Publication No. 2011/0290855, entitled “Robotically-Controlled Disposable Motor Driven Loading Unit”;

U.S. patent application Ser. No. 13/118,194, U.S. Patent Application Publication No. 2011/0295242, entitled “Robotically-Controlled Endoscopic Accessory Channel”;

U.S. patent application Ser. No. 13/118,253, U.S. Patent Application Publication No. 2011/0295269, entitled “Robotically-Controlled Motorized Surgical Instrument”;

U.S. patent application Ser. No. 13/118,278, U.S. Patent Application Publication No. 2011/0290851, entitled “Robotically-Controlled Surgical Stapling Devices That Produce Formed Staples Having Different Lengths”;

U.S. patent application Ser. No. 13/118,190, U.S. Patent Application Publication No. 2011/0288573, entitled “Robotically-Controlled Motorized Cutting and Fastening Instrument”;

U.S. patent application Ser. No. 13/118,223, U.S. Patent Application Publication No. 2011/0290854, entitled “Robotically-Controlled Shaft Based Rotary Drive Systems For Surgical Instruments”;

U.S. patent application Ser. No. 13/118,263, U.S. Patent Application Publication No. 2011/0295295, entitled “Robotically-Controlled Surgical Instrument Having Recording Capabilities”;

U.S. patent application Ser. No. 13/118,272, U.S. Patent Application Publication No. 2011/0290856, entitled “Robotically-Controlled Surgical Instrument With Force Feedback Capabilities”;

U.S. patent application Ser. No. 13/118,246, U.S. Patent Application Publication No. 2011/0290853, entitled “Robotically-Driven Surgical Instrument With E-Beam Driver”;

U.S. patent application Ser. No. 13/118,241, entitled “Surgical Stapling Instruments With Rotatable Staple Deployment Arrangements”.

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.

Various embodiments of the present invention are directed generally to a surgical instrument having at least one remote sensor transponder and means for communicating power and/or data signals to the transponder(s) from a control unit. The

11

present invention may be used with any type of surgical instrument comprising at least one sensor transponder, such as endoscopic or laparoscopic surgical instruments, but is particularly useful for surgical instruments where some feature of the instrument, such as a free rotating joint, prevents or otherwise inhibits the use of a wired connection to the sensor(s). Before describing aspects of the system, one type of surgical instrument in which embodiments of the present invention may be used—an endoscopic stapling and cutting instrument (i.e., an endocutter)—is first described by way of illustration.

FIGS. 1 and 2 depict an endoscopic surgical instrument 10 that comprises a handle 6, a shaft 8, and an articulating end effector 12 pivotally connected to the shaft 8 at an articulation pivot 14. Correct placement and orientation of the end effector 12 may be facilitated by controls on the hand 6, including (1) a rotation knob 28 for rotating the closure tube (described in more detail below in connection with FIGS. 4-5) at a free rotating joint 29 of the shaft 8 to thereby rotate the end effector 12 and (2) an articulation control 16 to effect rotational articulation of the end effector 12 about the articulation pivot 14. In the illustrated embodiment, the end effector 12 is configured to act as an endocutter for clamping, severing and stapling tissue, although in other embodiments, different types of end effectors may be used, such as end effectors for other types of surgical instruments, such as graspers, cutters, staplers, clip applicators, access devices, drug/gene therapy devices, ultrasound, RF or laser devices, etc.

The handle 6 of the instrument 10 may include a closure trigger 18 and a firing trigger 20 for actuating the end effector 12. It will be appreciated that instruments having end effectors directed to different surgical tasks may have different numbers or types of triggers or other suitable controls for operating the end effector 12. The end effector 12 is shown separated from the handle 6 by the preferably elongated shaft 8. In one embodiment, a clinician or operator of the instrument 10 may articulate the end effector 12 relative to the shaft 8 by utilizing the articulation control 16, as described in more detail in pending U.S. patent application Ser. No. 11/329,020, filed Jan. 10, 2006, entitled “Surgical Instrument Having An Articulating End Effector,” by Geoffrey C. Hueil et al., which is incorporated herein by reference.

The end effector 12 includes in this example, among other things, a staple channel 22 and a pivotally translatable clamping member, such as an anvil 24, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the end effector 12. The handle 6 includes a pistol grip 26 towards which a closure trigger 18 is pivotally drawn by the clinician to cause clamping or closing of the anvil 24 toward the staple channel 22 of the end effector 12 to thereby clamp tissue positioned between the anvil 24 and channel 22. The firing trigger 20 is farther outboard of the closure trigger 18. Once the closure trigger 18 is locked in the closure position, the firing trigger 20 may rotate slightly toward the pistol grip 26 so that it can be reached by the operator using one hand. Then the operator may pivotally draw the firing trigger 20 toward the pistol grip 26 to cause the stapling and severing of clamped tissue in the end effector 12. The '573 application describes various configurations for locking and unlocking the closure trigger 18. In other embodiments, different types of clamping members besides the anvil 24 could be used, such as, for example, an opposing jaw, etc.

It will be appreciated that the terms “proximal” and “distal” are used herein with reference to a clinician gripping the handle 6 of an instrument 10. Thus, the end effector 12 is distal with respect to the more proximal handle 6. It will be further appreciated that, for convenience and clarity, spatial

12

terms such as “vertical” and “horizontal” 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.

The closure trigger 18 may be actuated first. Once the clinician is satisfied with the positioning of the end effector 12, the clinician may draw back the closure trigger 18 to its fully closed, locked position proximate to the pistol grip 26. The firing trigger 20 may then be actuated. The firing trigger 20 returns to the open position (shown in FIGS. 1 and 2) when the clinician removes pressure. A release button 30 on the handle 6, and in this example, on the pistol grip 26 of the handle, when depressed may release the locked closure trigger 18.

FIG. 3 is an exploded view of the end effector 12 according to various embodiments. As shown in the illustrated embodiment, the end effector 12 may include, in addition to the previously-mentioned channel 22 and anvil 24, a cutting instrument 32, a sled 33, a staple cartridge 34 that is removably seated in the channel 22, and a helical screw shaft 36. The cutting instrument 32 may be, for example, a knife. The anvil 24 may be pivotally opened and closed at a pivot point 25 connected to the proximate end of the channel 22. The anvil 24 may also include a tab 27 at its proximate end that is inserted into a component of the mechanical closure system (described further below) to open and close the anvil 24. When the closure trigger 18 is actuated, that is, drawn in by a user of the instrument 10, the anvil 24 may pivot about the pivot point 25 into the clamped or closed position. If clamping of the end effector 12 is satisfactory, the operator may actuate the firing trigger 20, which, as explained in more detail below, causes the knife 32 and sled 33 to travel longitudinally along the channel 22, thereby cutting tissue clamped within the end effector 12. The movement of the sled 33 along the channel 22 causes the staples of the staple cartridge 34 to be driven through the severed tissue and against the closed anvil 24, which turns the staples to fasten the severed tissue. U.S. Pat. No. 6,978,921, entitled “Surgical stapling instrument incorporating an E-beam firing mechanism,” which is incorporated herein by reference, provides more details about such two-stroke cutting and fastening instruments. The sled 33 may be part of the cartridge 34, such that when the knife 32 retracts following the cutting operation, the sled 33 does not retract. The channel 22 and the anvil 24 may be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with the sensor(s) in the end effector, as described further below. The cartridge 34 could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the cartridge 34, as described further below.

It should be noted that although the embodiments of the instrument 10 described herein employ an end effector 12 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” to Yates et al., and U.S. Pat. No. 5,688,270, entitled “Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes” to Yates et al., 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, now U.S. Pat. No. 7,673,783, to Morgan et al. and U.S. patent application Ser. No. 11/267,383, now U.S. Pat. No. 7,607,557, to Shelton et al., which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly,

13

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.

FIGS. 4 and 5 are exploded views and FIG. 6 is a side view of the end effector 12 and shaft 8 according to various embodiments. As shown in the illustrated embodiment, the shaft 8 may include a proximate closure tube 40 and a distal closure tube 42 pivotably linked by a pivot links 44. The distal closure tube 42 includes an opening 45 into which the tab 27 on the anvil 24 is inserted in order to open and close the anvil 24. Disposed inside the closure tubes 40, 42 may be a proximate spine tube 46. Disposed inside the proximate spine tube 46 may be a main rotational (or proximate) drive shaft 48 that communicates with a secondary (or distal) drive shaft 50 via a bevel gear assembly 52. The secondary drive shaft 50 is connected to a drive gear 54 that engages a proximate drive gear 56 of the helical screw shaft 36. The vertical bevel gear 52b may sit and pivot in an opening 57 in the distal end of the proximate spine tube 46. A distal spine tube 58 may be used to enclose the secondary drive shaft 50 and the drive gears 54, 56. Collectively, the main drive shaft 48, the secondary drive shaft 50, and the articulation assembly (e.g., the bevel gear assembly 52a-c), are sometimes referred to herein as the "main drive shaft assembly." The closure tubes 40, 42 may be made of electrically conductive material (such as metal) so that they may serve as part of the antenna, as described further below. Components of the main drive shaft assembly (e.g., the drive shafts 48, 50) may be made of a nonconductive material (such as plastic).

A bearing 38, positioned at a distal end of the staple channel 22, receives the helical drive screw 36, allowing the helical drive screw 36 to freely rotate with respect to the channel 22. The helical screw shaft 36 may interface a threaded opening (not shown) of the knife 32 such that rotation of the shaft 36 causes the knife 32 to translate distally or proximally (depending on the direction of the rotation) through the staple channel 22. Accordingly, when the main drive shaft 48 is caused to rotate by actuation of the firing trigger 20 (as explained in more detail below), the bevel gear assembly 52a-c causes the secondary drive shaft 50 to rotate, which in turn, because of the engagement of the drive gears 54, 56, causes the helical screw shaft 36 to rotate, which causes the knife 32 to travel longitudinally along the channel 22 to cut any tissue clamped within the end effector. The sled 33 may be made of, for example, plastic, and may have a sloped distal surface. As the sled 33 traverses the channel 22, the sloped forward surface may push up or drive the staples in the staple cartridge 34 through the clamped tissue and against the anvil 24. The anvil 24 turns the staples, thereby stapling the severed tissue. When the knife 32 is retracted, the knife 32 and sled 33 may become disengaged, thereby leaving the sled 33 at the distal end of the channel 22.

According to various embodiments, as shown FIGS. 7-10, the surgical instrument may include a battery 64 in the handle 6. The illustrated embodiment provides user-feedback regarding the deployment and loading force of the cutting instrument in the end effector 12. In addition, the embodiment may use power provided by the user in retracting the firing trigger 18 to power the instrument 10 (a so-called "power assist" mode). As shown in the illustrated embodiment, the handle 6 includes exterior lower side pieces 59, 60 and exterior upper side pieces 61, 62 that fit together to form, in general, the exterior of the handle 6. The handle pieces 59-62 may be made of an electrically nonconductive material, such as plastic. A battery 64 may be provided in the pistol grip portion 26 of the handle 6. The battery 64 powers a motor 65

14

disposed in an upper portion of the pistol grip portion 26 of the handle 6. The battery 64 may be constructed according to any suitable construction or chemistry including, for example, a Li-ion chemistry such as LiCoO₂ or LiNiO₂, a Nickel Metal Hydride chemistry, etc. According to various embodiments, the motor 65 may be a DC brushed driving motor having a maximum rotation of, approximately, 5000 RPM to 100,000 RPM. The motor 64 may drive a 90° bevel gear assembly 66 comprising a first bevel gear 68 and a second bevel gear 70. The bevel gear assembly 66 may drive a planetary gear assembly 72. The planetary gear assembly 72 may include a pinion gear 74 connected to a drive shaft 76. The pinion gear 74 may drive a mating ring gear 78 that drives a helical gear drum 80 via a drive shaft 82. A ring 84 may be threaded on the helical gear drum 80. Thus, when the motor 65 rotates, the ring 84 is caused to travel along the helical gear drum 80 by means of the interposed bevel gear assembly 66, planetary gear assembly 72 and ring gear 78.

The handle 6 may also include a run motor sensor 110 in communication with the firing trigger 20 to detect when the firing trigger 20 has been drawn in (or "closed") toward the pistol grip portion 26 of the handle 6 by the operator to thereby actuate the cutting/stapling operation by the end effector 12. The sensor 110 may be a proportional sensor such as, for example, a rheostat or variable resistor. When the firing trigger 20 is drawn in, the sensor 110 detects the movement, and sends an electrical signal indicative of the voltage (or power) to be supplied to the motor 65. When the sensor 110 is a variable resistor or the like, the rotation of the motor 65 may be generally proportional to the amount of movement of the firing trigger 20. That is, if the operator only draws or closes the firing trigger 20 in a little bit, the rotation of the motor 65 is relatively low. When the firing trigger 20 is fully drawn in (or in the fully closed position), the rotation of the motor 65 is at its maximum. In other words, the harder the user pulls on the firing trigger 20, the more voltage is applied to the motor 65, causing greater rates of rotation. In another embodiment, for example, the control unit (described further below) may output a PWM control signal to the motor 65 based on the input from the sensor 110 in order to control the motor 65.

The handle 6 may include a middle handle piece 104 adjacent to the upper portion of the firing trigger 20. The handle 6 also may comprise a bias spring 112 connected between posts on the middle handle piece 104 and the firing trigger 20. The bias spring 112 may bias the firing trigger 20 to its fully open position. In that way, when the operator releases the firing trigger 20, the bias spring 112 will pull the firing trigger 20 to its open position, thereby removing actuation of the sensor 110, thereby stopping rotation of the motor 65. Moreover, by virtue of the bias spring 112, any time a user closes the firing trigger 20, the user will experience resistance to the closing operation, thereby providing the user with feedback as to the amount of rotation exerted by the motor 65. Further, the operator could stop retracting the firing trigger 20 to thereby remove force from the sensor 100, to thereby stop the motor 65. As such, the user may stop the deployment of the end effector 12, thereby providing a measure of control of the cutting/fastening operation to the operator.

The distal end of the helical gear drum 80 includes a distal drive shaft 120 that drives a ring gear 122, which mates with a pinion gear 124. The pinion gear 124 is connected to the main drive shaft 48 of the main drive shaft assembly. In that way, rotation of the motor 65 causes the main drive shaft assembly to rotate, which causes actuation of the end effector 12, as described above.

The ring 84 threaded on the helical gear drum 80 may include a post 86 that is disposed within a slot 88 of a slotted

15

arm 90. The slotted arm 90 has an opening 92 at its opposite end 94 that receives a pivot pin 96 that is connected between the handle exterior side pieces 59, 60. The pivot pin 96 is also disposed through an opening 100 in the firing trigger 20 and an opening 102 in the middle handle piece 104.

In addition, the handle 6 may include a reverse motor (or end-of-stroke sensor) 130 and a stop motor (or beginning-of-stroke) sensor 142. In various embodiments, the reverse motor sensor 130 may be a limit switch located at the distal end of the helical gear drum 80 such that the ring 84 threaded on the helical gear drum 80 contacts and trips the reverse motor sensor 130 when the ring 84 reaches the distal end of the helical gear drum 80. The reverse motor sensor 130, when activated, sends a signal to the control unit which sends a signal to the motor 65 to reverse its rotation direction, thereby withdrawing the knife 32 of the end effector 12 following the cutting operation.

The stop motor sensor 142 may be, for example, a normally-closed limit switch. In various embodiments, it may be located at the proximate end of the helical gear drum 80 so that the ring 84 trips the switch 142 when the ring 84 reaches the proximate end of the helical gear drum 80.

In operation, when an operator of the instrument 10 pulls back the firing trigger 20, the sensor 110 detects the deployment of the firing trigger 20 and sends a signal to the control unit which sends a signal to the motor 65 to cause forward rotation of the motor 65 at, for example, a rate proportional to how hard the operator pulls back the firing trigger 20. The forward rotation of the motor 65 in turn causes the ring gear 78 at the distal end of the planetary gear assembly 72 to rotate, thereby causing the helical gear drum 80 to rotate, causing the ring 84 threaded on the helical gear drum 80 to travel distally along the helical gear drum 80. The rotation of the helical gear drum 80 also drives the main drive shaft assembly as described above, which in turn causes deployment of the knife 32 in the end effector 12. That is, the knife 32 and sled 33 are caused to traverse the channel 22 longitudinally, thereby cutting tissue clamped in the end effector 12. Also, the stapling operation of the end effector 12 is caused to happen in embodiments where a stapling-type end effector is used.

By the time the cutting/stapling operation of the end effector 12 is complete, the ring 84 on the helical gear drum 80 will have reached the distal end of the helical gear drum 80, thereby causing the reverse motor sensor 130 to be tripped, which sends a signal to the control unit which sends a signal to the motor 65 to cause the motor 65 to reverse its rotation. This in turn causes the knife 32 to retract, and also causes the ring 84 on the helical gear drum 80 to move back to the proximate end of the helical gear drum 80.

The middle handle piece 104 includes a backside shoulder 106 that engages the slotted arm 90 as best shown in FIGS. 8 and 9. The middle handle piece 104 also has a forward motion stop 107 that engages the firing trigger 20. The movement of the slotted arm 90 is controlled, as explained above, by rotation of the motor 65. When the slotted arm 90 rotates CCW as the ring 84 travels from the proximate end of the helical gear drum 80 to the distal end, the middle handle piece 104 will be free to rotate CCW. Thus, as the user draws in the firing trigger 20, the firing trigger 20 will engage the forward motion stop 107 of the middle handle piece 104, causing the middle handle piece 104 to rotate CCW. Due to the backside shoulder 106 engaging the slotted arm 90, however, the middle handle piece 104 will only be able to rotate CCW as far as the slotted arm 90 permits. In that way, if the motor 65 should stop rotating for some reason, the slotted arm 90 will stop rotating, and the user will not be able to further draw in the firing

16

trigger 20 because the middle handle piece 104 will not be free to rotate CCW due to the slotted arm 90.

Components of an exemplary closure system for closing (or clamping) the anvil 24 of the end effector 12 by retracting the closure trigger 18 are also shown in FIGS. 7-10. In the illustrated embodiment, the closure system includes a yoke 250 connected to the closure trigger 18 by a pin 251 that is inserted through aligned openings in both the closure trigger 18 and the yoke 250. A pivot pin 252, about which the closure trigger 18 pivots, is inserted through another opening in the closure trigger 18 which is offset from where the pin 251 is inserted through the closure trigger 18. Thus, retraction of the closure trigger 18 causes the upper part of the closure trigger 18, to which the yoke 250 is attached via the pin 251, to rotate CCW. The distal end of the yoke 250 is connected, via a pin 254, to a first closure bracket 256. The first closure bracket 256 connects to a second closure bracket 258. Collectively, the closure brackets 256, 258 define an opening in which the proximate end of the proximate closure tube 40 (see FIG. 4) is seated and held such that longitudinal movement of the closure brackets 256, 258 causes longitudinal motion of the proximate closure tube 40. The instrument 10 also includes a closure rod 260 disposed inside the proximate closure tube 40. The closure rod 260 may include a window 261 into which a post 263 on one of the handle exterior pieces, such as exterior lower side piece 59 in the illustrated embodiment, is disposed to fixedly connect the closure rod 260 to the handle 6. In that way, the proximate closure tube 40 is capable of moving longitudinally relative to the closure rod 260. The closure rod 260 may also include a distal collar 267 that fits into a cavity 269 in proximate spine tube 46 and is retained therein by a cap 271 (see FIG. 4).

In operation, when the yoke 250 rotates due to retraction of the closure trigger 18, the closure brackets 256, 258 cause the proximate closure tube 40 to move distally (i.e., away from the handle end of the instrument 10), which causes the distal closure tube 42 to move distally, which causes the anvil 24 to rotate about the pivot point 25 into the clamped or closed position. When the closure trigger 18 is unlocked from the locked position, the proximate closure tube 40 is caused to slide proximally, which causes the distal closure tube 42 to slide proximally, which, by virtue of the tab 27 being inserted in the window 45 of the distal closure tube 42, causes the anvil 24 to pivot about the pivot point 25 into the open or unclamped position. In that way, by retracting and locking the closure trigger 18, an operator may clamp tissue between the anvil 24 and channel 22, and may unclamp the tissue following the cutting/stapling operation by unlocking the closure trigger 18 from the locked position.

The control unit (described further below) may receive the outputs from end-of-stroke and beginning-of-stroke sensors 130, 142 and the run-motor sensor 110, and may control the motor 65 based on the inputs. For example, when an operator initially pulls the firing trigger 20 after locking the closure trigger 18, the run-motor sensor 110 is actuated. If the staple cartridge 34 is present in the end effector 12, a cartridge lockout sensor may be closed, in which case the control unit may output a control signal to the motor 65 to cause the motor 65 to rotate in the forward direction. When the end effector 12 reaches the end of its stroke, the reverse motor sensor 130 will be activated. The control unit may receive this output from the reverse motor sensor 130 and cause the motor 65 to reverse its rotational direction. When the knife 32 is fully retracted, the stop motor sensor switch 142 is activated, causing the control unit to stop the motor 65.

In other embodiments, rather than a proportional-type sensor 110, an on-off type sensor could be used. In such embodi-

17

ments, the rate of rotation of the motor **65** would not be proportional to the force applied by the operator. Rather, the motor **65** would generally rotate at a constant rate. But the operator would still experience force feedback because the firing trigger **20** is geared into the gear drive train.

The instrument **10** may include a number of sensor transponders in the end effector **12** for sensing various conditions related to the end effector **12**, such as sensor transponders for determining the status of the staple cartridge **34** (or other type of cartridge depending on the type of surgical instrument), the progress of the stapler during closure and firing, etc. The sensor transponders may be passively powered by inductive signals, as described further below, although in other embodiments the transponders could be powered by a remote power source, such as a battery in the end effector **12**, for example. The sensor transponder(s) could include magnetoresistive, optical, electromechanical, RFID, MEMS, motion or pressure sensors, for example. These sensor transponders may be in communication with a control unit **300**, which may be housed in the handle **6** of the instrument **10**, for example, as shown in FIG. **11**.

As shown in FIG. **12**, according to various embodiments the control unit **300** may comprise a processor **306** and one or more memory units **308**. By executing instruction code stored in the memory **308**, the processor **306** may control various components of the instrument **10**, such as the motor **65** or a user display (not shown), based on inputs received from the various end effector sensor transponders and other sensor(s) (such as the run-motor sensor **110**, the end-of-stroke sensor **130**, and the beginning-of-stroke sensor **142**, for example). The control unit **300** may be powered by the battery **64** during surgical use of instrument **10**. The control unit **300** may comprise an inductive element **302** (e.g., a coil or antenna) to pick up wireless signals from the sensor transponders, as described in more detail below. Input signals received by the inductive element **302** acting as a receiving antenna may be demodulated by a demodulator **310** and decoded by a decoder **312**. The input signals may comprise data from the sensor transponders in the end effector **12**, which the processor **306** may use to control various aspects of the instrument **10**.

To transmit signals to the sensor transponders, the control unit **300** may comprise an encoder **316** for encoding the signals and a modulator **318** for modulating the signals according to the modulation scheme. The inductive element **302** may act as the transmitting antenna. The control unit **300** may communicate with the sensor transponders using any suitable wireless communication protocol and any suitable frequency (e.g., an ISM band). Also, the control unit **300** may transmit signals at a different frequency range than the frequency range of the received signals from the sensor transponders. Also, although only one antenna (inductive element **302**) is shown in FIG. **12**, in other embodiments the control unit **300** may have separate receiving and transmitting antennas.

According to various embodiments, the control unit **300** may comprise a microcontroller, a microprocessor, a field programmable gate array (FPGA), one or more other types of integrated circuits (e.g., RF receivers and PWM controllers), and/or discrete passive components. The control units may also be embodied as system-on-chip (SoC) or a system-in-package (SIP), for example.

As shown in FIG. **11**, the control unit **300** may be housed in the handle **6** of the instrument **10** and one or more of the sensor transponders **368** for the instrument **10** may be located in the end effector **12**. To deliver power and/or transmit data to or from the sensor transponders **368** in the end effector **12**, the inductive element **302** of the control unit **300** may be inductively

18

coupled to a secondary inductive element (e.g., a coil) **320** positioned in the shaft **8** distally from the rotation joint **29**. The secondary inductive element **320** is preferably electrically insulated from the conductive shaft **8**.

The secondary inductive element **320** may be connected by an electrically conductive, insulated wire **322** to a distal inductive element (e.g., a coil) **324** located near the end effector **12**, and preferably distally relative to the articulation pivot **14**. The wire **322** may be made of an electrically conductive polymer and/or metal (e.g., copper) and may be sufficiently flexible so that it could pass through the articulation pivot **14** and not be damaged by articulation. The distal inductive element **324** may be inductively coupled to the sensor transponder **368** in, for example, the cartridge **34** of the end effector **12**. The transponder **368**, as described in more detail below, may include an antenna (or coil) for inductive coupling to the distal coil **324**, a sensor and integrated control electronics for receiving and transmitting wireless communication signals.

The transponder **368** may use a portion of the power of the inductive signal received from the distal inductive element **326** to passively power the transponder **368**. Once sufficiently powered by the inductive signals, the transponder **368** may receive and transmit data to the control unit **300** in the handle **6** via (i) the inductive coupling between the transponder **368** and the distal inductive element **324**, (ii) the wire **322**, and (iii) the inductive coupling between the secondary inductive element **320** and the control unit **300**. That way, the control unit **300** may communicate with the transponder **368** in the end effector **12** without a direct wired connection through complex mechanical joints like the rotating joint **29** and/or without a direct wired connection from the shaft **8** to the end effector **12**, places where it may be difficult to maintain such a wired connection. In addition, because the distances between the inductive elements (e.g., the spacing between (i) the transponder **368** and the distal inductive element **324**, and (ii) the secondary inductive element **320** and the control unit **300**) and fixed and known, the couplings could be optimized for inductive transfer of energy. Also, the distances could be relatively short so that relatively low power signals could be used to thereby minimize interference with other systems in the use environment of the instrument **10**.

In the embodiment of FIG. **12**, the inductive element **302** of the control unit **300** is located relatively near to the control unit **300**. According to other embodiments, as shown in FIG. **13**, the inductive element **302** of the control unit **300** may be positioned closer to the rotating joint **29** to that it is closer to the secondary inductive element **320**, thereby reducing the distance of the inductive coupling in such an embodiment. Alternatively, the control unit **300** (and hence the inductive element **302**) could be positioned closer to the secondary inductive element **320** to reduce the spacing.

In other embodiments, more or fewer than two inductive couplings may be used. For example, in some embodiments, the surgical instrument **10** may use a single inductive coupling between the control unit **300** in the handle **6** and the transponder **368** in the end effector **12**, thereby eliminating the inductive elements **320**, **324** and the wire **322**. Of course, in such an embodiment, a stronger signal may be required due to the greater distance between the control unit **300** in the handle **6** and the transponder **368** in the end effector **12**. Also, more than two inductive couplings could be used. For example, if the surgical instrument **10** had numerous complex mechanical joints where it would be difficult to maintain a direct wired connection, inductive couplings could be used to span each such joint. For example, inductive couplers could be used on both sides of the rotary joint **29** and both sides of

19

the articulation pivot **14**, with the inductive element **321** on the distal side of the rotary joint **29** connected by a wire **322** to the inductive element **324** of the proximate side of the articulation pivot, and a wire **323** connecting the inductive elements **325**, **326** on the distal side of the articulation pivot **14** as shown in FIG. **14**. In this embodiment, the inductive element **326** may communicate with the sensor transponder **368**.

In addition, the transponder **368** may include a number of different sensors. For example, it may include an array of sensors. Further, the end effector **12** could include a number of sensor transponders **368** in communication with the distal inductive element **324** (and hence the control unit **300**). Also, the inductive elements **320**, **324** may or may not include ferrite cores. As mentioned before, they are also preferably insulated from the electrically conductive outer shaft (or frame) of the instrument **10** (e.g., the closure tubes **40**, **42**), and the wire **322** is also preferably insulated from the outer shaft **8**.

FIG. **15** is a diagram of an end effector **12** including a transponder **368** held or embedded in the cartridge **34** at the distal end of the channel **22**. The transponder **368** may be connected to the cartridge **34** by a suitable bonding material, such as epoxy. In this embodiment, the transponder **368** includes a magnetoresistive sensor. The anvil **24** also includes a permanent magnet **369** at its distal end and generally facing the transponder **368**. The end effector **12** also includes a permanent magnet **370** connected to the sled **33** in this example embodiment. This allows the transponder **368** to detect both opening/closing of the end effector **12** (due to the permanent magnet **369** moving further or closer to the transponder as the anvil **24** opens and closes) and completion of the stapling/cutting operation (due to the permanent magnet **370** moving toward the transponder **368** as the sled **33** traverses the channel **22** as part of the cutting operation).

FIG. **15** also shows the staples **380** and the staple drivers **382** of the staple cartridge **34**. As explained previously, according to various embodiments, when the sled **33** traverses the channel **22**, the sled **33** drives the staple drivers **382** which drive the staples **380** into the severed tissue held in the end effector **12**, the staples **380** being formed against the anvil **24**. As noted above, such a surgical cutting and fastening instrument is but one type of surgical instrument in which the present invention may be advantageously employed. Various embodiments of the present invention may be used in any type of surgical instrument having one or more sensor transponders.

In the embodiments described above, the battery **64** powers (at least partially) the firing operation of the instrument **10**. As such, the instrument may be a so-called "power-assist" device. More details and additional embodiments of power-assist devices are described in the '573 application, which is incorporated herein. It should be recognized, however, that the instrument **10** need not be a power-assist device and that this is merely an example of a type of device that may utilize aspects of the present invention. For example, the instrument **10** may include a user display (such as a LCD or LED display) that is powered by the battery **64** and controlled by the control unit **300**. Data from the sensor transponders **368** in the end effector **12** may be displayed on such a display.

In another embodiment, the shaft **8** of the instrument **10**, including for example, the proximate closure tube **40** and the distal closure tube **42**, may collectively serve as part of an antenna for the control unit **300** by radiating signals to the sensor transponder **368** and receiving radiated signals from the sensor transponder **368**. That way, signals to and from the

20

remote sensor in the end effector **12** may be transmitted via the shaft **8** of the instrument **10**.

The proximate closure tube **40** may be grounded at its proximate end by the exterior lower and upper side pieces **59-62**, which may be made of a nonelectrically conductive material, such as plastic. The drive shaft assembly components (including the main drive shaft **48** and secondary drive shaft **50**) inside the proximate and distal closure tubes **40**, **42** may also be made of a nonelectrically conductive material, such as plastic. Further, components of end effector **12** (such as the anvil **24** and the channel **22**) may be electrically coupled to (or in direct or indirect electrical contact with) the distal closure tube **42** such that they may also serve as part of the antenna. Further, the sensor transponder **368** could be positioned such that it is electrically insulated from the components of the shaft **8** and end effector **12** serving as the antenna. For example, the sensor transponder **368** may be positioned in the cartridge **34**, which may be made of a nonelectrically conductive material, such as plastic. Because the distal end of the shaft **8** (such as the distal end of the distal closure tube **42**) and the portions of the end effector **12** serving as the antenna may be relatively close in distance to the sensor **368**, the power for the transmitted signals may be held at low levels, thereby minimizing or reducing interference with other systems in the use environment of the instrument **10**.

In such an embodiment, as shown in FIG. **16**, the control unit **300** may be electrically coupled to the shaft **8** of the instrument **10**, such as to the proximate closure tube **40**, by a conductive link **400** (e.g., a wire). Portions of the outer shaft **8**, such as the closure tubes **40**, **42**, may therefore act as part of an antenna for the control unit **300** by radiating signals to the sensor **368** and receiving radiated signals from the sensor **368**. Input signals received by the control unit **300** may be demodulated by the demodulator **310** and decoded by the decoder **312** (see FIG. **12**). The input signals may comprise data from the sensors **368** in the end effector **12**, which the processor **306** may use to control various aspects of the instrument **10**, such as the motor **65** or a user display.

To transmit data signals to or from the sensors **368** in the end effector **12**, the link **400** may connect the control unit **300** to components of the shaft **8** of the instrument **10**, such as the proximate closure tube **40**, which may be electrically connected to the distal closure tube **42**. The distal closure tube **42** is preferably electrically insulated from the remote sensor **368**, which may be positioned in the plastic cartridge **34** (see FIG. **3**). As mentioned before, components of the end effector **12**, such as the channel **22** and the anvil **24** (see FIG. **3**), may be conductive and in electrical contact with the distal closure tube **42** such that they, too, may serve as part of the antenna.

With the shaft **8** acting as the antenna for the control unit **300**, the control unit **300** can communicate with the sensor **368** in the end effector **12** without a direct wired connection. In addition, because the distances between shaft **8** and the remote sensor **368** is fixed and known, the power levels could be optimized for low levels to thereby minimize interference with other systems in the use environment of the instrument **10**. The sensor **368** may include communication circuitry for radiating signals to the control unit **300** and for receiving signals from the control unit **300**, as described above. The communication circuitry may be integrated with the sensor **368**.

In another embodiment, the components of the shaft **8** and/or the end effector **12** may serve as an antenna for the remote sensor **368**. In such an embodiment, the remote sensor **368** is electrically connected to the shaft (such as to distal closure tube **42**, which may be electrically connected to the

21

proximate closure tube 40) and the control unit 300 is insulated from the shaft 8. For example, the sensor 368 could be connected to a conductive component of the end effector 12 (such as the channel 22), which in turn may be connected to conductive components of the shaft (e.g., the closure tubes 40, 42). Alternatively, the end effector 12 may include a wire (not shown) that connects the remote sensor 368 the distal closure tube 42.

Typically, surgical instruments, such as the instrument 10, are cleaned and sterilized prior to use. In one sterilization technique, the instrument 10 is placed in a closed and sealed container 280, such as a plastic or TYVEK container or bag, as shown in FIGS. 17 and 18. The container and the instrument are then placed in a field of radiation that can penetrate the container, such as gamma radiation, x-rays, or high-energy electrons. The radiation kills bacteria on the instrument 10 and in the container 280. The sterilized instrument 10 can then be stored in the sterile container 280. The sealed, sterile container 280 keeps the instrument 10 sterile until it is opened in a medical facility or some other use environment. Instead of radiation, other means of sterilizing the instrument 10 may be used, such as ethylene oxide or steam.

When radiation, such as gamma radiation, is used to sterilize the instrument 10, components of the control unit 300, particularly the memory 308 and the processor 306, may be damaged and become unstable. Thus, according to various embodiments of the present invention, the control unit 300 may be programmed after packaging and sterilization of the instrument 10.

As shown in FIG. 17, a remote programming device 320, which may be a handheld device, may be brought into wireless communication with the control unit 300. The remote programming device 320 may emit wireless signals that are received by the control unit 300 to program the control unit 300 and to power the control unit 300 during the programming operation. That way, the battery 64 does not need to power the control unit 300 during the programming operation. According to various embodiments, the programming code downloaded to the control unit 300 could be of relatively small size, such as 1 MB or less, so that a communications protocol with a relatively low data transmission rate could be used if desired. Also, the remote programming unit 320 could be brought into close physical proximity with the surgical instrument 10 so that a low power signal could be used.

Referring back to FIG. 19, the control unit 300 may comprise an inductive coil 402 to pick up wireless signals from a remote programming device 320. A portion of the received signal may be used by a power circuit 404 to power the control unit 300 when it is not being powered by the battery 64.

Input signals received by the coil 402 acting as a receiving antenna may be demodulated by a demodulator 410 and decoded by a decoder 412. The input signals may comprise programming instructions (e.g., code), which may be stored in a non-volatile memory portion of the memory 308. The processor 306 may execute the code when the instrument 10 is in operation. For example, the code may cause the processor 306 to output control signals to various sub-systems of the instrument 10, such as the motor 65, based on data received from the sensors 368.

The control unit 300 may also comprise a non-volatile memory unit 414 that comprises boot sequence code for execution by the processor 306. When the control unit 300 receives enough power from the signals from the remote control unit 320 during the post-sterilization programming operation, the processor 306 may first execute the boot sequence code ("boot loader") 414, which may load the processor 306 with an operating system.

22

The control unit 300 may also send signals back to the remote programming unit 320, such as acknowledgement and handshake signals, for example. The control unit 300 may comprise an encoder 416 for encoding the signals to then be sent to the programming device 320 and a modulator 418 for modulating the signals according to the modulation scheme. The coil 402 may act as the transmitting antenna. The control unit 300 and the remote programming device 320 may communicate using any suitable wireless communication protocol (e.g., Bluetooth) and any suitable frequency (e.g., an ISM band). Also, the control unit 300 may transmit signals at a different frequency range than the frequency range of the received signals from the remote programming unit 320.

FIG. 20 is a simplified diagram of the remote programming device 320 according to various embodiments of the present invention. As shown in FIG. 20, the remote programming unit 320 may comprise a main control board 230 and a boosted antenna board 232. The main control board 230 may comprise a controller 234, a power module 236, and a memory 238. The memory 238 may store the operating instructions for the controller 234 as well as the programming instructions to be transmitted to the control unit 300 of the surgical instrument 10. The power module 236 may provide a stable DC voltage for the components of the remote programming device 320 from an internal battery (not shown) or an external AC or DC power source (not shown).

The boosted antenna board 232 may comprise a coupler circuit 240 that is in communication with the controller 234 via an I²C bus, for example. The coupler circuit 240 may communicate with the control unit 300 of the surgical instrument via an antenna 244. The coupler circuit 240 may handle the modulating/demodulating and encoding/decoding operations for transmissions with the control unit. According to other embodiments, the remote programming device 320 could have a discrete modulator, demodulator, encoder and decoder. As shown in FIG. 20, the boost antenna board 232 may also comprise a transmitting power amp 246, a matching circuit 248 for the antenna 244, and a filter/amplifier 249 for receiving signals.

According to other embodiments, as shown in FIG. 20, the remote programming device could be in communication with a computer device 460, such as a PC or a laptop, via a USB and/or RS232 interface, for example. In such a configuration, a memory of the computing device 460 may store the programming instructions to be transmitted to the control unit 300. In another embodiment, the computing device 460 could be configured with a wireless transmission system to transmit the programming instructions to the control unit 300.

In addition, according to other embodiments, rather than using inductive coupling between the control unit 300 and the remote programming device 320, capacitively coupling could be used. In such an embodiment, the control unit 300 could have a plate instead of a coil, as could the remote programming unit 320.

In another embodiment, rather than using a wireless communication link between the control unit 300 and the remote programming device 320, the programming device 320 may be physically connected to the control unit 300 while the instrument 10 is in its sterile container 280 in such a way that the instrument 10 remains sterilized. FIG. 21 is a diagram of a packaged instrument 10 according to such an embodiment. As shown in FIG. 22, the handle 6 of the instrument 10 may include an external connection interface 470. The container 280 may further comprise a connection interface 472 that mates with the external connection interface 470 of the instrument 10 when the instrument 10 is packaged in the container 280. The programming device 320 may include an external

23

connection interface (not shown) that may connect to the connection interface **472** at the exterior of the container **280** to thereby provide a wired connection between the programming device **320** and the external connection interface **470** of the instrument **10**.

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”, U.S. Pat. No. 6,231,565, entitled “Robotic Arm DLUS For Performing Surgical Tasks”, U.S. Pat. No. 6,783,524, entitled “Robotic Surgical Tool With Ultrasound Cauterizing and Cutting Instrument”, U.S. Pat. No. 6,364,888, entitled “Alignment of Master and Slave In a Minimally Invasive Surgical Apparatus”, U.S. Pat. No. 7,524,320, entitled “Mechanical Actuator Interface System For Robotic Surgical Tools”, U.S. Pat. No. 7,691,098, entitled Platform Link Wrist Mechanism”, U.S. Pat. No. 7,806,891, entitled “Repositioning and Reorientation of Master/Slave Relationship in Minimally Invasive Telesurgery”, and U.S. Pat. No. 7,824,401, entitled “Surgical Tool With Writed Monopolar Electrosurgical End Effectors”. 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. **23** 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. **23A**. 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 embodiments and forms of the present invention. As is known, the master controller **1001** generally includes master controllers (generally represented as **1003** in FIG. **23**) 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 actuatable 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. **23A**, 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”, 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

24

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. **24**, 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, 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. **23A**) 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 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. **25**. 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”, 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. **27**) 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. **26**. As can be seen in that Figure, the surgical tool **1200** includes a surgical end

25

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. 27-31. 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. 31) 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. 29) 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. 27-30, 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 levers **1303** along the sides of the tool mounting portion housing **1301** are actuated (See FIG. 26). 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. 31) 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. Addi-

26

tionally, 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. 30.

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. 30) for receiving a pin array (not shown) from the tool mounting portion **1300**. In addition to transmitting electrical signals from 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. 29) 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. 27. For example, as can be seen in FIG. 27, 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. 29. 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. 31-38, 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. 37, 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 show) 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

27

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. 31-38, 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. 32. 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. 34, the rotational gear

28

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. 31. 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. 34). 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 be seen in FIG. 39, 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. 36 and 39, 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. 36.

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. 31. 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. 35 and 36, 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

29

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. **37** and **39**. 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 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. **40** and **41**, 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. **39**. Such arrangement permits the proximal spine portion **2052** to rotate, but not move axially, within the proximal closure tube **2040**.

As shown in FIG. **37**, 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. **33-38**, 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. **36**, 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. **31**. Thus,

30

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. **39** and **41**. 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 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. **40**, 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 jour-

31

naled 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. **34**, 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. **31**. 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. **39** and **40**, 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 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. **32**.

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, vari-

32

ous 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. **43-47** 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 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" to Yates et al., and U.S. Pat. No. 5,688,270, entitled "Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes" to Yates et al., 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, now U.S. Pat. No. 7,673,783, to Morgan et al. and U.S. patent application Ser.

No. 11/267,383, now U.S. Pat. No. 7,607,557, to Shelton et al., 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. 44-46.

As shown in FIG. 44, 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. 44 and 45, 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 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. 45.

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. 44 and 45, 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. 44. As can also be seen in FIGS. 44-46, 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. 44 and 45, 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 shaft segment **2430** about the stationary shaft **2350**. As can be seen in FIGS. 44-46, 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. 47, 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

35

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. 31 and 47. 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. 47, it can be seen that a proximal end portion 2359 of the proximal spine portion 2353 extends through the 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. 31 and 47. 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.

36

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. 47. 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. 31 and 47. 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 position (FIG. 44), 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. 45. 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

37

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 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. 44-46, 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. 44).

FIGS. 48-52 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 clo-

38

sure 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” to Yates et al., and U.S. Pat. No. 5,688,270, entitled “Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes” to Yates et al., 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 to Morgan et al. and U.S. patent application Ser. No. 11/267,363 to Shelton et al., 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. As shown in FIG. 48, the elongated shaft assembly 2508 may include an articulation joint 2511 of the type and construction described herein to permit the surgical end effector 2512 to be selectively articulated about an axis that is substantially transverse to the tool axis LT-LT'. Other embodiments, however, may lack an articulation joint arrangement. 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. 49 and 50, 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. 49 and 50, 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 thread-

39

ably 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 1540. 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. 49.

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. 49-51, 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 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. 47, 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. 31 and 52. 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

40

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. 52. 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. 31 and 52. 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. 52, 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 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. 31 and 52. 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

41

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. 49). 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 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

42

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. 53-58B 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 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" to Yates et al., and U.S. Pat. No. 5,688,270, entitled "Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes" to Yates et al., 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, now U.S. Pat. No. 7,673,783, to Morgan et al. and U.S. patent application Ser. No. 11/267,383, now U.S. Pat. No. 7,607,557, to Shelton et al., 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 recog-

nized 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. 54 and 55, 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. 56. 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. 54 and 55, 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. 54 and 55, 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 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. 54.

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. 54 and 55, 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. 54 and 55, 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. 54).

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. 58, 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. 31 and 58. The rotation drive assembly 2910 further comprises a rotary 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. 58, 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. 31 and 58. 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

45

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. 58 and 58B, 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. 58A, 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. 52, 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 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. 31 and 58. 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. 59 and 60 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.

46

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. 61 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. 61, 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 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. 30) 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

47

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. 61. 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. 61, 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 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. 62 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. 63 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"

48

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. 63, the tool mounting plate 3212 has an array of electrical connecting pins 3014 which are configured to interface with the slots 1258 (FIG. 30) 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. 63, 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 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. 63 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. 63, 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. 63. 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 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. 63 does not include an articulation joint. FIGS. 64 and 65 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. 64, 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 33345 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. 65 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''.

51

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. **66-68** 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. **67**, 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. **67**, 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 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

52

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. **63**) 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. **69-73** 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 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. **69**) and closed positions (FIGS. **70-72**) 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. **69-72**, 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. **69-72**, 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**.

53

As indicated above, the anvil **2524** 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. **73**, 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. **31** and **73**. 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 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. **73** 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. **31** and **73**. 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.

54

FIGS. **74-83** 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. **74**, 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”, 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. **79**, 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 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

55

member **3686** includes a proximal porthole **3687** configured to receive the distal end **3722** of control rod **2720** (See FIG. **83**) when the proximal end of disposable loading unit **3614** is engaged with elongated shaft **3700** of surgical tool **3600**.

Referring to FIGS. **74** and **81-83**, 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. **81** 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. **80** and **83** 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. **81**) of block plate **3730** to initially move plate **3730** in the direction indicated by arrow "C" in FIG. **81** 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. **80** and **83** from behind engagement member **3734** to once again permit longitudinal 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. **84** 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. **84**, 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,

56

as shown in FIGS. **85** and **86**, 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. **74** and **87**, 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. **87**, 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. **87**, 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

57

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. 87, 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.

58

FIG. 88 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. 88, 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" and U.S. Patent Application Publication No. US 2008/0308603A1, entitled "Cable Driven Surgical Stapling and Cutting Instrument With Improved Cable Attachment Arrangements", 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. 88, 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 therebetween. 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. 89. In various embodiments, the tube adapter 3870 may be slidingly 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

59

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. **89**. 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. **89**.

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 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. **90** and **91** 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

60

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. **30**) 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. **88**. 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 **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. **92-97**, 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. **30** and **95**. 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. **92-95**, 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

61

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 drivably 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 drivably 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 gear 3952 and the firing driven gear 3962 such that they cannot rotate. That is, as shown in FIG. 93, 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. 92, 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. 88. 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

62

in FIG. 94, 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. 92). 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 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. 98 illustrates a surgical tool 4000 that employs a gear driven firing bar 4092 as shown in FIGS. 99-101. 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 operably 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. 101, 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

63

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. **31** and **101**. 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. **99** and **100**. 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. **101** 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 **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. **31** and **101**. 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. **102-108** 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. **104**, 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

64

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. **104**. As can be seen in FIGS. **103**, **104**, **107**, and **108**, 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. **104**, 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. **106** and **108**, the sled assembly **5030** further includes a reciprocatably or sequentially activatable drive assembly **5050** for driving staple pushers toward the closed anvil **5070**.

More specifically and with reference to FIGS. **104** and **105**, 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. **104**. 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

65

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. 105. As can also be seen in FIGS. 105 and 107, 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. 104 and 105.

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 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. 102, 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. 102).

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

66

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. 102, 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

67

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. 103, 105, and 106. 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

68

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 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. 109-114 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. 109-115. 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. 109 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. 110) until the actuator portion 5055 contacts the end wall 5029a of the activation cavity 5026, 5028 as shown in FIG. 111. 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. 112. As the driver 5052', 5054' rotates, the pusher 5088a rides up the cam surface 5053 to the final vertical position shown in FIG. 113. When the pusher 5088a reaches the final vertical position shown in FIGS. 113 and 114, the staple (not shown) supported thereon has been driven into the staple forming surface of the anvil to form the staple.

FIGS. 116-121 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. **116-118**. 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. **116**, **117**, 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 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. **116**, 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. **121**. 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. **118**, 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. **116**. 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. **37**). 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. **116** and **117**. 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 portion 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. **122-126** 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 disposable 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. **23A**) 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. **23A** 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. **23A**.

As can be seen in FIG. **122**, 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 **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 a 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 **5334** protruding therefrom. See FIGS. **122** and **125**. 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. **124** illustrates the introduction of the surgical end effector **2012** that is operably attached to the manipulatable surgical 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. **125**). 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. **126**.

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. 126, 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. 123 and 126, 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. 127-131 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. 74-87) that is operably attached to an arm cart 1100 or other portion of a robotic system 1000 and reload a new disposable loading unit 3612 therein. As can be seen in FIGS. 127 and 128, 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. 128 and 129, 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. 128 and 129, 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. 127, 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. 128 and 129, 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. 127-129, the replaceable tray 5652 may be provided with one 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. 131, 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. 131, 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.

75

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.

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. **80**, **81**), 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 sup-

76

ported in the orientation tube **5660** that is in driving engagement with the drive assembly **5680**. Once the robotic controller **1001** (FIG. **23**) 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 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. **132-137** 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. **27**) 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. **132**, 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**.

77

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 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. **132**, 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. **133**. 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. **134**, 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

78

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. **136**, 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 articulation 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. **133**.

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. **137**. 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**.

79

As can be seen in FIG. 133, 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 with reference to FIG. 137, 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. 137, 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. 137, 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. 136 and 137, 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 corre-

80

sponding 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. 31. Thus, application of a rotary input motion from the robotic system 1000 through the tool drive assembly 1010 to the 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. 136. Pins 6352 are oriented to electrically communicate with slots 1258 (FIG. 30) 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. 137, 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.

81

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 there-around. 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. **137**, 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. **136** and **137**, 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** 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 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

82

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 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. **31**. The rotational gear

83

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 seen in FIG. 136, 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. 136.

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. 31. 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

84

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. 136. 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 articulation 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. 136, 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. 136, 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. 31. 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. 136, the second knife driven gear 6568 is in meshing engagement with a fourth knife driven gear 6572 of

85

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 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 applier, 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. **138** 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", 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

86

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. **139** 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 describe 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", the entire disclosure of which is herein incorporated by reference.

Various sensor embodiments described in U.S. Patent Publication No. 2011/0062212 A1 to Shelton, I V et al., 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. **1**. 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),

87

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 feed back 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.

In still other embodiments, the various robotic systems and tools disclosed herein may employ many of the sensor/transponder arrangements disclosed above. Such sensor arrangements may include, but are not limited to, run motor sensors, reverse motor sensors, stop motor sensors, end-of-stroke sensors, beginning-of-stroke sensors, cartridge lockout sensors, sensor transponders, etc. The sensors may be employed in connection with any of the surgical tools disclosed herein that are adapted for use with a robotic system. The sensors may be configured to communicate with the robotic system controller. In other embodiments, components of the shaft/end effector may serve as antennas to communicate between the sensors and the robotic controller. In still other embodiments, the various remote programming device arrangements described above may also be employed with the robotic controller.

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

88

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 surgical tool for use with a robotic system that has a tool drive assembly that is operatively coupled to a control unit of the robotic system that is operable by inputs from an operator and is configured to provide at least one rotary output motion to at least one rotatable body portion supported on the tool drive assembly, said surgical tool comprising:

a surgical end effector comprising:

an elongated channel configured to operably support a surgical staple cartridge therein;

an anvil that is selectively movable between a first open position and second closed positions relative to the elongated channel and wherein the surgical tool further comprises:

an elongated shaft assembly operably coupled to said surgical end effector, said elongated shaft assembly comprising:

a spine assembly including a distal end portion that is coupled to said elongated channel;

a closure tube assembly movably supported on said spine assembly, said closure tube assembly comprising a distal end configured for operable interaction with said anvil; and

at least one gear-driven portion, wherein one said gear driven portion is in operable communication with said closure tube assembly and wherein said surgical tool further comprises:

a tool mounting portion operably coupled to said elongated shaft assembly, said tool mounting portion being configured to operably interface with the tool drive assembly when coupled thereto and operably supporting a proximal end of the spine assembly thereon, said tool mounting portion comprising:

a driven element rotatably supported on said tool mounting portion and configured for driving engagement with a corresponding one of the at least one rotatable body portions of the tool drive assembly to receive corresponding rotary output motions therefrom; and

a transmission assembly in operable engagement with said driven element and in meshing engagement with a corresponding one of said at least one gear-driven portions to apply actuation motions thereto to cause said corresponding one of said at least one gear driven portions to apply at least one control motion to said closure tube assembly.

2. The surgical tool of claim **1** wherein another one of said at least one gear driven portions comprises a tube gear segment on said proximal end portion of said closure tube assembly that is in operable engagement with said transmission assembly.

3. The surgical tool of claim **2** wherein said transmission assembly comprises a closure transmission assembly comprising a closure sled movably supported on said tool mounting portion and operably supporting a proximal end portion of said closure tube assembly thereon, said closure sled configured for meshing engagement with a closure gear assembly

89

operably coupled to one of the at least one rotatable body portions supported on the tool drive assembly such that upon application of a rotary output motion in a first direction to said closure gear assembly by said at least one rotatable body portion, said closure tube assembly is driven distally on said spine assembly into closing engagement with said anvil to move said anvil from said first open position to one of said second closed positions and upon application of said rotary output motion in a second direction to said closure gear assembly, said closure tube assembly is driven proximally on said spine assembly to enable said anvil to move to said open position.

4. The surgical tool of claim 1 further comprising a cutting instrument that is axially movable within said surgical staple cartridge between a starting position and an ending position.

5. The surgical tool of claim 4 wherein another one of said at least one gear driven portion comprises a knife bar that is movably supported within said elongated shaft assembly for selective axial travel therein, said knife bar interfacing with said cutting instrument and said transmission assembly.

6. The surgical tool of claim 5 wherein said knife bar has a knife gear rack formed on a proximal end thereof and wherein said transmission assembly comprises a knife transmission assembly comprising a knife gear assembly in meshing engagement with said knife gear rack, said knife gear assembly operably coupled to one of the at least one rotatable body portions supported on the tool drive assembly such that upon application of a rotary output motion in a first direction to said knife gear assembly by said at least one rotatable body portion, said knife bar drives said cutting instrument distally through said surgical staple cartridge and upon application of said rotary output motion in a second direction to said knife gear assembly, said knife bar moves said cutting instrument proximally through said surgical staple cartridge.

7. The surgical tool of claim 4 wherein said cutting instrument comprises:

- a rotary end effector drive shaft operably supported within the elongated channel; and
- a knife member having a tissue-cutting portion thereon threadedly received on said rotary end effector drive shaft such that rotation of said rotary end effector drive shaft in a first direction causes said knife member to move in a distal direction through said surgical staple cartridge and when said rotary end effector drive shaft is rotated in a second direction, said knife member moves in a proximal direction through said surgical staple cartridge.

8. The surgical tool of claim 7 wherein one of said at least one of said gear driven portions comprises an elongated proximal drive shaft operably supported in said elongated shaft assembly and having a distal end in driving engagement with said rotary end effector drive shaft, and wherein said transmission assembly comprises a rotary drive transmission operably supported on said tool mounting portion and in driving engagement with a proximal end of said proximal drive shaft and operably coupled to one of the at least one rotatable body portions supported on the tool drive assembly such that, upon application of a rotary output motion in one direction to said rotary drive transmission by said at least one rotatable body portion, said proximal drive shaft rotates said rotary end effector drive shaft in said first direction and upon application of said rotary output motion in a second direction to rotary drive transmission, said proximal drive shaft causes said rotary end effector drive shaft to rotate in said second direction.

9. The surgical tool of claim 1 wherein said elongated shaft assembly comprises a distal end portion operably coupled to

90

said surgical end effector and a proximal end rotatably supported on said tool mounting portion for selective rotational travel about a longitudinal tool axis.

10. The surgical tool of claim 9 wherein said at least one gear-driven portion comprises a tube gear segment on said proximal end portion of said elongated shaft assembly and wherein said transmission assembly comprises a rotational transmission assembly comprising a rotational gear assembly operably coupled to one of the at least one rotatable body portions supported on the tool drive assembly such that upon application of a rotary output motion in a first direction to said rotational gear assembly by said at least one rotatable body portion, said rotational gear assembly rotates said elongated shaft assembly and said surgical end effector in a first rotary direction about said longitudinal tool axis and upon application of said rotary output motion in a second direction to said rotational gear assembly, said rotational gear assembly rotates said elongated shaft assembly and said surgical end effector about said longitudinal tool axis in a second rotary direction.

11. The surgical tool of claim 1 wherein said elongated shaft assembly defines a longitudinal tool axis and further comprises an articulation joint therein that facilitates selective articulation of said surgical end effector about an articulation axis that is substantially transverse to said longitudinal tool axis.

12. The surgical tool of claim 11 wherein said elongated shaft assembly comprises:

- a distal spine portion operably coupled to said end effector; and
- a proximal spine portion pivotally coupled to said distal portion at said articulation joint and comprising a distal end portion operably supported on said tool mounting portion.

13. The surgical tool of claim 12 wherein said at least one gear-driven portion comprises an articulation system interfacing with said distal spine portion and said transmission assembly.

14. The surgical tool of claim 13 wherein said transmission assembly comprises an articulation transmission and wherein said articulation system comprises:

- a first articulation bar having a distal end coupled to said proximal portion of said elongated shaft assembly at a first lateral point that is laterally offset in a first lateral direction from said articulation axis, said first articulation bar having a proximal end that operably interfaces with said articulation transmission; and
- a second articulation bar having a distal end coupled to said proximal portion of said elongated shaft assembly at a second lateral point that is laterally offset in a second lateral direction from said articulation axis, said second articulation bar having a proximal end that operably interfaces with said articulation transmission.

15. The surgical tool of claim 14 wherein said articulation transmission comprises:

- an articulation gear assembly operably coupled to one of the at least one rotatable body portions supported on the tool drive assembly; and
- an articulation nut in meshing engagement with said articulation gear assembly and rotatably supported on said proximal spine portion for rotary travel thereon in response to actuation motions from said articulation gear assembly and wherein said distal ends of said first and second articulation bars each operably interface with said articulation nut such that upon application of a first actuation motion to said articulation nut by said articulation gear assembly causes said first articulation

91

bar to move axially in a first direction and said second articulation bar to move axially in a second direction that is opposite to said first direction and upon application of a second actuation motion to said articulation nut from said articulation gear assembly causes said first articulation bar to axially move in said second direction and said second articulation bar to axially move in said first direction.

16. The surgical tool of claim 15 wherein each said distal end of said first and second articulation bars have a guide rod protruding therefrom that is slidably received with corresponding helical slots in said articulation nut.

17. A surgical tool for use with a robotic system that has a tool drive assembly that is operatively coupled to a controller of the robotic system that is operable by inputs from an operator and is configured to provide a plurality of rotary output motions to a plurality of corresponding rotatable body portions supported on the tool drive assembly, said surgical tool comprising:

- an end effector, comprising:
 - an elongated channel;
 - a surgical staple cartridge supported within said elongated channel;
 - a cutting instrument axially movable within said surgical staple cartridge between a starting position and an ending position; and
 - an anvil movably supported relative to said elongated channel and being selectively movable between an open position relative to said surgical staple cartridge and a closed position relative to said surgical staple cartridge and wherein said surgical tool further comprises:
- an elongated shaft assembly comprising:
 - a spine assembly coupled to said elongated channel;
 - a closure tube assembly movably supported on said spine assembly, said closure tube assembly having a distal end portion configured for operable interaction with said anvil and wherein said surgical tool further comprises:
 - a tool mounting portion coupled to a distal end of said spine assembly and configured to operably interface with the tool drive assembly of the robotic system when coupled thereto, said tool mounting portion comprising:
 - a first driven disc rotatably supported on said tool mounting portion and configured for driving engagement with a corresponding first rotatable body portion of the drive assembly to receive corresponding first rotary output motions therefrom;
 - a closure gear assembly supported on said tool mounting portion and being operably coupled to the first driven disc for receiving said first rotary output motions therefrom;
 - a closure sled operably supporting a proximal end of said closure tube assembly on said tool mounting portion and supported in meshing engagement with said closure gear assembly such that upon application of one said first rotary output motions in a first direction to said closure gear assembly, said closure tube assembly is driven distally on said spine assembly into closing engagement with said anvil to move said anvil from said first open position to said second closed position and upon application of another one of said first rotary output motions in a second direction to said closure gear assembly, said closure tube assembly is driven proximally on said spine assembly to enable said anvil to move to said open position;

92

a second driven disc rotatably supported on said tool mounting portion and configured for driving engagement with a corresponding second one of rotatable body portions of the drive assembly of the robotic system to receive corresponding second rotary output motions therefrom;

a knife gear assembly supported on said tool mounting portion and being operably coupled to said second rotatable body portion for receiving said second rotary output motions therefrom;

a knife bar having a distal end operably interfacing with said cutting instrument and having a proximal end portion in meshing engagement with said knife gear assembly such that upon application of the second rotary output motion in a first direction to said knife gear assembly by said second driven disc, said knife bar drives said cutting instrument distally through said staple cartridge and upon application of another one of said second rotary output motions in a second direction to said knife gear assembly, said knife bar moves said cutting instrument proximally through said surgical staple cartridge;

a third driven disc rotatably supported on said tool mounting portion and configured for driving engagement with a corresponding third rotatable body portion of the drive assembly of the robotic system to receive corresponding third rotary output motions therefrom; and

a rotational gear assembly operably supported on said tool mounting portion and in meshing engagement with a tube gear segment on a proximal end portion of the closure tube assembly and operably coupled to the third driven disc such that upon application of a third rotary output motion in a first direction to said rotational gear assembly by said third driven disc, said rotational gear assembly rotates said elongated shaft assembly and said surgical end effector in a first rotary direction about said longitudinal tool axis and upon application of said rotary output motion in a second direction to said rotational gear assembly, said rotational gear assembly rotates said elongated shaft assembly and said surgical end effector about said longitudinal tool axis in a second rotary direction.

18. The surgical tool of claim 17 wherein said spine assembly comprises:

- a distal spine portion operably coupled to said elongated channel of said effector; and
- a proximal spine portion pivotally coupled to said distal spine portion and having a proximal end portion operably supported on said tool mounting portion and wherein said closure tube assembly comprises:
 - a distal closure tube portion operably supported on said distal spine portion; and
 - a proximal closure tube portion pivotally attached to said distal closure tube portion and wherein said surgical tool comprises:
 - a first articulation bar having a distal end coupled to said proximal portion of said elongated shaft assembly at a first lateral point that is laterally offset in a first lateral direction from said articulation axis;
 - a second articulation bar having a distal end coupled to said proximal portion of said elongated shaft assembly at a second lateral point that is laterally offset in a second lateral direction from said articulation axis;
 - a fourth driven disc rotatably supported on said tool mounting portion and configured for driving engagement with a corresponding fourth one of the rotatable body por-

93

tions of the drive assembly of the robotic system to receive corresponding fourth rotary output motions therefrom;

an articulation gear assembly operably supported on said tool mounting portion and operably coupled to the fourth driven disc to receive said fourth rotary output motions therefrom; and

an articulation nut in meshing engagement with said articulation gear assembly and rotatably supported on said proximal spine portion for rotary travel thereon in response to said fourth rotary output motions from said articulation gear assembly and wherein said distal ends of said first and second articulation bars each operably interface with said articulation nut such that an application of a fourth rotary output motion to said articulation nut by said articulation gear assembly causes said first articulation bar to move axially in a first direction and said second articulation bar to move axially in a second direction that is opposite to said first direction and upon application of another fourth rotary output motion to said articulation nut from said articulation gear assembly causes said first articulation bar to axially move in said second direction and said second articulation bar to axially move in said first direction.

19. A surgical tool for use with a robotic system that has a tool drive assembly that is operatively coupled to a control unit of the robotic system that is operable by inputs from an operator and is configured to provide at least one rotary output motion to at least one rotatable body portion supported on the tool drive assembly, said surgical tool comprising:

a surgical end effector comprising:

a surgical staple cartridge; and

a cutting instrument that is axially movable within said surgical staple cartridge between a starting position and an ending position in response to control motions applied thereto and wherein said surgical tool further comprises:

an elongated shaft assembly operably coupled to said surgical end effector, said elongated shaft assembly comprising at least one gear-driven portion comprising a knife bar that is movably supported within said elongated shaft assembly for selective axial travel therein, said knife bar interfacing with said cutting instrument;

a tool mounting portion operably coupled to said elongated shaft assembly, said tool mounting portion being configured to operably interface with the tool drive assembly when coupled thereto, said tool mounting portion comprising:

a driven element rotatably supported on said tool mounting portion and configured for driving engagement with a corresponding one of the at least one rotatable body portions of the tool drive assembly to receive corresponding rotary output motions therefrom; and

a transmission assembly in operable engagement with said driven element and in meshing engagement with the knife bar to apply actuation motions thereto to cause said knife bar to apply at least one control motion thereto.

20. The surgical tool of claim **19** wherein said knife bar has a knife gear rack formed on a proximal end thereof and wherein said transmission assembly comprises a knife transmission assembly comprising a knife gear assembly in meshing engagement with said knife gear rack, said knife gear assembly operably coupled to one of the at least one rotatable body portions supported on the tool drive assembly such that upon application of a rotary output motion in a first direction to said knife gear assembly by said at least one rotatable body

94

portion, said knife bar drives said cutting instrument distally through said surgical staple cartridge and upon application of said rotary output motion in a second direction to said knife gear assembly, said knife bar moves said cutting instrument proximally through said surgical staple cartridge.

21. A surgical tool for use with a robotic system that has a tool drive assembly that is operatively coupled to a control unit of the robotic system that is operable by inputs from an operator and is configured to provide at least one rotary output motion to at least one rotatable body portion supported on the tool drive assembly, said surgical tool comprising:

a surgical end effector comprising:

an elongated channel configured to support a surgical staple cartridge therein;

a rotary end effector drive shaft operably supported within an elongated channel;

a knife member having a tissue-cutting portion thereon threadedly received on said rotary end effector drive shaft such that rotation of said rotary end effector drive shaft in a first direction causes said knife member to move in a distal direction through said surgical staple cartridge and when said rotary end effector drive shaft is rotated in a second direction, said knife member moves in a proximal direction through said surgical staple cartridge and wherein said surgical tool further comprises:

an elongated shaft assembly operably coupled to said elongated channel, said elongated shaft assembly comprising at least one gear-driven portion that is in operable communication with said rotary end effector drive shaft;

a tool mounting portion operably coupled to said elongated shaft assembly, said tool mounting portion being configured to operably interface with the tool drive assembly when coupled thereto, said tool mounting portion comprising:

a driven element rotatably supported on said tool mounting portion and configured for driving engagement with a corresponding one of the at least one rotatable body portions of the tool drive assembly to receive corresponding rotary output motions therefrom; and

a transmission assembly in operable engagement with said driven element and in meshing engagement with a corresponding one of said at least one gear-driven portions to apply actuation motions thereto to cause said corresponding one of said at least one gear driven portions to apply at least one control motion to said rotary end effector drive shaft.

22. The surgical tool of claim **21** wherein one of said at least one of said gear driven portions comprises an elongated proximal drive shaft operably supported in said elongated shaft assembly and having a distal end in driving engagement with said rotary end effector drive shaft, and wherein said transmission assembly comprises a rotary drive transmission operably supported on said tool mounting portion and in driving engagement with a proximal end of said proximal drive shaft and operably coupled to one of the at least one rotatable body portions supported on the tool drive assembly such that, upon application of a rotary output motion in one direction to said rotary drive transmission by said at least one rotatable body portion, said proximal drive shaft rotates said rotary end effector drive shaft in said first direction and upon application of said rotary output motion in a second direction to rotary drive transmission, said proximal drive shaft causes said rotary end effector drive shaft to rotate in said second direction.

23. A surgical tool for use with a robotic system that has a tool drive assembly that is operatively coupled to a control

95

unit of the robotic system that is operable by inputs from an operator and is configured to provide at least one rotary output motion to at least one rotatable body portion supported on the tool drive assembly, said surgical tool comprising:

a surgical end effector comprising at least one component portion that is selectively movable between first and second positions relative to at least one other component portion thereof in response to control motions applied to said selectively movable component portion;

an elongated shaft assembly including a distal end operably coupled to said surgical end effector and defining a longitudinal tool axis, said elongated shaft assembly including a tube gear segment on a proximal end thereof; and

a tool mounting portion operably coupled to said elongated shaft assembly, said tool mounting portion being configured to operably interface with the tool drive assembly when coupled thereto, said tool mounting portion comprising a rotational transmission assembly comprising a rotational gear assembly in meshing engagement with the tube gear segment and operably coupled to one of the at least one rotatable body portions supported on the tool drive assembly such that upon application of a rotary output motion in a first direction to said rotational gear assembly by said at least one rotatable body portion, said rotational gear assembly rotates said elongated shaft and said surgical end effector in a first rotary direction about said longitudinal tool axis and upon application of said rotary output motion in a second direction to said rotational gear assembly, said rotational gear assembly rotates said elongated shaft assembly and said surgical end effector about said longitudinal tool axis in a second rotary direction relative to the tool mounting portion.

24. A surgical tool for use with a robotic system that has a tool drive assembly that is operatively coupled to a control unit of the robotic system that is operable by inputs from an operator and is configured to provide at least one rotary output motion to at least one rotatable body portion supported on the tool drive assembly, said surgical tool comprising:

a surgical end effector comprising at least one component portion that is selectively movable between first and second positions relative to at least one other component portion thereof in response to control motions applied to said selectively movable component portion;

an elongated shaft assembly defining a longitudinal tool axis and comprising:

a distal spine portion operably coupled to said end effector; and

a proximal spine portion pivotally coupled to said distal spine portion at an articulation joint to facilitate articulation of said surgical end effector about an articulation axis that is substantially transverse to said longitudinal tool axis; and

at least one gear-driven portion that is in operable communication with said at least one selectively movable component portion of said surgical end effector and wherein said surgical tool further comprises:

a tool mounting portion operably coupled to a distal end of said proximal spine portion, said tool mounting portion being configured to operably interface with

96

the tool drive assembly when coupled thereto, said tool mounting portion comprising:

a driven element rotatably supported on said tool mounting portion and configured for driving engagement with a corresponding one of the at least one rotatable body portions of the tool drive assembly to receive corresponding rotary output motions therefrom; and a transmission assembly in operable engagement with said driven element and in meshing engagement with a corresponding one of said at least one gear-driven portions to apply actuation motions thereto to cause said corresponding one of said at least one gear driven portions to apply at least one control motion to said selectively movable component.

25. The surgical tool of claim 24 wherein said at least one gear-driven portion comprises an articulation system interfacing with said distal spine portion and said transmission assembly.

26. The surgical tool of claim 25 wherein said transmission assembly comprises an articulation transmission and wherein said articulation system comprises:

a first articulation bar having a distal end coupled to said proximal portion of said elongated shaft assembly at a first lateral point that is laterally offset in a first lateral direction from said articulation axis, said first articulation bar having a proximal end that operably interfaces with said articulation transmission; and

a second articulation bar having a distal end coupled to said proximal portion of said elongated shaft assembly at a second lateral point that is laterally offset in a second lateral direction from said articulation axis, said second articulation bar having a proximal end that operably interfaces with said articulation transmission.

27. The surgical tool of claim 26 wherein said articulation transmission comprises:

an articulation gear assembly operably coupled to one of the at least one rotatable body portions supported on the tool drive assembly; and

an articulation nut in meshing engagement with said articulation gear assembly and rotatably supported on said proximal spine portion for rotary travel thereon in response to actuation motions from said articulation gear assembly and wherein said distal ends of said first and second articulation bars each operably interface with said articulation nut such that upon application of a first actuation motion to said articulation nut by said articulation gear assembly causes said first articulation bar to move axially in a first direction and said second articulation bar to move axially in a second direction that is opposite to said first direction and upon application of a second actuation motion to said articulation nut from said articulation gear assembly causes said first articulation bar to axially move in said second direction and said second articulation bar to axially move in said first direction.

28. The surgical tool of claim 27 wherein each said distal end of said first and second articulation bars have a guide rod protruding therefrom that is slidably received with corresponding helical slots in said articulation nut.

* * * * *