US008568409B2

(12) **United States Patent**
**O'Brien et al.**

(10) **Patent No.: US 8,568,409 B2**
(45) **Date of Patent: Oct. 29, 2013**

(54) **FLUID-ASSISTED MEDICAL DEVICES, SYSTEMS AND METHODS**

(75) Inventors: **Scott D. O'Brien**, Milton, NH (US); **Michael F. McClurken**, Durham, NH (US); **Robert Luzzi**, Pleasanton, CA (US)

(73) Assignee: **Medtronic Advanced Energy LLC**, Minneapolis, MN (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1755 days.

(21) Appl. No.: **11/931,312**

(22) Filed: **Oct. 31, 2007**

(65) **Prior Publication Data**

US 2008/0058796 A1 Mar. 6, 2008

**Related U.S. Application Data**

(60) Division of application No. 10/365,170, filed on Feb. 11, 2003, and a continuation-in-part of application No. 09/947,658, filed on Sep. 5, 2001, now Pat. No. 7,115,139, which is a continuation-in-part of application No. 09/797,049, filed on Mar. 1, 2001, now Pat. No. 6,702,810.

(60) Provisional application No. 60/368,177, filed on Mar. 27, 2002, provisional application No. 60/356,390, filed on Feb. 12, 2002, provisional application No. 60/187,114, filed on Mar. 6, 2000.

(51) **Int. Cl.**
*A61B 18/12* (2006.01)

(52) **U.S. Cl.**
USPC ..... **606/49**; 128/898

(58) **Field of Classification Search**
USPC ..... 128/898; 606/41, 45, 46, 48–50; 607/96, 104
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,735,271 A 11/1929 Groff
2,888,928 A 6/1959 Seiger
(Continued)

FOREIGN PATENT DOCUMENTS

DE 1 007 960 5/1957
EP 0 175 595 3/1986
(Continued)

OTHER PUBLICATIONS

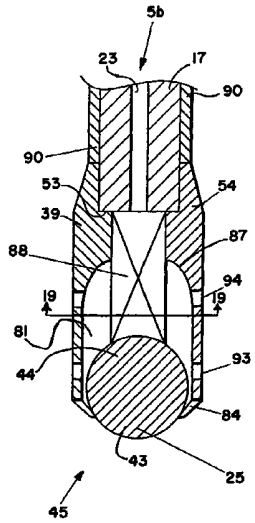
U.S. Office Action issued in related U.S. Appl. No. 10/265,170 dated Jan. 12, 2009.
(Continued)

*Primary Examiner* — Aaron Roane
(74) *Attorney, Agent, or Firm* — Jeffrey J. Hohenshell

(57) **ABSTRACT**

Surgical devices for treating tissue are provided. Also provided are systems for treating tissue and methods of treating tissue. An exemplary surgical device has a handle, a fluid passage connectable to a fluid source, a tip portion and a distal end. The tip portion can simultaneously provide RF power and conductive fluid to tissue. The tip portion includes an electrode having a domed portion having a domed surface and a cylindrical portion having a cylindrical surface. The domed portion is located distal to the cylindrical portion and occupies at least a portion of the distal end of the surgical device. The device includes a fluid outlet opening in fluid communication with the fluid passage, the fluid outlet opening configured to provide the conductive fluid to a surface of the electrode proximal to the distal end surface of the surgical device.

**50 Claims, 37 Drawing Sheets**



(56) **References Cited**

U.S. PATENT DOCUMENTS

3,682,130 A 8/1972 Jeffers
3,736,936 A 6/1973 Basiulis et al.
3,750,650 A 8/1973 Ruttgers
3,807,403 A 4/1974 Stumpf et al.
3,823,575 A 7/1974 Parel
3,823,718 A 7/1974 Tromovitch
3,827,436 A 8/1974 Stumpf et al.
3,830,239 A 8/1974 Stumpf
3,859,986 A 1/1975 Okada et al.
3,862,627 A 1/1975 Hans, Sr.
3,886,945 A 6/1975 Stumpf et al.
3,907,339 A 9/1975 Stumpf et al.
3,910,277 A 10/1975 Zimmer
3,913,581 A 10/1975 Ritson et al.
3,924,628 A 12/1975 Droegemueller et al.
4,018,227 A 4/1977 Wallach
4,022,215 A 5/1977 Benson
4,060,088 A 11/1977 Morrison, Jr. et al.
4,061,135 A 12/1977 Widran et al.
4,063,560 A 12/1977 Thomas et al.
4,072,152 A 2/1978 Linehan
4,082,096 A 4/1978 Benson
4,207,897 A 6/1980 Lloyd et al.
4,244,371 A 1/1981 Farin
4,248,224 A 2/1981 Jones
4,275,734 A 6/1981 Mitchiner
4,276,874 A 7/1981 Wolvek et al.
4,278,090 A 7/1981 van Gerven
4,321,931 A 3/1982 Hon
4,342,218 A 8/1982 Fox
4,355,642 A 10/1982 Alferness
4,377,168 A 3/1983 Rzasa et al.
4,381,007 A 4/1983 Doss
4,519,389 A 5/1985 Gudkin et al.
4,598,698 A 7/1986 Siegmund
4,601,290 A 7/1986 Effron et al.
4,664,110 A 5/1987 Schanzlin
4,671,274 A 6/1987 Sorochenko
4,736,749 A 4/1988 Lundback
4,779,611 A 10/1988 Grooters et al.
4,802,475 A 2/1989 Weshahy
4,815,470 A 3/1989 Curtis et al.
4,872,346 A 10/1989 Kelly-Fry et al.
4,916,922 A 4/1990 Mullens
4,917,095 A 4/1990 Fry et al.
4,919,129 A 4/1990 Weber, Jr.
4,931,047 A 6/1990 Broadwin et al.
4,932,952 A 6/1990 Wojciechowicz, Jr.
4,936,281 A 6/1990 Stasz
4,943,290 A 7/1990 Rexroth et al.
4,946,460 A 8/1990 Merry et al.
4,950,232 A 8/1990 Ruzicka et al.
4,985,030 A 1/1991 Melzer et al.
4,998,933 A 3/1991 Eggers et al.
5,013,312 A 5/1991 Parins et al.
5,029,574 A 7/1991 Shimamura et al.
5,044,165 A 9/1991 Linner et al.
5,078,713 A 1/1992 Varney
5,080,102 A 1/1992 Dory
5,080,660 A 1/1992 Buelna
5,100,388 A 3/1992 Behl et al.
5,108,390 A 4/1992 Potocky et al.
5,147,355 A 9/1992 Friedman et al.
5,178,133 A 1/1993 Pena
5,190,541 A 3/1993 Abele et al.
5,195,959 A 3/1993 Smith
5,207,674 A 5/1993 Hamilton
5,217,860 A 6/1993 Fahy et al.
5,222,501 A 6/1993 Ideker et al.
5,224,943 A 7/1993 Goddard
5,228,923 A 7/1993 Hed
5,231,995 A 8/1993 Desai
5,232,516 A 8/1993 Hed
5,234,428 A 8/1993 Kaufman
5,254,116 A 10/1993 Baust et al.
5,254,117 A 10/1993 Rigby
5,263,493 A 11/1993 Avitall
5,269,291 A 12/1993 Carter
5,275,595 A 1/1994 Dobak, III
5,277,201 A 1/1994 Stern
5,281,215 A 1/1994 Milder
5,290,286 A 3/1994 Parins
5,295,484 A 3/1994 Marcus et al.
5,309,896 A 5/1994 Moll et al.
5,316,000 A 5/1994 Chapelon et al.
5,317,878 A 6/1994 Bradshaw et al.
5,318,525 A 6/1994 West et al.
5,322,520 A 6/1994 Milder
5,323,781 A 6/1994 Ideker et al.
5,324,255 A 6/1994 Passafaro et al.
5,324,284 A 6/1994 Imran
5,324,286 A 6/1994 Fowle
5,330,521 A 7/1994 Cohen
5,334,181 A 8/1994 Rubinsky et al.
5,334,193 A 8/1994 Nardella
5,336,220 A 8/1994 Ryan et al.
5,348,554 A 9/1994 Imran et al.
5,353,783 A 10/1994 Nakao et al.
5,354,258 A 10/1994 Dory
5,361,752 A 11/1994 Moll et al.
5,383,874 A 1/1995 Jackson et al.
5,385,148 A 1/1995 Lesh et al.
5,395,312 A 3/1995 Desai
5,396,887 A 3/1995 Imran
5,397,304 A 3/1995 Truckai
5,400,770 A 3/1995 Nakao et al.
5,400,783 A 3/1995 Pomeranz et al.
5,401,272 A 3/1995 Perkins
5,403,309 A 4/1995 Coleman et al.
5,403,311 A 4/1995 Abele et al.
5,405,376 A 4/1995 Mulier et al.
5,409,483 A 4/1995 Campbell et al.
5,417,709 A 5/1995 Slater
5,423,807 A 6/1995 Mlilder
5,423,811 A 6/1995 Imran et al.
5,427,119 A 6/1995 Swartz et al.
5,431,168 A 7/1995 Webster, Jr.
5,431,649 A 7/1995 Mulier et al.
5,433,708 A 7/1995 Nichols et al.
5,435,308 A 7/1995 Gallup et al.
5,437,651 A 8/1995 Todd et al.
5,441,503 A 8/1995 Considine et al.
5,443,463 A 8/1995 Stern et al.
5,443,470 A 8/1995 Stern et al.
5,445,638 A 8/1995 Rydell et al.
5,450,843 A 9/1995 Moll et al.
5,452,582 A 9/1995 Longsworth
5,452,733 A 9/1995 Sterman et al.
5,460,629 A 10/1995 Shlain et al.
5,462,545 A 10/1995 Wang et al.
5,465,717 A 11/1995 Imran et al.
5,469,853 A 11/1995 Law et al.
5,472,876 A 12/1995 Fahy
5,478,309 A 12/1995 Sweezer et al.
5,478,330 A 12/1995 Imran et al.
5,486,193 A 1/1996 Bourne et al.
5,487,385 A 1/1996 Avitall
5,487,757 A 1/1996 Truckai et al.
5,490,819 A 2/1996 Nicholas et al.
5,496,312 A 3/1996 Klicek
5,497,774 A 3/1996 Swartz et al.
5,498,248 A 3/1996 Milder
5,500,012 A 3/1996 Brucker et al.
5,505,730 A 4/1996 Edwards
5,516,505 A 5/1996 McDow
5,520,682 A 5/1996 Baust et al.
5,522,870 A 6/1996 Ben-Zion
5,536,267 A 7/1996 Edwards et al.
5,540,562 A 7/1996 Giter
5,542,945 A 8/1996 Fritzsch
5,545,195 A 8/1996 Lennox et al.
5,545,200 A 8/1996 West et al.
5,549,661 A 8/1996 Kordis et al.
5,555,883 A 9/1996 Avitall

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,556,397 A 9/1996 Long et al.
5,558,671 A 9/1996 Yates
5,560,362 A 10/1996 Silwa, Jr. et al.
5,562,702 A 10/1996 Huitema et al.
5,569,241 A 10/1996 Edwards
5,569,243 A 10/1996 Kortenbach et al.
5,571,088 A 11/1996 Lennox et al.
5,571,215 A 11/1996 Sterman et al.
5,573,532 A 11/1996 Chang et al.
5,575,766 A 11/1996 Swartz et al.
5,575,788 A 11/1996 Baker et al.
5,575,810 A 11/1996 Swanson et al.
5,578,007 A 11/1996 Imran
5,582,609 A 12/1996 Swanson et al.
5,588,432 A 12/1996 Crowley
5,590,657 A 1/1997 Cain et al.
5,595,183 A 1/1997 Swanson et al.
5,599,346 A 2/1997 Edwards et al.
5,605,539 A 2/1997 Buelna et al.
5,607,462 A 3/1997 Imran
5,617,854 A 4/1997 Munsif
5,630,837 A 5/1997 Crowley
5,637,090 A 6/1997 McGee et al.
5,643,197 A 7/1997 Brucker et al.
5,647,869 A 7/1997 Goble et al.
5,658,278 A 8/1997 Imran et al.
5,671,747 A 9/1997 Connor
5,673,695 A 10/1997 McGee et al.
5,676,662 A 10/1997 Fleischhacker et al.
5,676,692 A 10/1997 Sanghvi et al.
5,676,693 A 10/1997 Lafontaine
5,678,550 A 10/1997 Bassen et al.
5,680,860 A 10/1997 Imran
5,681,278 A 10/1997 Igo et al.
5,681,294 A 10/1997 Osborne et al.
5,681,308 A 10/1997 Edwards et al.
5,687,723 A 11/1997 Avitall
5,687,737 A 11/1997 Branham et al.
5,688,267 A 11/1997 Panescu et al.
5,690,611 A 11/1997 Swartz et al.
5,697,536 A 12/1997 Eggers et al.
5,697,882 A 12/1997 Eggers et al.
5,697,925 A 12/1997 Taylor
5,697,927 A 12/1997 Imran et al.
5,697,928 A 12/1997 Walcott et al.
5,713,942 A 2/1998 Stern
5,716,389 A 2/1998 Walinsky et al.
5,718,241 A 2/1998 Ben-Haim et al.
5,718,701 A 2/1998 Shai et al.
5,720,775 A 2/1998 Lanard
5,722,402 A 3/1998 Swanson et al.
5,730,074 A 3/1998 Peter
5,730,127 A 3/1998 Avitall
5,730,704 A 3/1998 Avitall
5,733,280 A 3/1998 Avitall
5,735,280 A 4/1998 Sherman et al.
5,735,290 A 4/1998 Sterman et al.
5,743,903 A 4/1998 Stern et al.
5,755,760 A 5/1998 Maguire et al.
5,766,167 A 6/1998 Eggers et al.
5,769,846 A 6/1998 Edwards et al.
5,782,828 A 7/1998 Chen et al.
5,785,706 A 7/1998 Bednarek
5,788,636 A 8/1998 Curley
5,792,140 A 8/1998 Tu et al.
5,797,905 A 8/1998 Fleischman et al.
5,797,960 A 8/1998 Stevens et al.
5,800,428 A 9/1998 Nelson et al.
5,800,482 A 9/1998 Pomeranz et al.
5,810,764 A 9/1998 Eggers et al.
5,810,802 A 9/1998 Panescu et al.
5,827,216 A 10/1998 Igo et al.
5,836,947 A 11/1998 Fleischman et al.
5,840,030 A 11/1998 Ferek-Petric et al.
5,843,021 A 12/1998 Edwards et al.
5,843,152 A 12/1998 Tu et al.
5,844,349 A 12/1998 Oakley et al.
5,846,187 A 12/1998 Wells et al.
5,846,191 A 12/1998 Wells et al.
5,849,028 A 12/1998 Chen
5,861,021 A 1/1999 Thome et al.
5,871,523 A 2/1999 Fleischman et al.
5,871,525 A 2/1999 Edwards et al.
5,873,845 A 2/1999 Cline et al.
5,873,855 A 2/1999 Eggers
5,876,399 A 3/1999 Chia et al.
5,879,295 A 3/1999 Li et al.
5,879,296 A 3/1999 Ockuly et al.
5,879,348 A 3/1999 Owens et al.
5,881,732 A 3/1999 Sung et al.
5,882,346 A 3/1999 Pomeranz et al.
5,885,278 A 3/1999 Fleischman
5,891,142 A 4/1999 Eggers et al.
5,893,848 A 4/1999 Negus et al.
5,895,355 A 4/1999 Schaer
5,895,417 A 4/1999 Pomeranz et al.
5,897,553 A 4/1999 Mulier et al.
5,897,554 A 4/1999 Chia et al.
5,899,898 A 5/1999 Arless et al.
5,899,899 A 5/1999 Arless et al.
5,902,289 A 5/1999 Swartz et al.
5,904,711 A 5/1999 Flom et al.
5,906,580 A 5/1999 Kline-Schoder et al.
5,906,587 A 5/1999 Zimmon
5,906,606 A 5/1999 Chee et al.
5,908,029 A 6/1999 Knudson et al.
5,913,854 A 6/1999 Maguire et al.
5,916,213 A 6/1999 Haissaguerre et al.
5,916,214 A 6/1999 Cosio et al.
5,921,924 A 7/1999 Avitall
5,921,982 A 7/1999 Lesh et al.
5,925,045 A 7/1999 Reimels et al.
5,927,284 A 7/1999 Borst et al.
5,928,191 A 7/1999 Houser et al.
5,931,810 A 8/1999 Grabek
5,931,848 A 8/1999 Saadat
5,935,123 A 8/1999 Edwards et al.
5,944,715 A 8/1999 Goble et al.
5,954,661 A 9/1999 Greenspon et al.
5,957,919 A 9/1999 Laufer
5,971,980 A 10/1999 Sherman
5,971,983 A 10/1999 Lesh
5,980,516 A 11/1999 Mulier et al.
5,989,248 A 11/1999 Tu et al.
5,992,418 A * 11/1999 de la Rama et al. ..... 128/898
5,993,412 A 11/1999 Deily et al.
5,993,447 A 11/1999 Blewett et al.
6,004,316 A 12/1999 Laufer
6,004,319 A 12/1999 Goble et al.
6,007,499 A 12/1999 Martin et al.
6,010,500 A 1/2000 Sherman et al.
6,012,457 A 1/2000 Lesh
6,015,391 A 1/2000 Rishton et al.
6,016,811 A 1/2000 Knopp et al.
6,018,676 A 1/2000 Davis et al.
6,019,757 A 2/2000 Scheldrup
6,024,733 A 2/2000 Eggers et al.
6,030,381 A 2/2000 Jones
6,036,687 A 3/2000 Laufer et al.
6,042,556 A 3/2000 Beach et al.
6,048,333 A 4/2000 Lennox et al.
6,056,744 A 5/2000 Edwards
6,056,745 A 5/2000 Panescu et al.
6,056,746 A 5/2000 Goble et al.
6,056,747 A 5/2000 Saadat et al.
6,063,081 A 5/2000 Mulier
6,066,139 A 5/2000 Ryan et al.
6,068,653 A 5/2000 LaFontaine
6,071,279 A 6/2000 Whayne et al.
6,083,237 A 7/2000 Huitema et al.
6,086,585 A 7/2000 Hovda et al.
6,088,894 A 7/2000 Oakley
6,096,037 A 8/2000 Mulier et al.
6,113,592 A 9/2000 Taylor

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,113,596 A 9/2000 Hooven et al.
6,117,101 A 9/2000 Diederich et al.
6,120,496 A 9/2000 Whayne et al.
6,141,576 A 10/2000 Littmann et al.
6,142,993 A 11/2000 Whayne et al.
6,142,994 A 11/2000 Swanson et al.
6,149,620 A 11/2000 Baker et al.
6,152,920 A 11/2000 Thompson et al.
6,161,543 A 12/2000 Cox et al.
6,165,169 A 12/2000 Panescu et al.
6,165,174 A 12/2000 Jacobs et al.
6,190,384 B1 2/2001 Ouchi
6,193,716 B1 2/2001 Shannon, Jr.
6,210,406 B1 4/2001 Webster
6,210,410 B1 4/2001 Farin et al.
6,210,411 B1 4/2001 Hofmann et al.
6,212,426 B1 4/2001 Swanson
6,217,528 B1 4/2001 Koblish et al.
6,217,576 B1 4/2001 Tu et al.
6,224,592 B1 5/2001 Eggers et al.
6,231,518 B1 5/2001 Grabek et al.
6,231,591 B1 5/2001 Desai
6,235,020 B1 5/2001 Cheng et al.
6,235,024 B1 5/2001 Tu
6,237,605 B1 5/2001 Vaska et al.
6,238,347 B1 5/2001 Nix et al.
6,238,387 B1 5/2001 Miller, III
6,238,393 B1 5/2001 Mulier
6,245,061 B1 6/2001 Panescu et al.
6,245,064 B1 6/2001 Lesh et al.
6,245,065 B1 6/2001 Panescu et al.
6,251,092 B1 6/2001 Qin et al.
6,251,110 B1 6/2001 Wampler
6,251,128 B1 6/2001 Knopp et al.
6,258,087 B1 7/2001 Edwards et al.
6,264,650 B1 7/2001 Hovda et al.
6,266,551 B1 7/2001 Osadchy et al.
6,270,471 B1 8/2001 Hechel et al.
6,283,988 B1 9/2001 Laufer et al.
6,283,989 B1 9/2001 Laufer et al.
6,293,943 B1 9/2001 Panescu et al.
6,296,619 B1 10/2001 Brisken et al.
6,299,633 B1 10/2001 Laufer
6,302,880 B1 10/2001 Schaer
6,311,692 B1 11/2001 Vaska et al.
6,312,383 B1 11/2001 Lizzi et al.
6,314,962 B1 11/2001 Vaska et al.
6,314,963 B1 11/2001 Vaska et al.
6,322,559 B1 11/2001 Daulton et al.
6,325,797 B1 12/2001 Stewart et al.
6,328,735 B1 12/2001 Curley et al.
6,328,736 B1 12/2001 Mulier
6,332,881 B1 12/2001 Carner et al.
6,352,533 B1 3/2002 Ellman et al.
6,358,245 B1 3/2002 Edwards et al.
6,358,248 B1 3/2002 Mulier
6,361,531 B1 3/2002 Hissong
6,364,876 B1 4/2002 Erb et al.
6,368,275 B1 4/2002 Sliwa et al.
6,371,955 B1 4/2002 Fuimaono et al.
6,371,956 B1 4/2002 Wilson et al.
6,383,151 B1 5/2002 Diederich et al.
6,385,472 B1 5/2002 Hall et al.
6,398,792 B1 6/2002 O'Connor
6,409,722 B1 6/2002 Hoey et al.
6,413,254 B1 7/2002 Hissong et al.
6,416,509 B1 7/2002 Goble et al.
6,419,648 B1 7/2002 Vitek et al.
6,425,867 B1 7/2002 Vaezy et al.
6,430,426 B2 8/2002 Avitall
6,440,130 B1 8/2002 Mulier
6,443,952 B1 9/2002 Mulier
6,447,507 B1 9/2002 Bednarek et al.
6,461,314 B1 10/2002 Pant et al.
6,461,356 B1 10/2002 Patterson
6,464,700 B1 10/2002 Koblish et al.
6,471,697 B1 10/2002 Lesh
6,471,698 B1 10/2002 Edwards et al.
6,474,340 B1 11/2002 Vaska et al.
6,475,216 B2 11/2002 Mulier
6,477,396 B1 11/2002 Mest et al.
6,478,793 B1 11/2002 Cosman et al.
6,484,727 B1 11/2002 Vaska et al.
6,488,680 B1 12/2002 Francischelli
6,497,704 B2 12/2002 Ein-Gal
6,502,575 B1 1/2003 Jacobs et al.
6,508,815 B1 1/2003 Strul et al.
6,514,250 B1 2/2003 Jahns
6,517,536 B2 2/2003 Hooven et al.
6,527,767 B2 3/2003 Wang et al.
6,537,248 B2 3/2003 Mulier
6,558,382 B2 5/2003 Jahns
6,558,385 B1 5/2003 McClurken et al.
6,575,969 B1 6/2003 Rittman, III et al.
6,579,288 B1 6/2003 Swanson et al.
6,584,360 B2 6/2003 Francischelli
6,585,732 B2 7/2003 Mulier
6,602,248 B1 8/2003 Sharps et al.
6,603,988 B2 8/2003 Dowlatshahi
6,605,084 B2 8/2003 Acker et al.
6,610,055 B1 8/2003 Swanson et al.
6,610,060 B2 8/2003 Mulier et al.
6,613,048 B2 9/2003 Mulier
6,635,034 B1 10/2003 Cosmescu
6,645,199 B1 11/2003 Jenkins et al.
6,645,202 B1 11/2003 Pless et al.
6,648,883 B2 11/2003 Francischelli
6,656,175 B2 12/2003 Francischelli
6,663,627 B2 12/2003 Francischelli
6,666,862 B2 12/2003 Jain et al.
6,679,882 B1 1/2004 Kornerup
6,682,501 B1 1/2004 Nelson et al.
6,689,131 B2 2/2004 McClurken
6,692,450 B1 2/2004 Coleman
6,699,240 B2 3/2004 Francischelli
6,702,810 B2 3/2004 McClurken et al.
6,702,811 B2 3/2004 Stewart et al.
6,706,038 B2 3/2004 Francischelli
6,706,039 B2 3/2004 Mulier
6,716,211 B2 4/2004 Mulier
6,736,810 B2 5/2004 Hoey
6,755,827 B2 6/2004 Mulier
6,764,487 B2 7/2004 Mulier
6,766,202 B2 7/2004 Underwood et al.
6,766,817 B2 7/2004 da Silva
6,773,433 B2 8/2004 Stewart et al.
6,775,575 B2 8/2004 Bommannan et al.
6,776,780 B2 8/2004 Mulier
6,807,968 B2 10/2004 Francischelli
6,827,713 B2 12/2004 Bek et al.
6,827,715 B2 12/2004 Francischelli
6,832,996 B2 12/2004 Woloszko et al.
6,849,073 B2 2/2005 Hoey
6,858,028 B2 2/2005 Mulier
6,887,238 B2 5/2005 Jahns
6,899,711 B2 5/2005 Stewart et al.
6,911,019 B2 6/2005 Mulier
6,915,806 B2 7/2005 Pacek et al.
6,916,318 B2 7/2005 Francischelli
6,918,404 B2 7/2005 Dias da Silva
6,936,046 B2 8/2005 Hissong
6,942,661 B2 9/2005 Swanson
6,949,097 B2 9/2005 Stewart et al.
6,949,098 B2 9/2005 Mulier
6,953,461 B2 10/2005 McClurken et al.
6,960,205 B2 11/2005 Jahns
6,962,589 B2 11/2005 Mulier
7,066,586 B2 6/2006 da Silva
7,115,139 B2 10/2006 McClurken et al.
7,156,845 B2 1/2007 Mulier et al.
7,166,106 B2 1/2007 Bartel et al.
7,207,471 B2 4/2007 Heinrich et al.
7,232,440 B2 6/2007 Dumbauld et al.
7,247,155 B2 7/2007 Hoey et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 7,261,711 | B2 | 8/2007 | Mulier et al. |
| 7,309,325 | B2 | 12/2007 | Mulier et al. |
| 7,311,708 | B2 | 12/2007 | McClurken |
| 7,322,974 | B2 | 1/2008 | Swoyer et al. |
| 7,361,175 | B2 | 4/2008 | Suslov |
| 7,364,579 | B2 | 4/2008 | Mulier et al. |
| 7,537,595 | B2 | 5/2009 | McClurken |
| 7,604,635 | B2 | 10/2009 | McClurken et al. |
| 7,645,277 | B2 | 1/2010 | McClurken et al. |
| 7,651,494 | B2 | 1/2010 | McClurken et al. |
| 7,736,361 | B2 | 6/2010 | Palanker |
| 7,811,282 | B2 | 10/2010 | McClurken |
| 7,815,634 | B2 | 10/2010 | McClurken et al. |
| 7,909,820 | B2 | 3/2011 | Lipson |
| 7,976,544 | B2 | 7/2011 | McClurken et al. |
| 8,012,154 | B2 | 9/2011 | Livneh |
| 8,048,070 | B2 | 11/2011 | O'Brien |
| 8,083,736 | B2 | 12/2011 | McClurken et al. |
| 8,177,783 | B2 | 5/2012 | Davison et al. |
| 8,216,233 | B2 | 7/2012 | McClurken et al. |
| 8,323,276 | B2 | 12/2012 | Palanker et al. |
| 8,348,946 | B2 | 1/2013 | McClurken et al. |
| 2002/0049483 | A1 | 4/2002 | Knowlton |
| 2003/0014050 | A1 | 1/2003 | Sharkey et al. |
| 2003/0032954 | A1 | 2/2003 | Carranza et al. |
| 2003/0045872 | A1 | 3/2003 | Jacobs |
| 2003/0073993 | A1 | 4/2003 | Ciarrocca |
| 2003/0144656 | A1 | 7/2003 | Ocel |
| 2003/0191462 | A1 | 10/2003 | Jacobs |
| 2003/0204185 | A1 | 10/2003 | Sherman |
| 2003/0216724 | A1 | 11/2003 | Jahns |
| 2004/0015106 | A1 | 1/2004 | Coleman |
| 2004/0015219 | A1 | 1/2004 | Francischelli |
| 2004/0024395 | A1 | 2/2004 | Ellman et al. |
| 2004/0044340 | A1 | 3/2004 | Francischelli |
| 2004/0049179 | A1 | 3/2004 | Francischelli |
| 2004/0078069 | A1 | 4/2004 | Francischelli |
| 2004/0082948 | A1 | 4/2004 | Stewart et al. |
| 2004/0087940 | A1 | 5/2004 | Jahns |
| 2004/0092926 | A1 | 5/2004 | Hoey |
| 2004/0111136 | A1 | 6/2004 | Sharkey et al. |
| 2004/0111137 | A1 | 6/2004 | Sharkey et al. |
| 2004/0116923 | A1 | 6/2004 | Desinger |
| 2004/0138621 | A1 | 7/2004 | Jahns |
| 2004/0138656 | A1 | 7/2004 | Francischelli |
| 2004/0143260 | A1 | 7/2004 | Francischelli |
| 2004/0186465 | A1 | 9/2004 | Francischelli |
| 2004/0215183 | A1 | 10/2004 | Hoey |
| 2004/0220560 | A1 | 11/2004 | Briscoe |
| 2004/0236322 | A1 | 11/2004 | Mulier |
| 2004/0267326 | A1 | 12/2004 | Ocel |
| 2005/0010095 | A1 | 1/2005 | Stewart et al. |
| 2005/0033280 | A1 | 2/2005 | Francischelli |
| 2005/0090815 | A1 | 4/2005 | Francischelli |
| 2005/0143729 | A1 | 6/2005 | Francischelli |
| 2005/0165392 | A1 | 7/2005 | Francischelli |
| 2005/0209564 | A1 | 9/2005 | Bonner |
| 2005/0267454 | A1 | 12/2005 | Hissong |
| 2006/0009756 | A1 | 1/2006 | Francischelli |
| 2006/0009759 | A1 | 1/2006 | Christian |
| 2006/0064085 | A1 | 3/2006 | Baker et al. |
| 2007/0049920 | A1 | 3/2007 | McClurken et al. |
| 2007/0093808 | A1 | 4/2007 | Mulier et al. |
| 2007/0118114 | A1 | 5/2007 | Mulier et al. |
| 2007/0208332 | A1 | 9/2007 | Mulier et al. |
| 2008/0015563 | A1 | 1/2008 | Hoey et al. |
| 2008/0071270 | A1 | 3/2008 | Baker et al. |
| 2008/0103494 | A1 | 5/2008 | Rioux et al. |
| 2009/0264879 | A1 | 10/2009 | McClurken et al. |
| 2010/0100095 | A1 | 4/2010 | McClurken et al. |
| 2011/0028965 | A1 | 2/2011 | McClurken |
| 2012/0101496 | A1 | 4/2012 | McClurken et al. |
| 2012/0116397 | A1 | 5/2012 | Rencher et al. |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| FR | 2 235 669 | 1/1975 |
| JP | 5-092009 | 4/1993 |
| JP | 7-124245 | 5/1995 |
| WO | WO 97/05829 A1 | 2/1997 |
| WO | WO 98/38932 A1 | 9/1998 |
| WO | WO 99/66850 A1 | 12/1999 |
| WO | WO 00/78240 A1 | 12/2000 |
| WO | WO 2005/122938 A1 | 12/2005 |
| WO | WO 2006/062916 A2 | 6/2006 |
| WO | WO 2006/062939 A2 | 6/2006 |

OTHER PUBLICATIONS

European Office Action dated Feb. 20, 2009 issued in related European Patent Application No. 02798936.7.
European Office Action dated May 6, 2009 issued in related European Patent Application No. 05851938.0.
European Office Action dated Nov. 25, 2008 issued in related European Patent Application No. 05851938.0.
Office Action dated Apr. 26, 2010 issued in related U.S. Appl. No. 11/537,852.
Office Action dated Mar. 18, 2010 issued in related U.S. Appl. No. 10/365,170.
Notice of Allowance dated Apr. 2, 2010 issued in related U.S. Appl. No. 11/274,908.
Supplemental Notice of Allowance dated May 27, 2010 issued in related U.S. Appl. No. 11/274,908.
Office Action dated Apr. 5, 2010 issued in related U.S. Appl. No. 11/318,207.
Office Action dated Jul. 17, 2009 received in related U.S. Appl. No. 11/274,908.
U.S. Office Action dated Jul. 16, 2009 issued in related U.S. Appl. No. 10/746,222.
United States Office Action dated Aug. 4, 2009 issued in related U.S. Appl. No. 11/537,852.
Office Action dated Jul. 2, 2009 issued in related U.S. Appl. No. 10/813,736.
Office Action dated Sep. 8, 2009 issued in related U.S. Appl. No. 10/488,801.
Office Action dated Sep. 15, 2009 issued in related U.S. Appl. No. 10/365,170.
Office Action dated Apr. 14, 2009 issued in related U.S. Appl. No. 10/547,881.
Office Action dated Sep. 17, 2009 issued in related U.S. Appl. No. 11/318,207.
Office Action dated Jun. 22, 2009 issued in related U.S. Appl. No. 10/486,807.
U.S. Office Action issued in related U.S. Appl. No. 11/318,207 dated Dec. 30, 2008.
U.S. Office Action issued in related U.S. Appl. No. 10/488,801 dated Dec. 2, 2008.
Office Action dated Dec. 24, 2009 issued in related U.S. Appl. No. 10/813,736.
Office Action dated Jan. 27, 2010 issued in related U.S. Appl. No. 10/746,222.
Office Action dated Jan. 29, 2010 issued in related U.S. Appl. No. 10/488,801.

* cited by examiner

FIG. 1

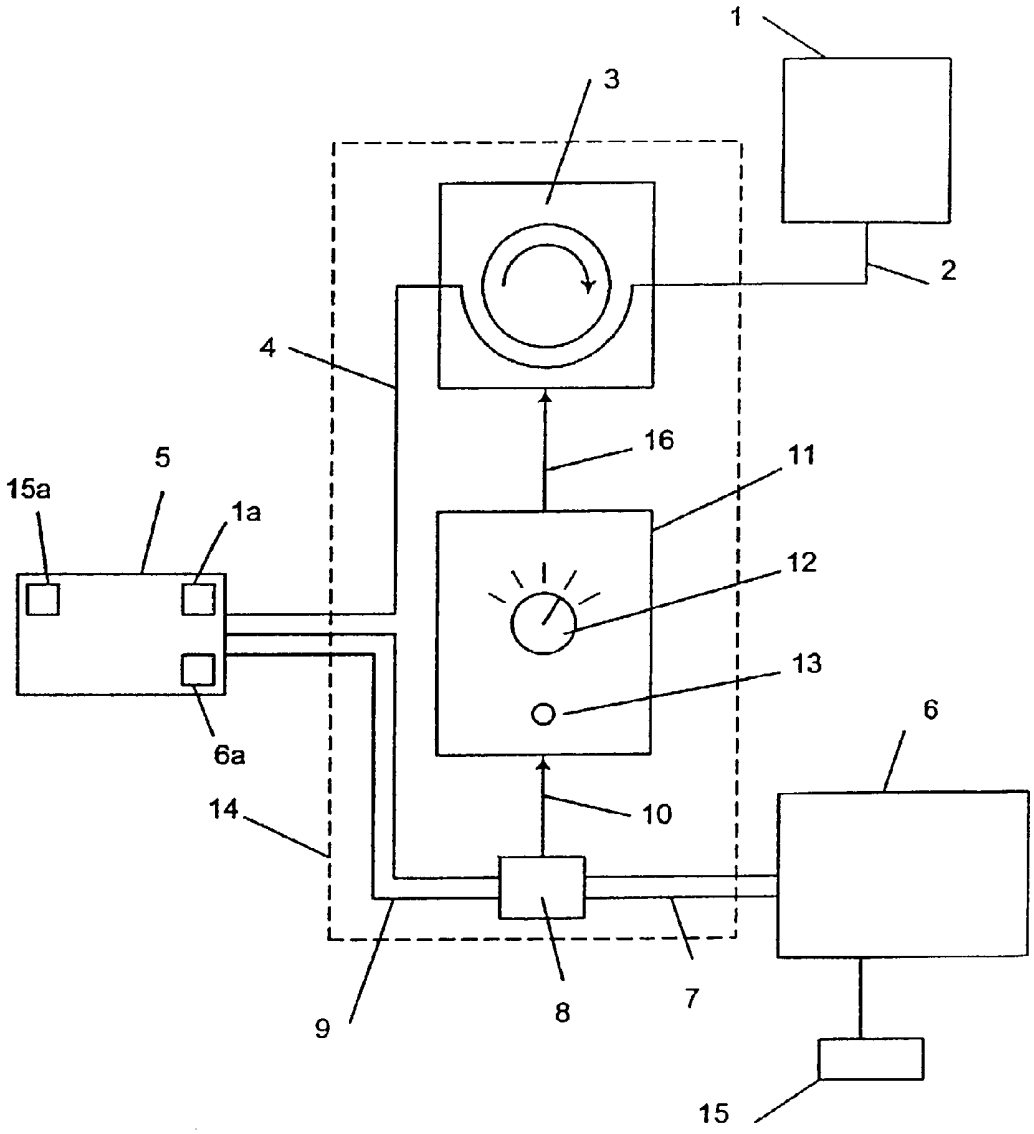


FIG. 2

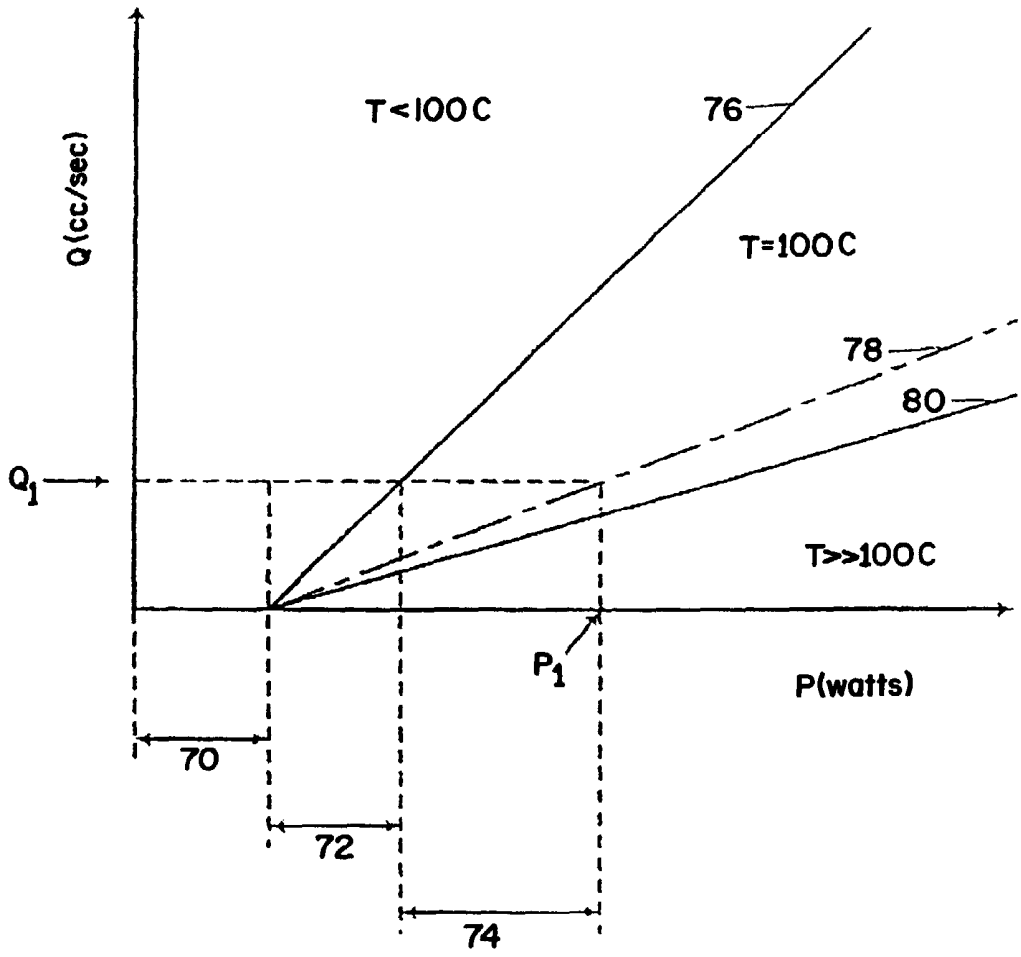


FIG. 3

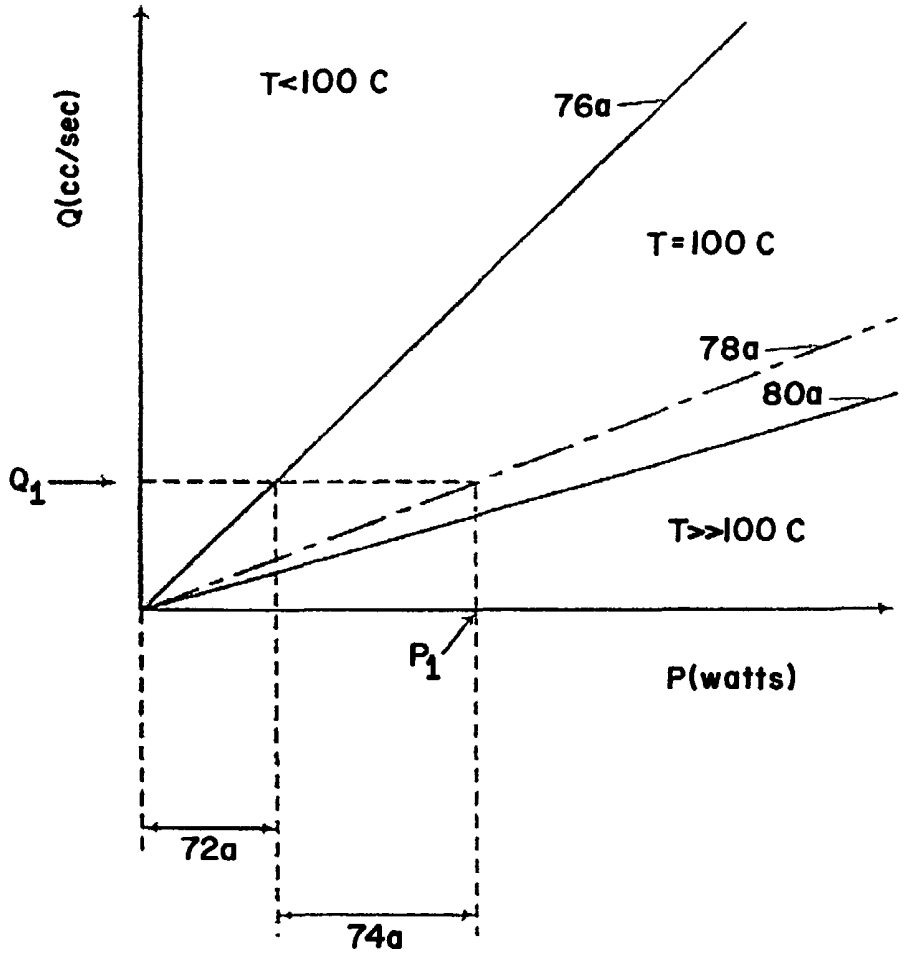


FIG. 4

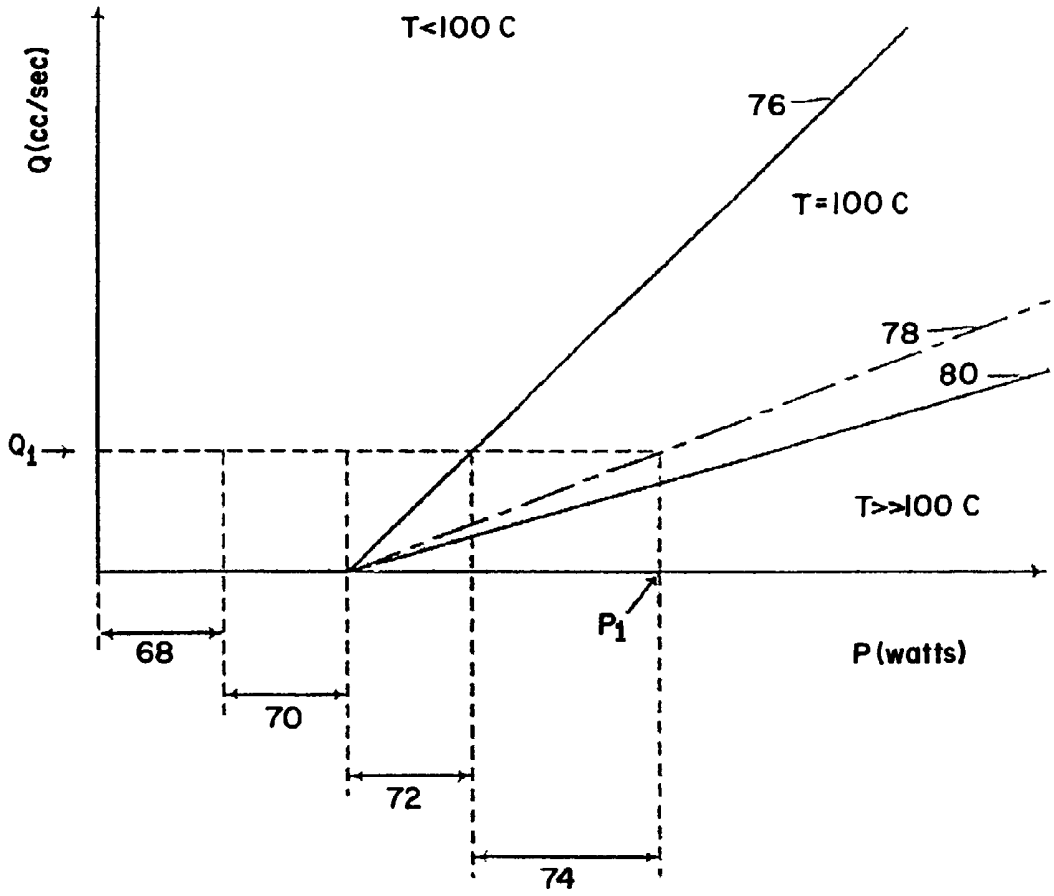


FIG. 5

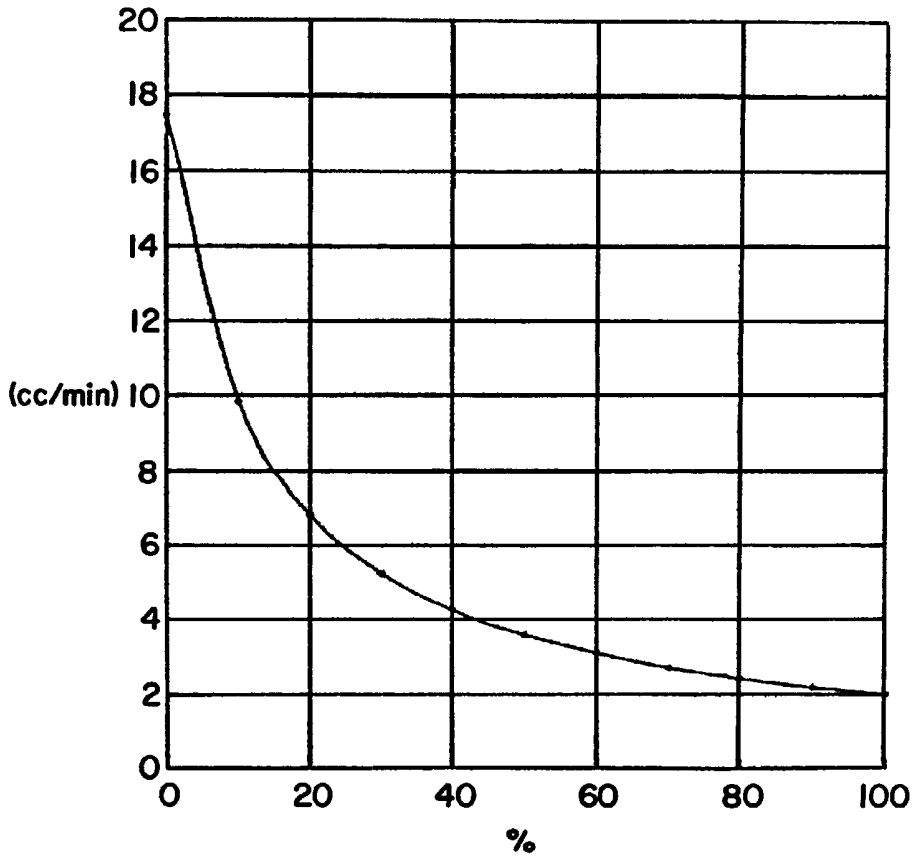


FIG. 6

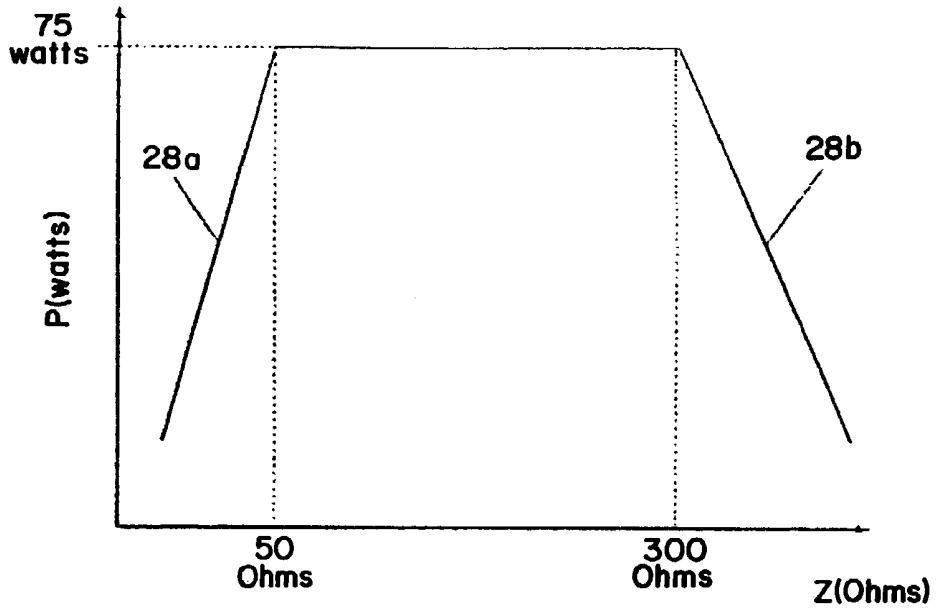
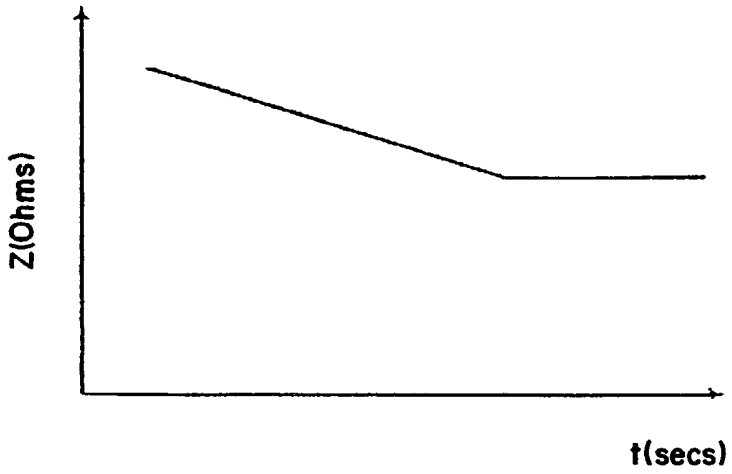



FIG. 7



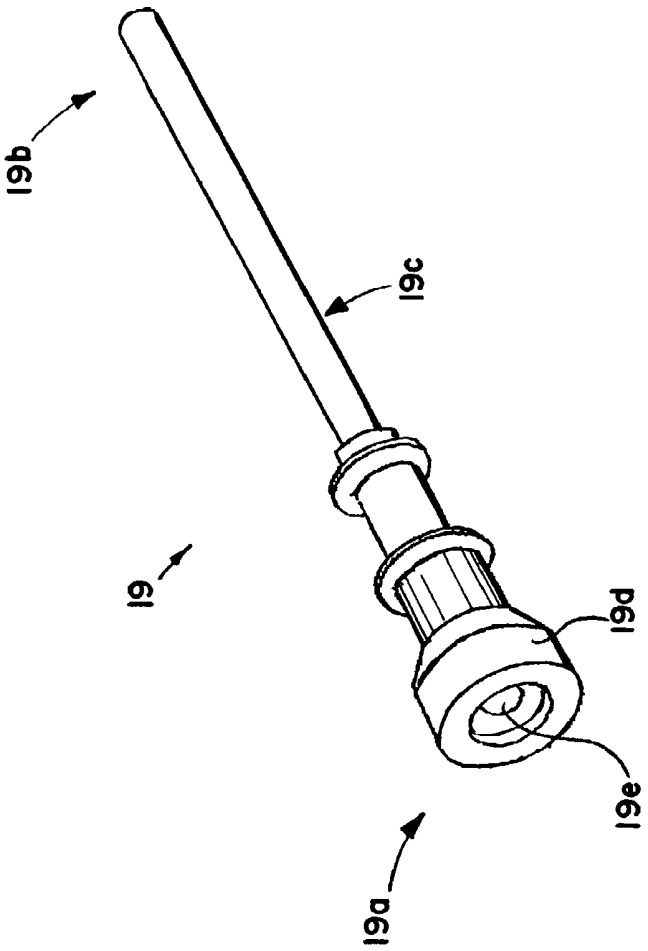



FIG. 8

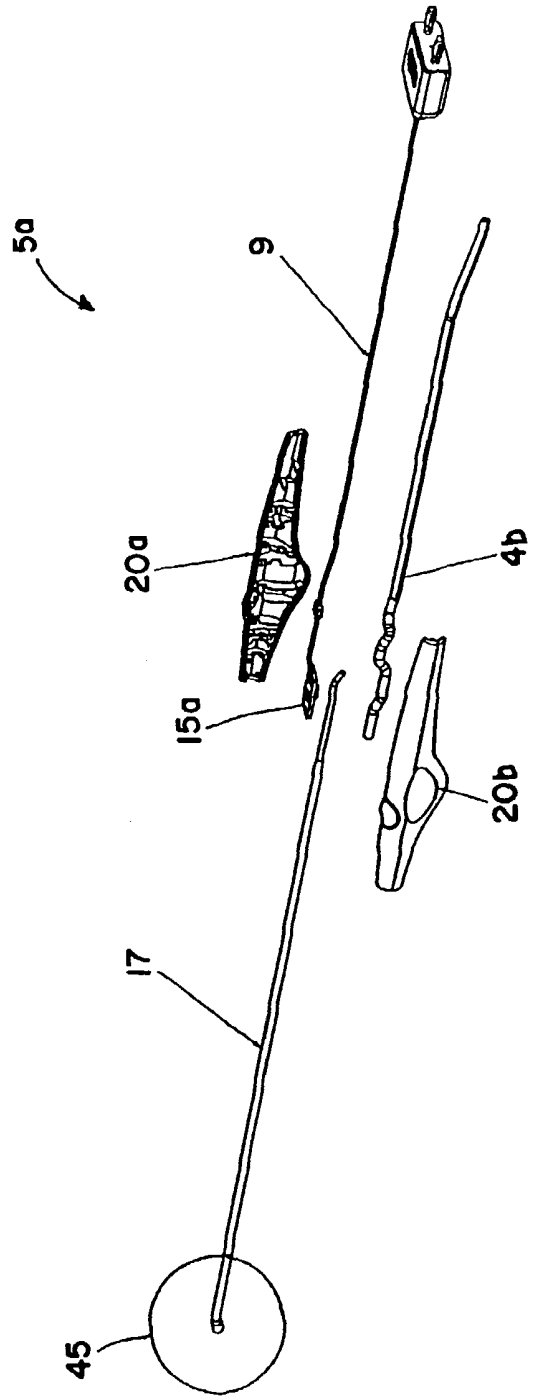



FIG. 9

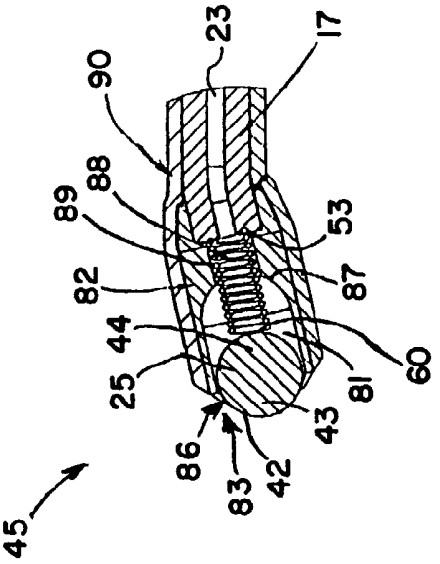



FIG. 11

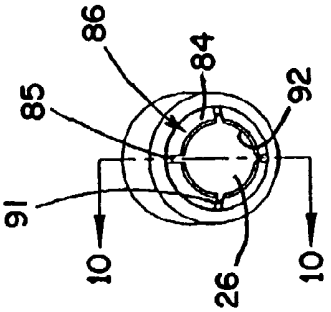



FIG. 12

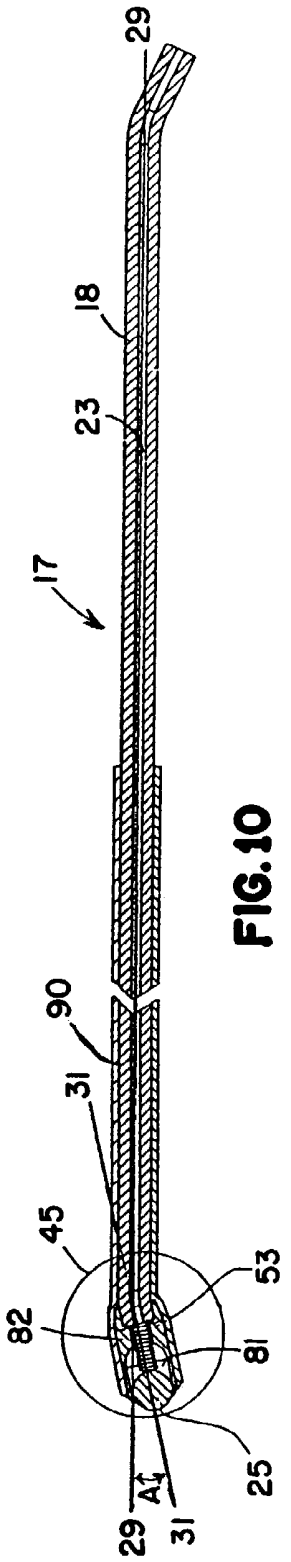



FIG. 10

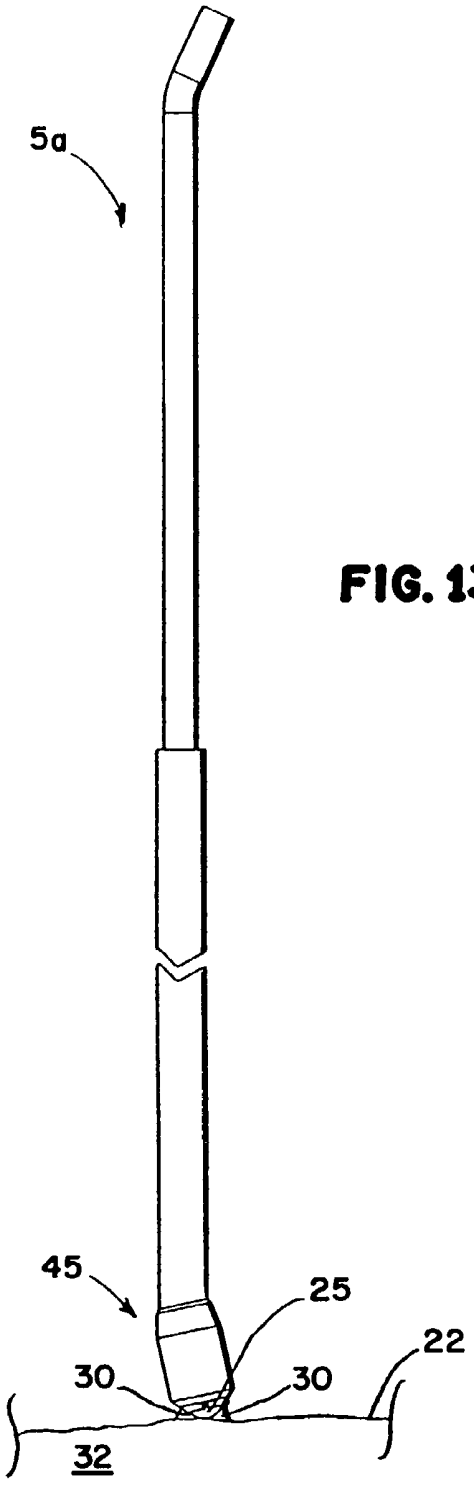



FIG. 13

FIG. 15

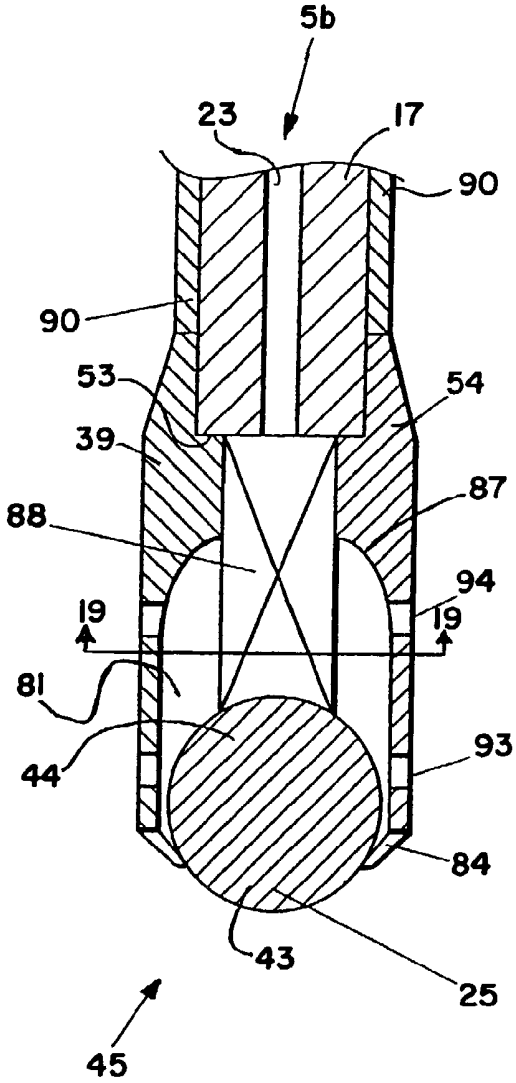

5b
23
17
90
90
53
54
39
87
88
94
19
19
81
44
93
84
43
25
45

FIG. 14

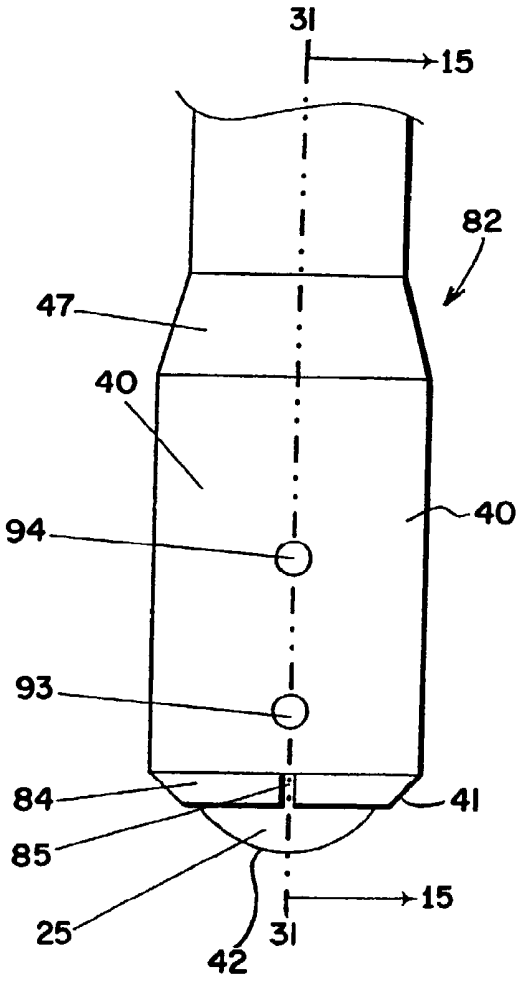

31
15
82
47
40
40
94
93
84
41
85
25
42
31
15

FIG. 16

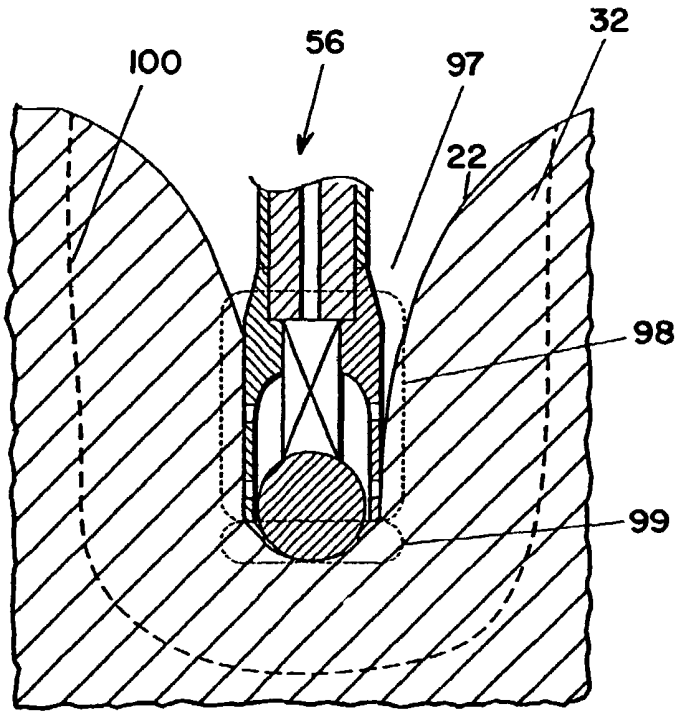


FIG. 17

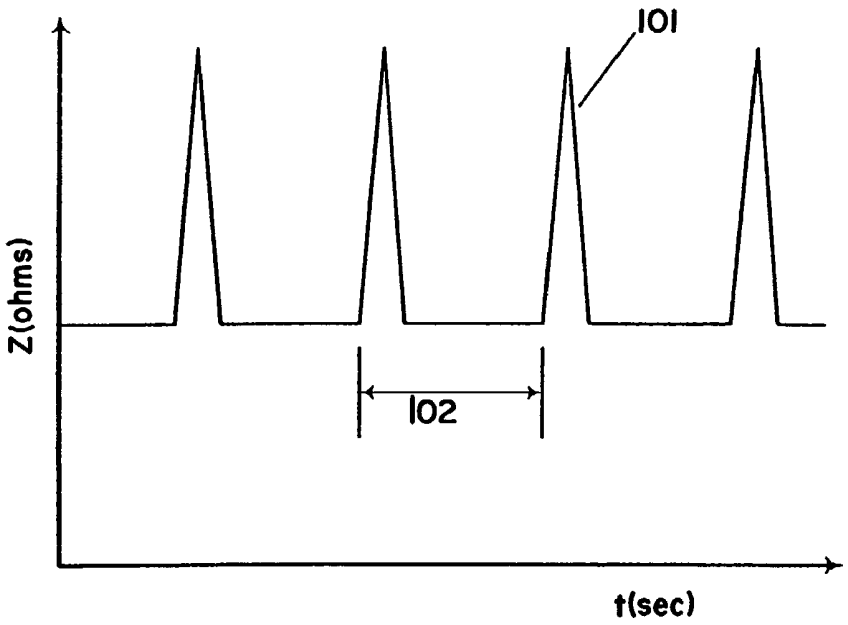


FIG. 18

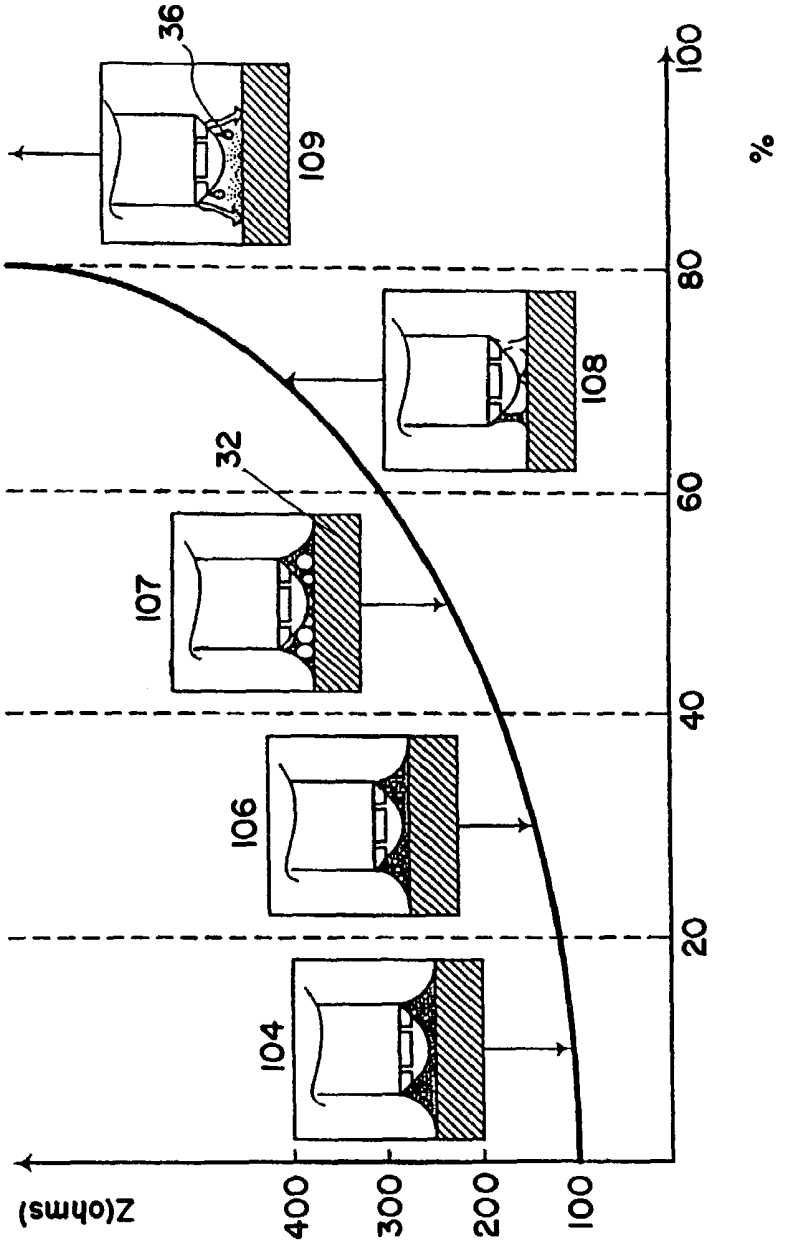
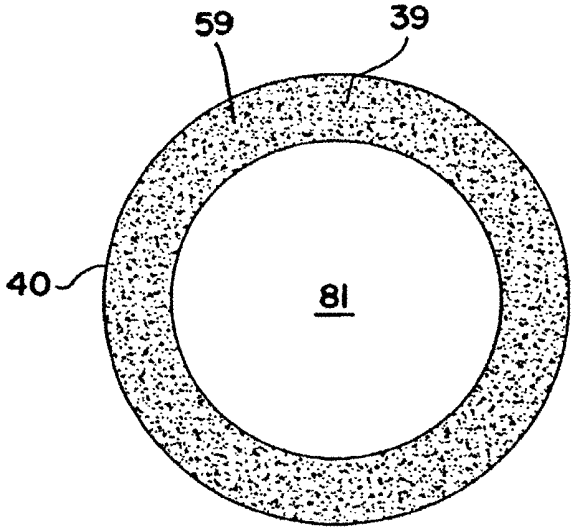


FIG. 19



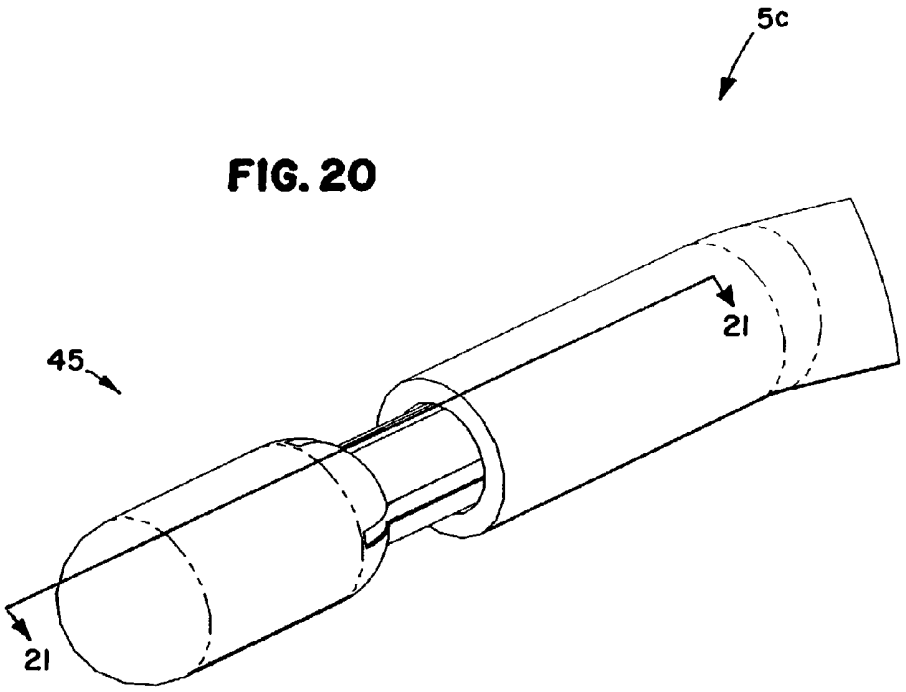

5c
45
21
21

FIG. 20

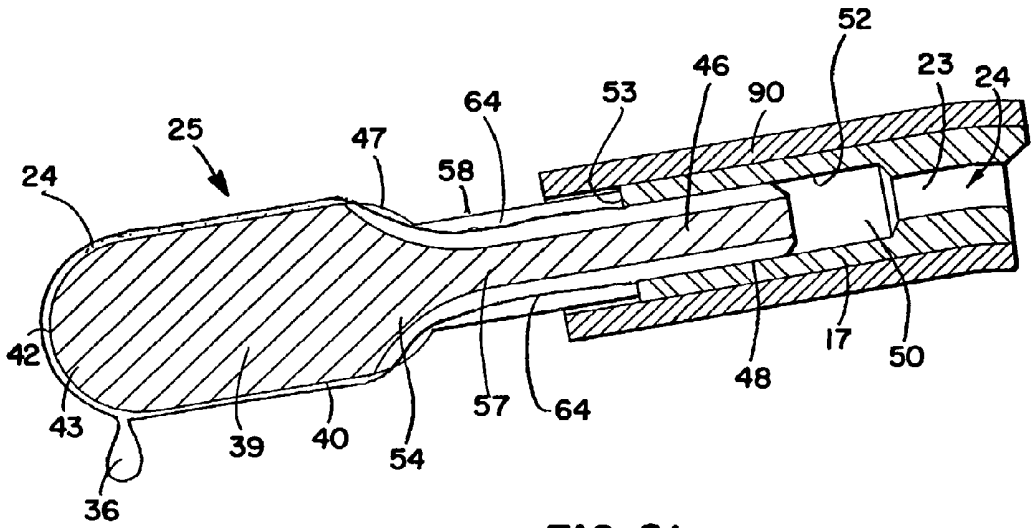

52
46
23
24
64
53
90
25
47
58
24
42
43
39
40
54
57
64
48
17
50
36

FIG. 21

FIG. 22

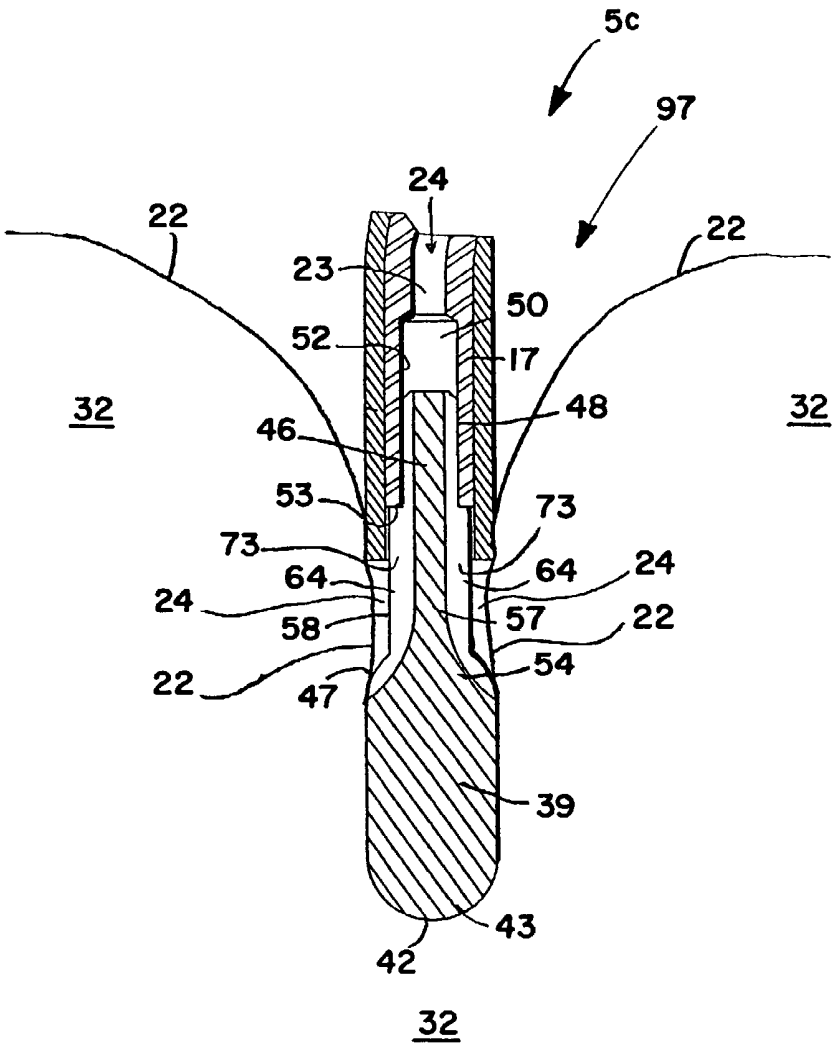
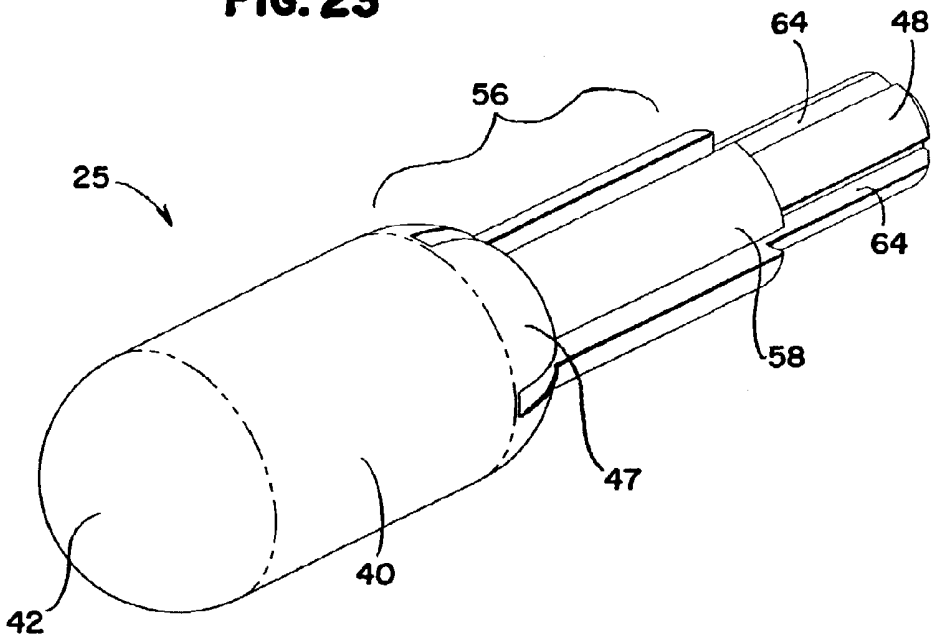

5c
97
24
22
22
23
50
52
17
32
48
32
46
53
73
73
64
64
24
24
58
57
22
22
54
47
39
43
42
32

FIG. 23



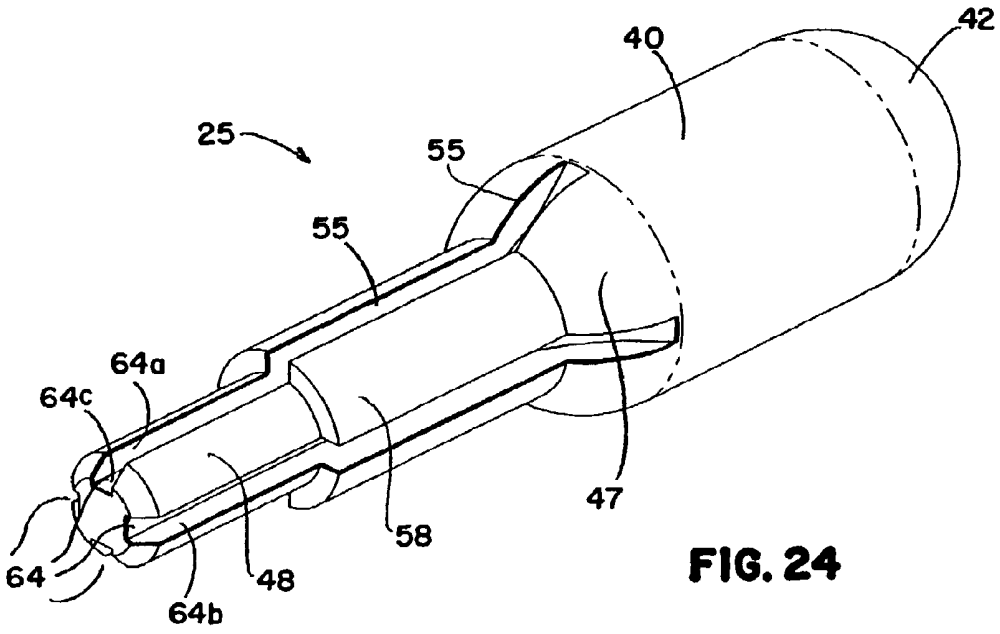




FIG. 24

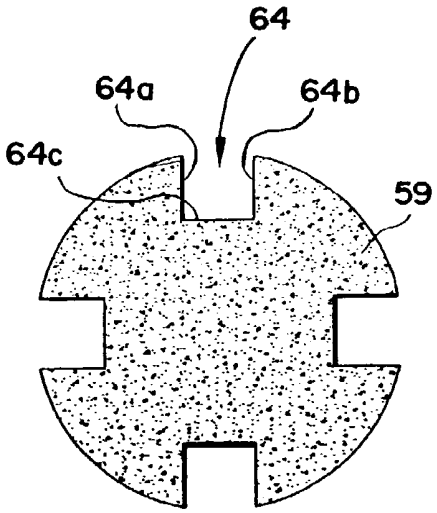



FIG. 25

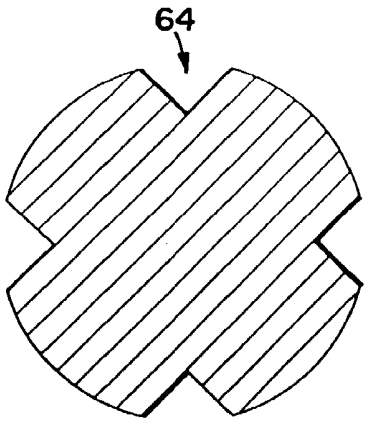



FIG. 27

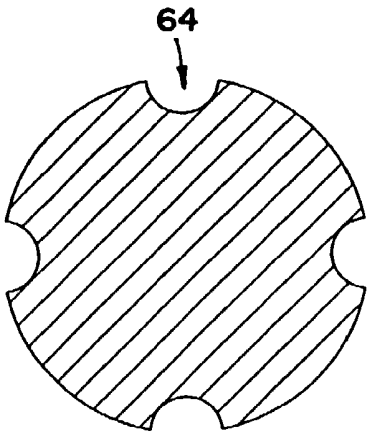



FIG. 26

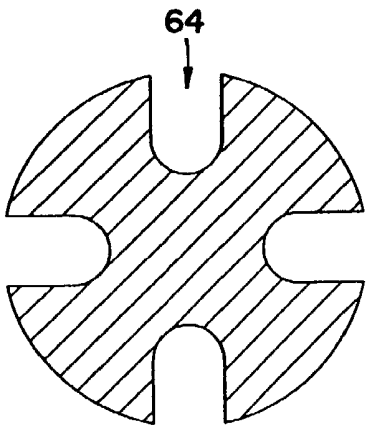
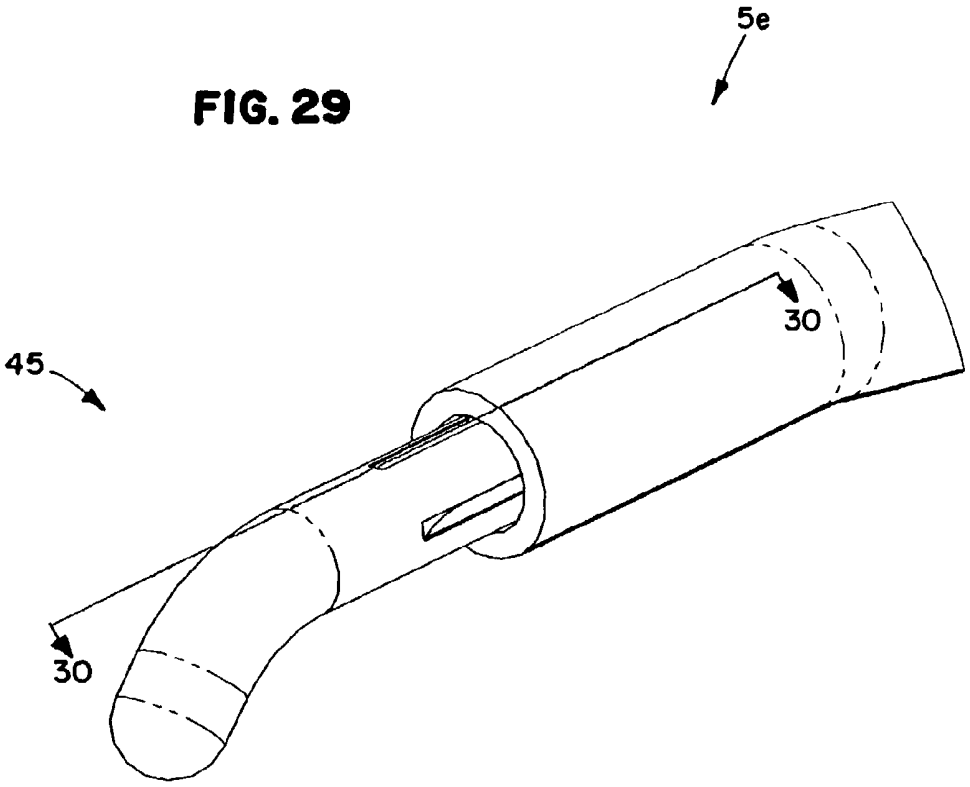



FIG. 28

FIG. 29



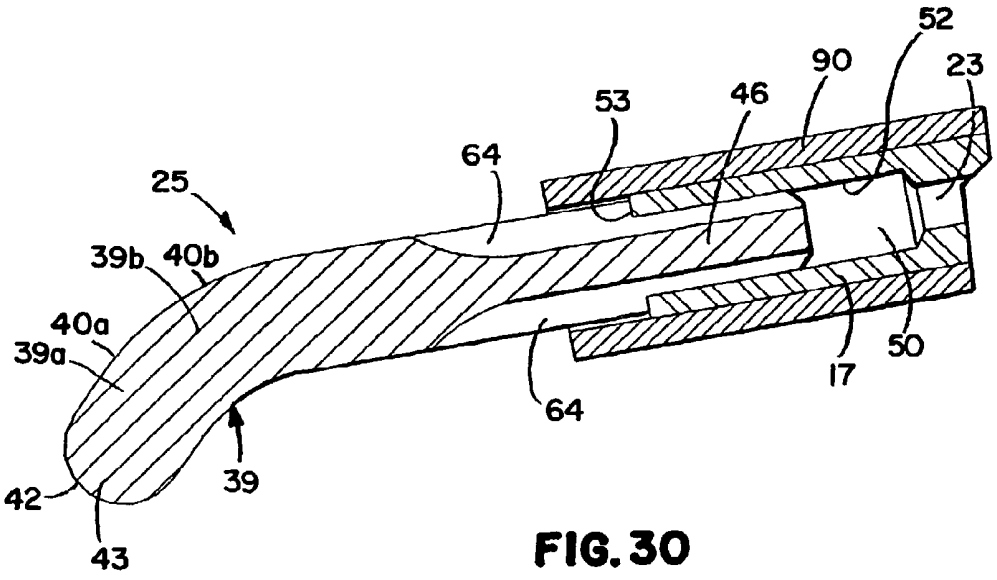
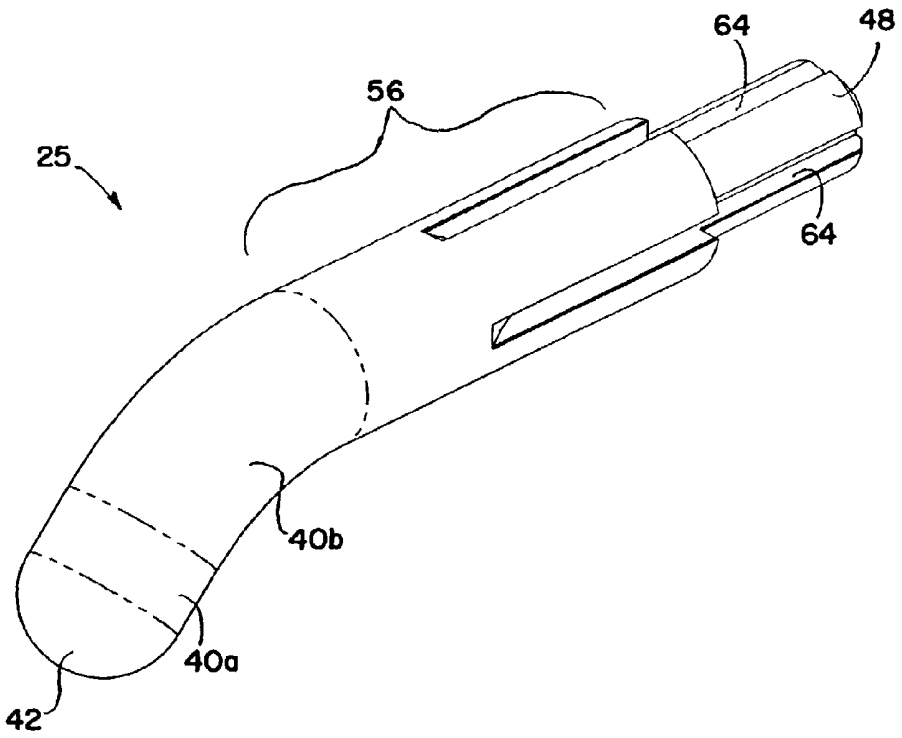




FIG. 30

FIG. 31



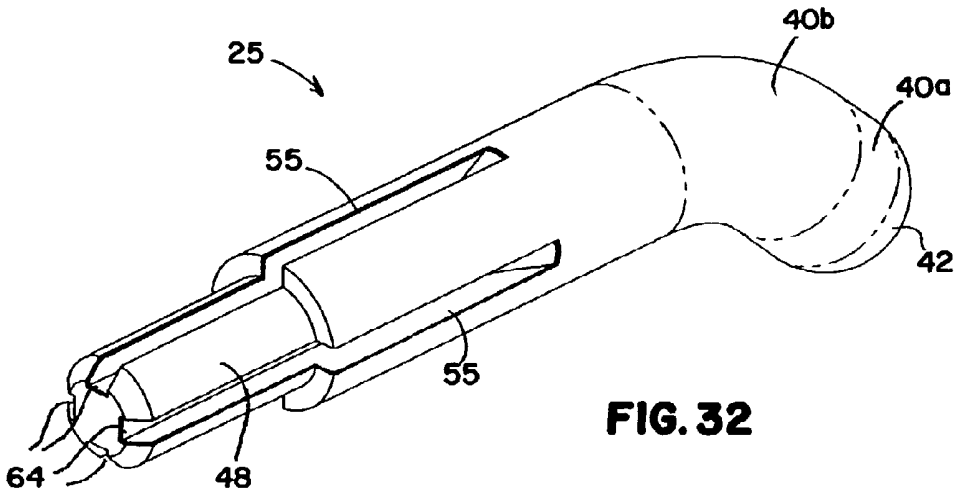
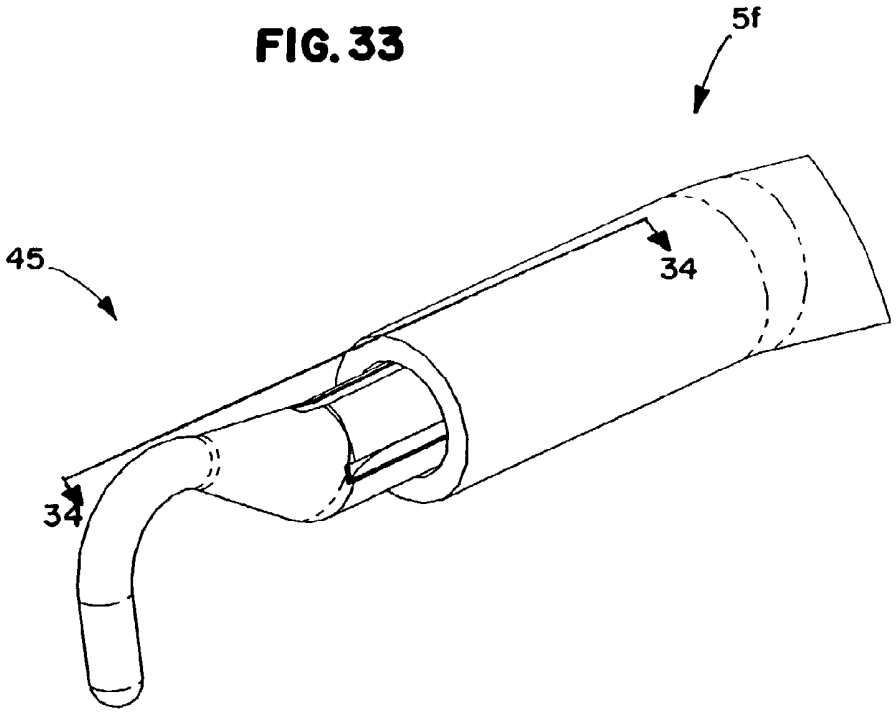




FIG. 32

FIG. 33


5f
45
34
34

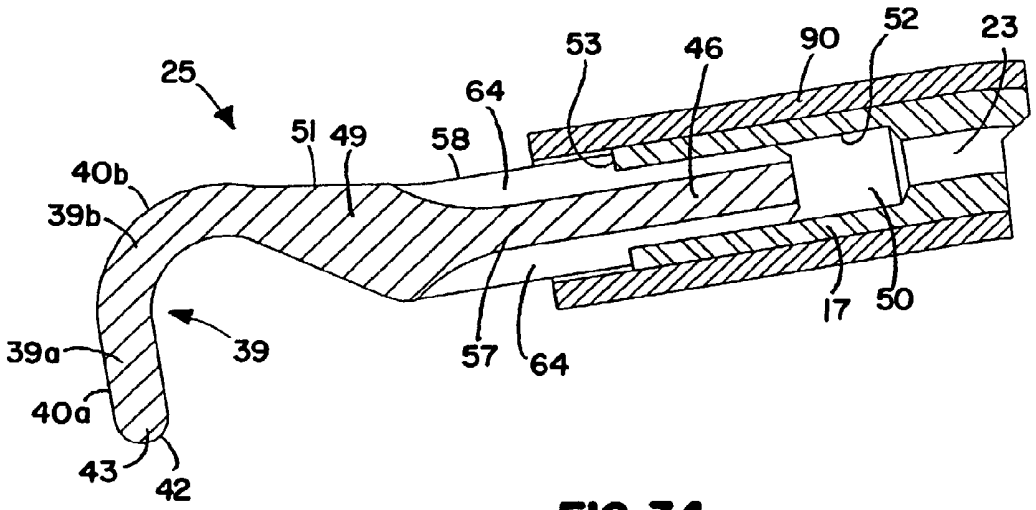
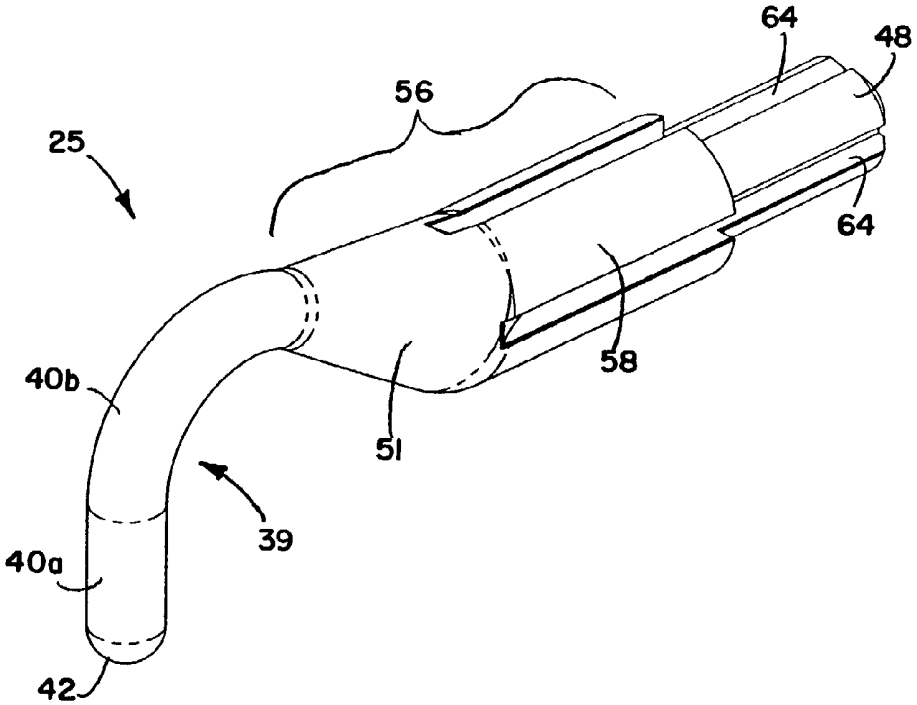

25
51
49
58
64
53
46
90
52
23
40b
39b
39
39a
40a
43
42
57
64
17
50

FIG. 34

FIG. 35



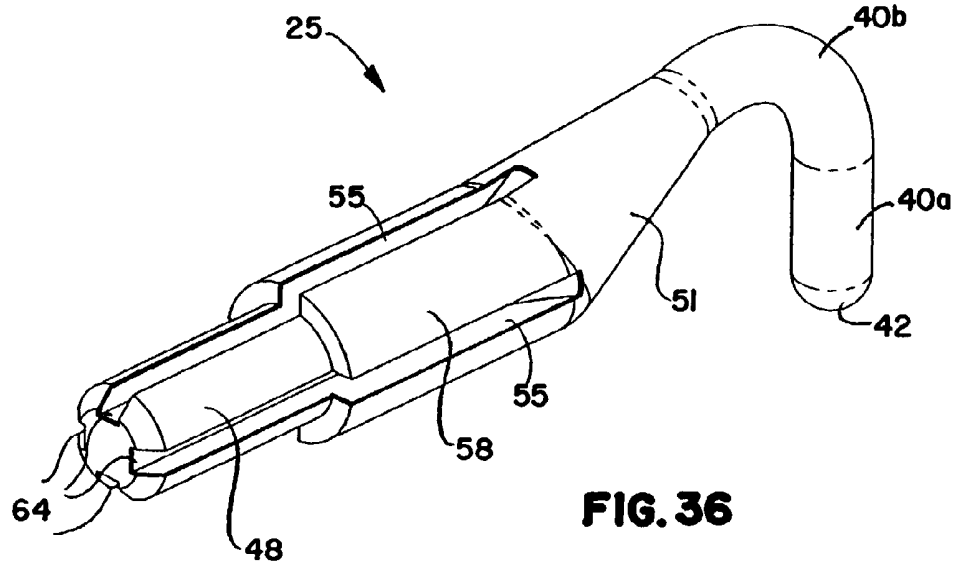
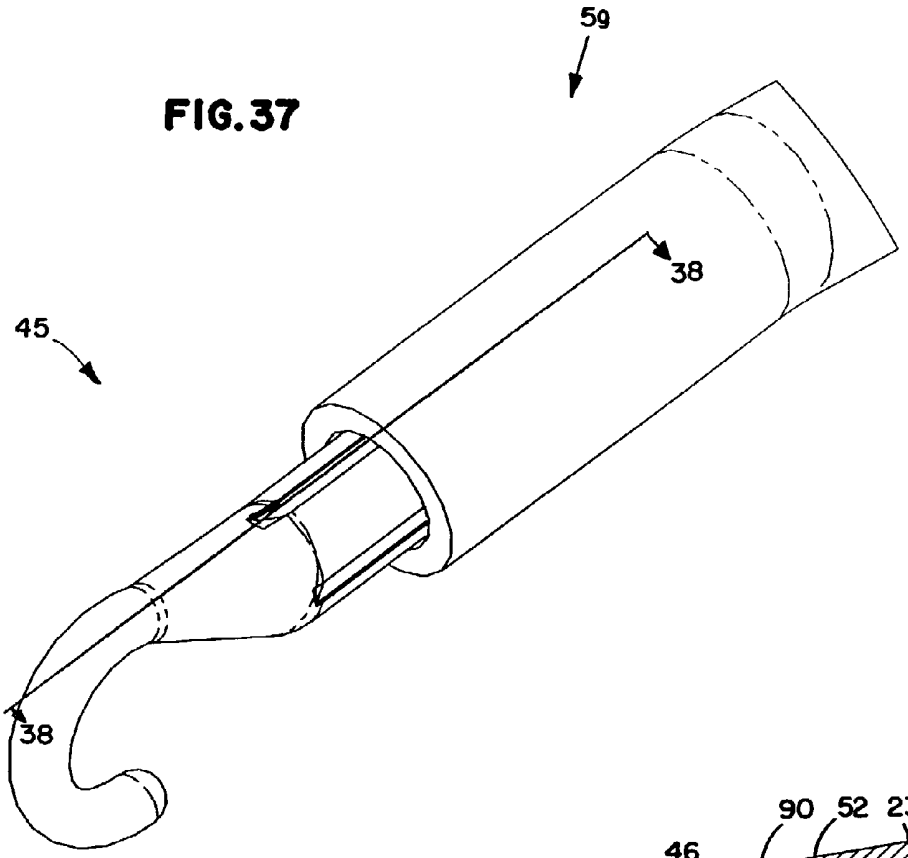




FIG. 36

FIG. 37



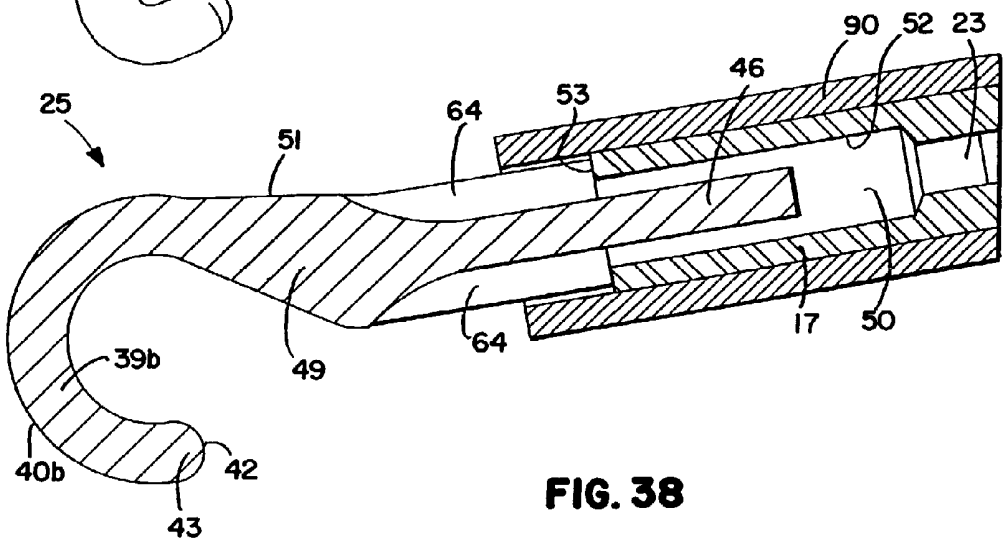
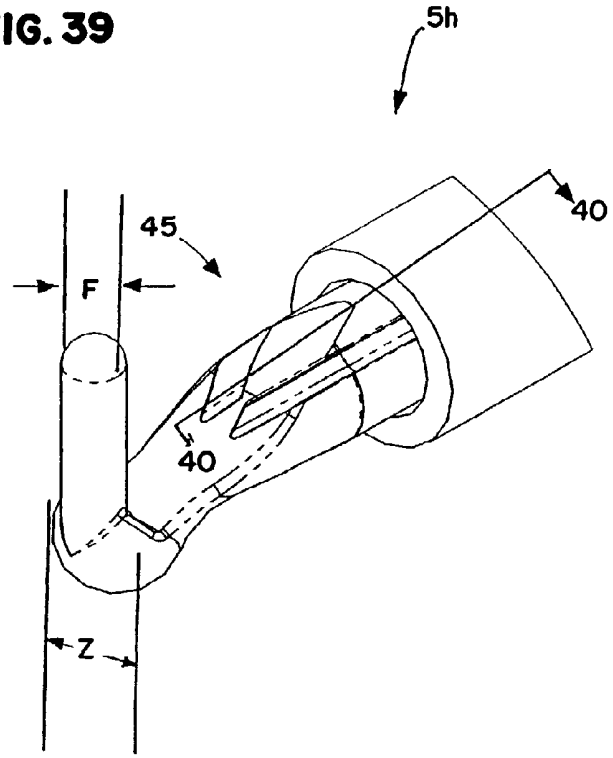




FIG. 38

FIG. 39


5h
45
F
40
40
Z

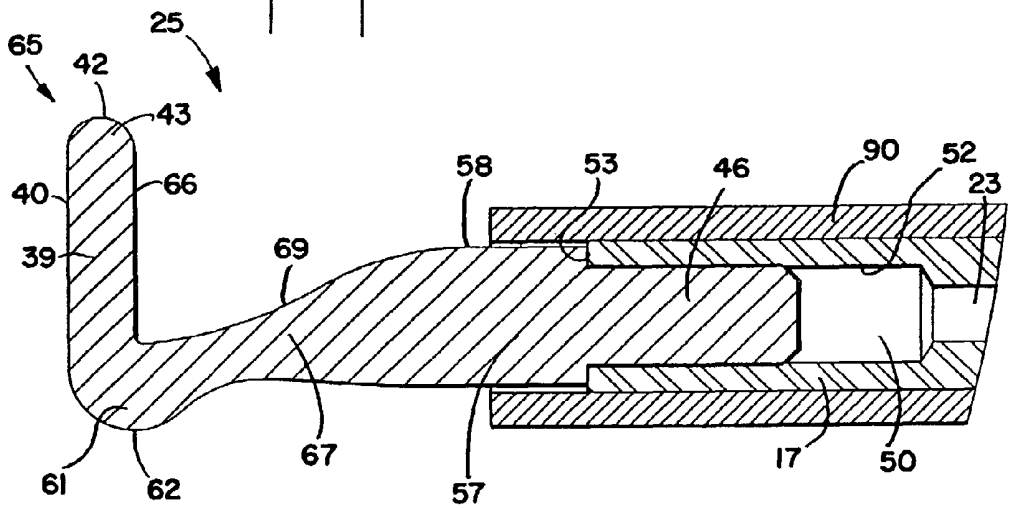
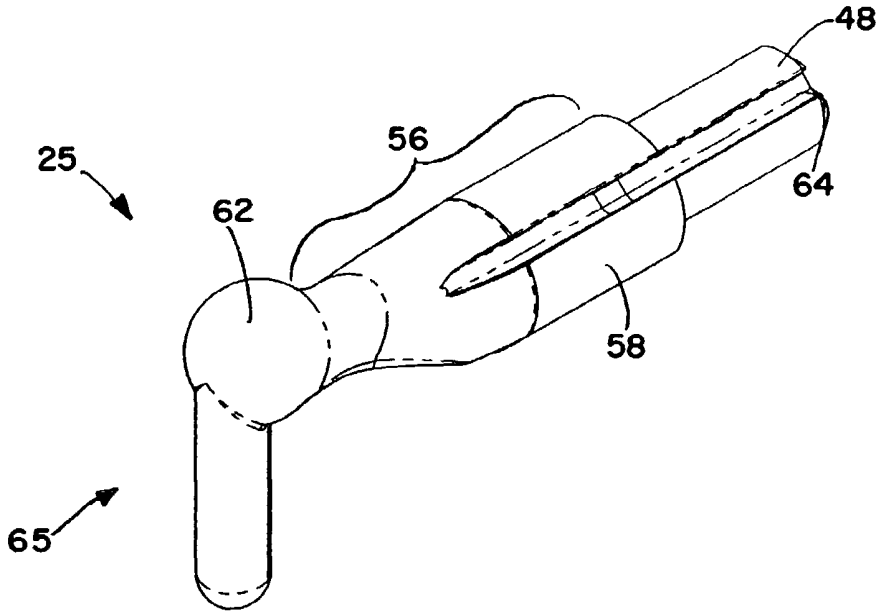

25
65
42
43
40
66
39
69
58
53
46
90
52
23
67
57
17
50
61
62

FIG. 40

FIG. 41



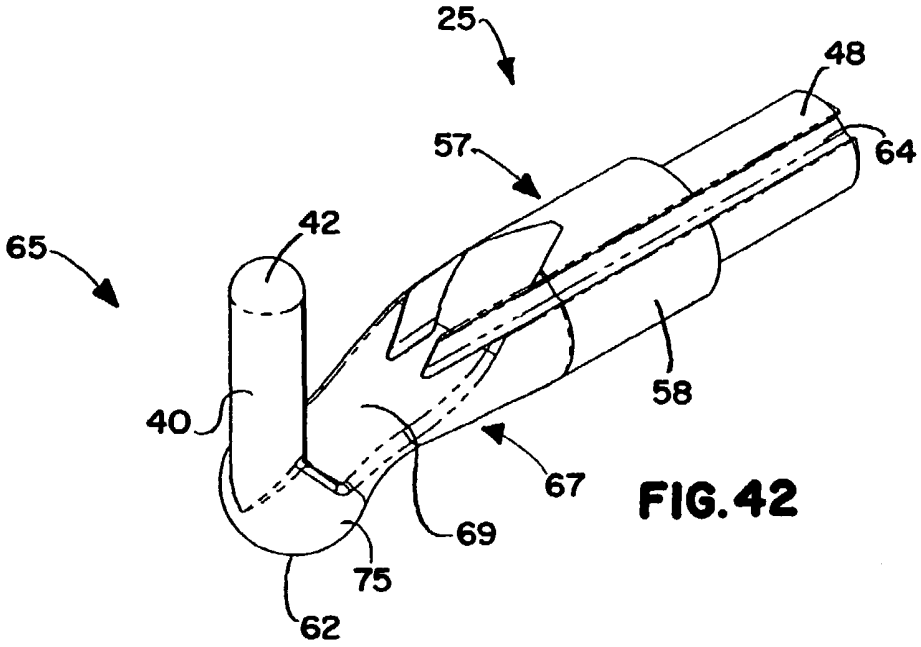
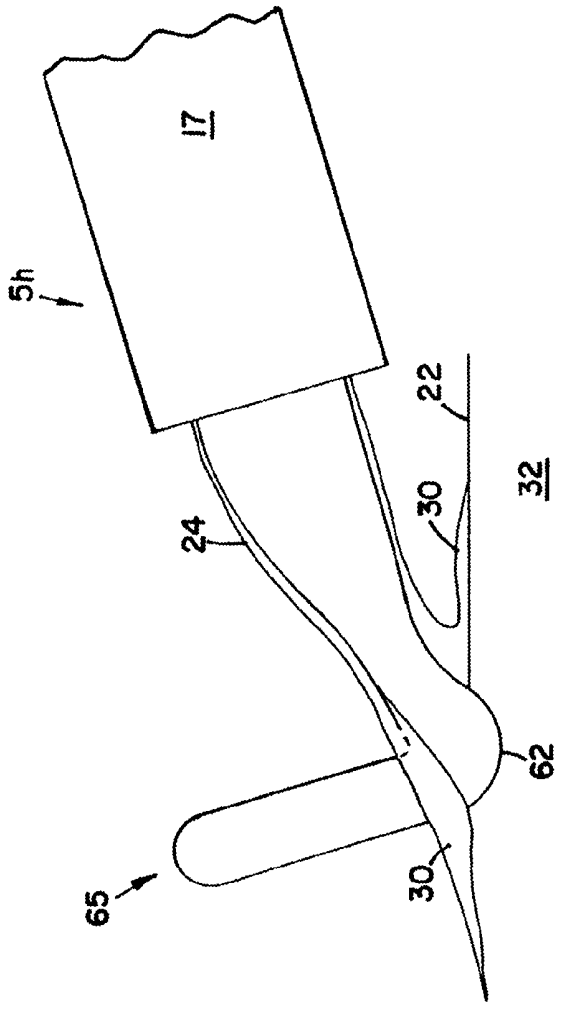




FIG. 42

FIG. 43



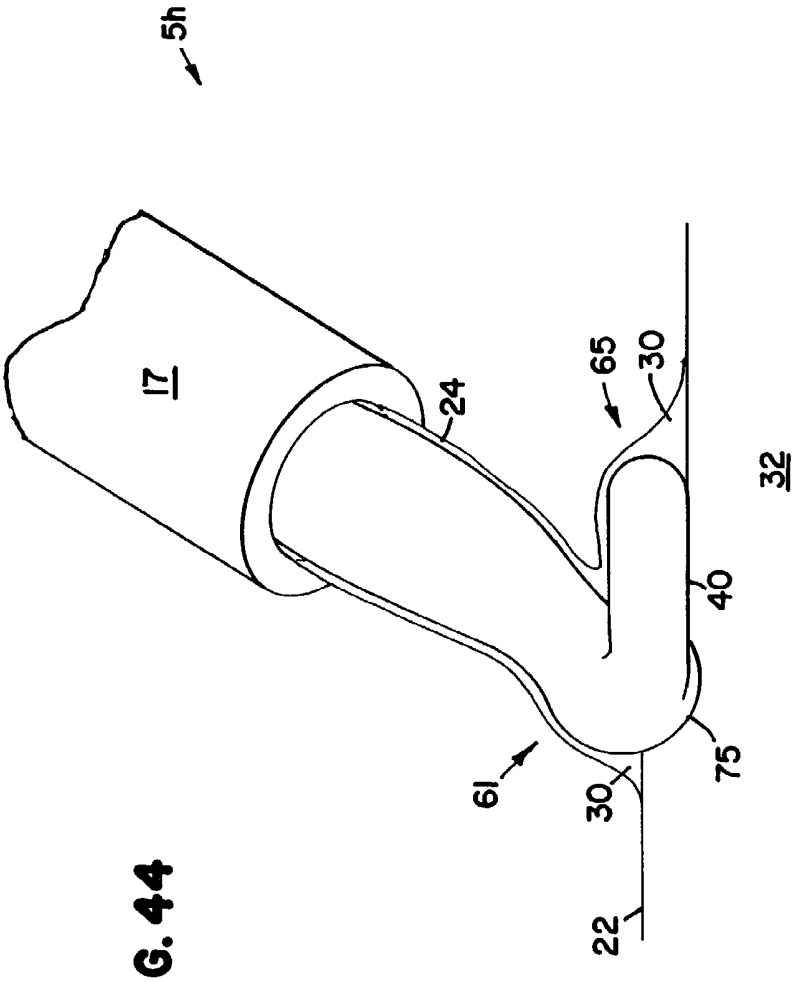



FIG. 44

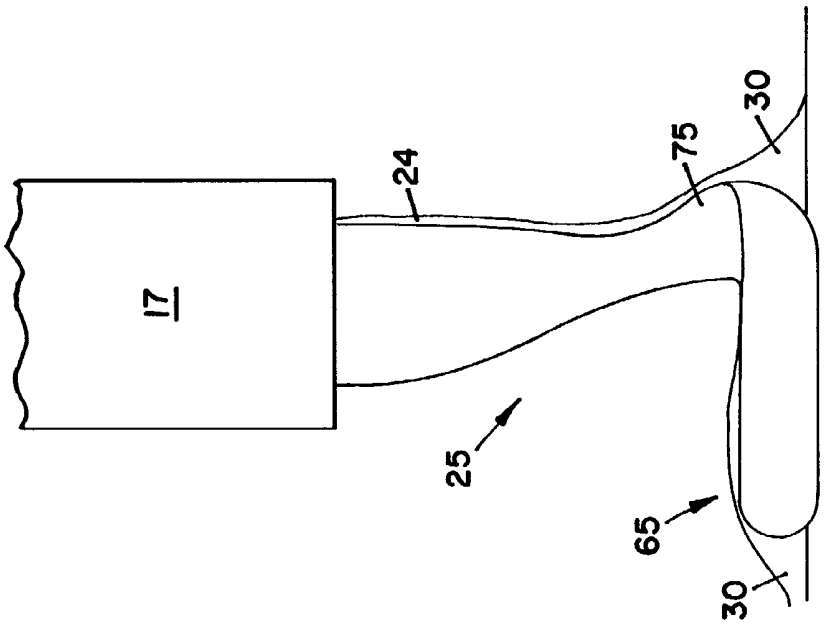



FIG. 45

FIG. 46

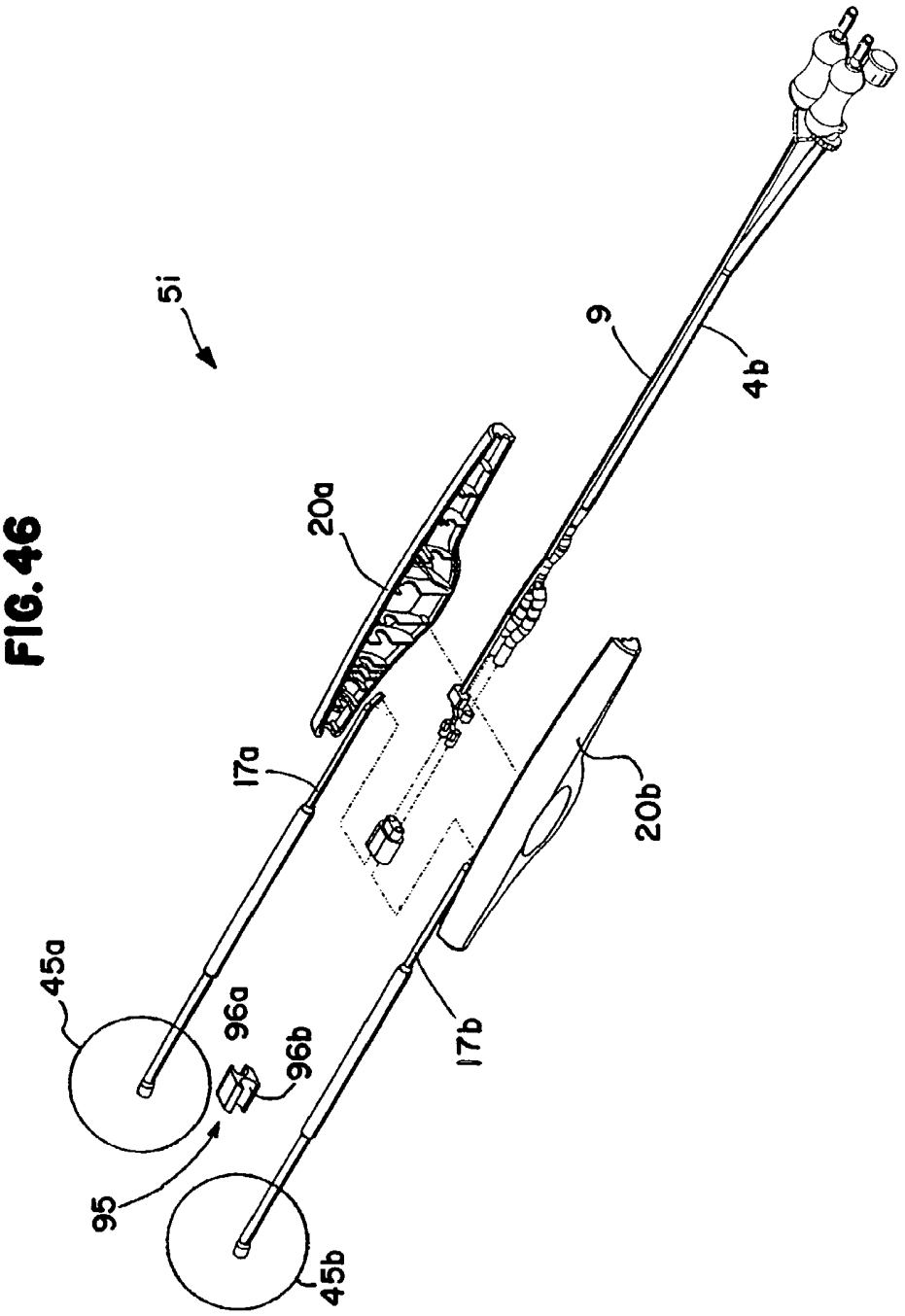


FIG. 47

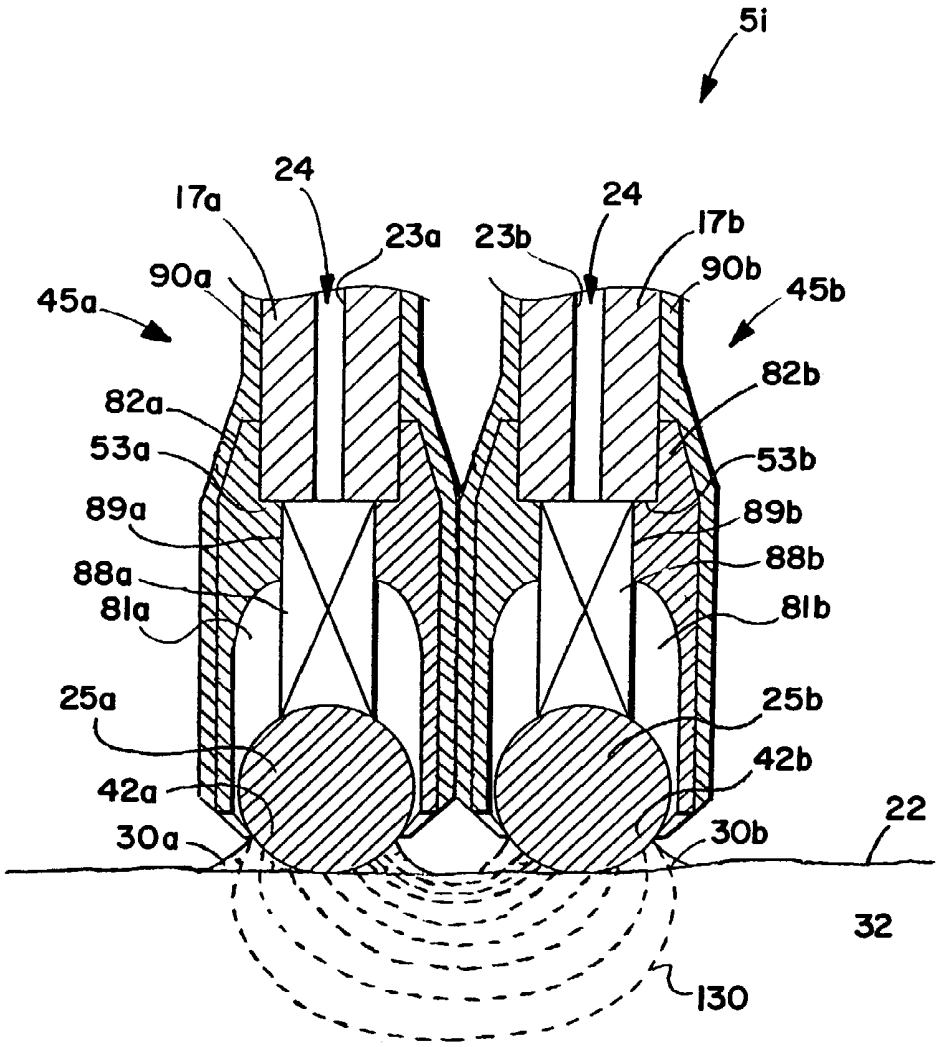

5i
24
17a
23a
23b
24
17b
90a
90b
45a
45b
82a
82b
53a
53b
89a
89b
88a
88b
81a
81b
25a
25b
42a
42b
30a
30b
22
32
130

FIG. 48

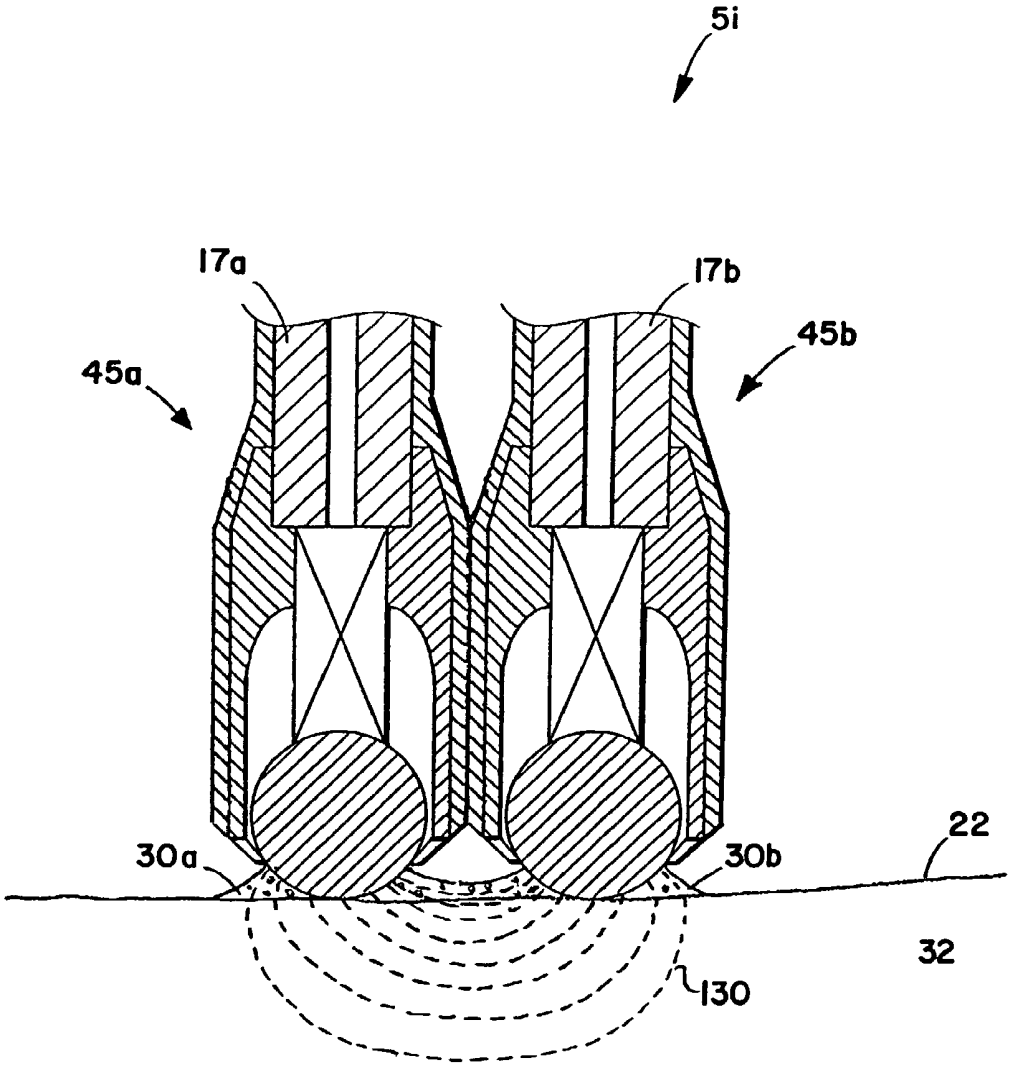


FIG. 49

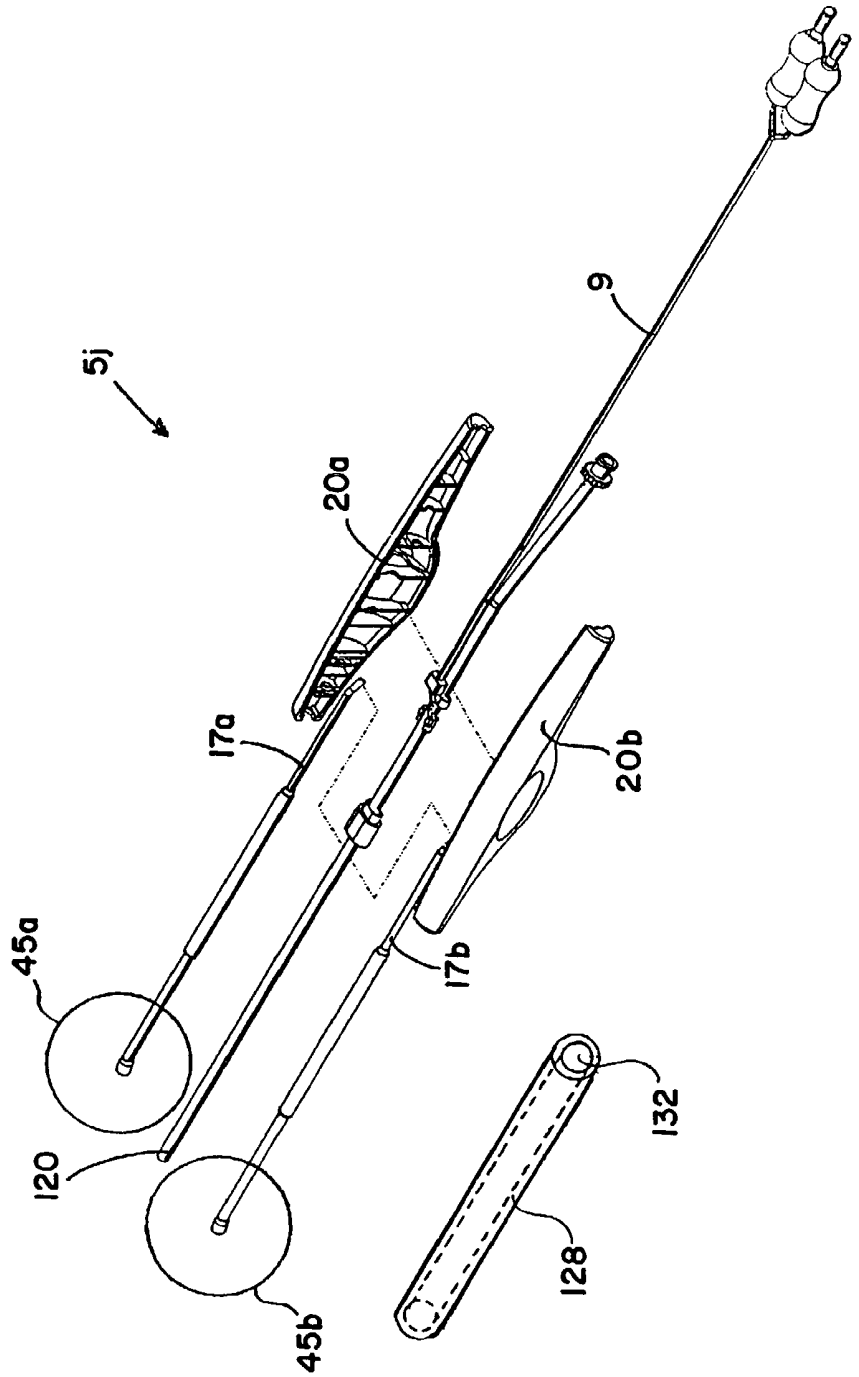
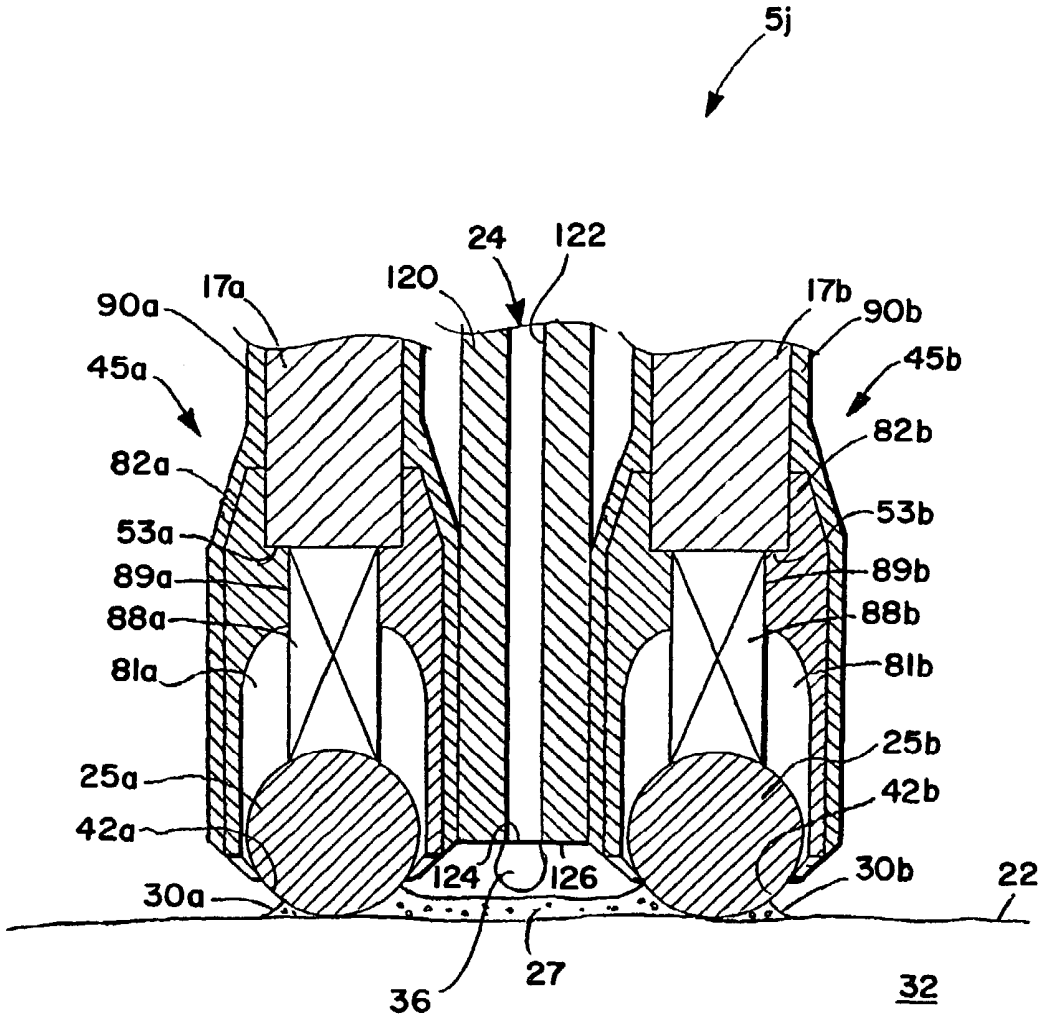


FIG. 50


5j
24
122
120
17a
17b
90a
90b
45a
45b
82a
82b
53a
53b
89a
89b
88a
88b
81a
81b
25a
25b
42a
42b
124
126
30a
30b
22
27
36
32

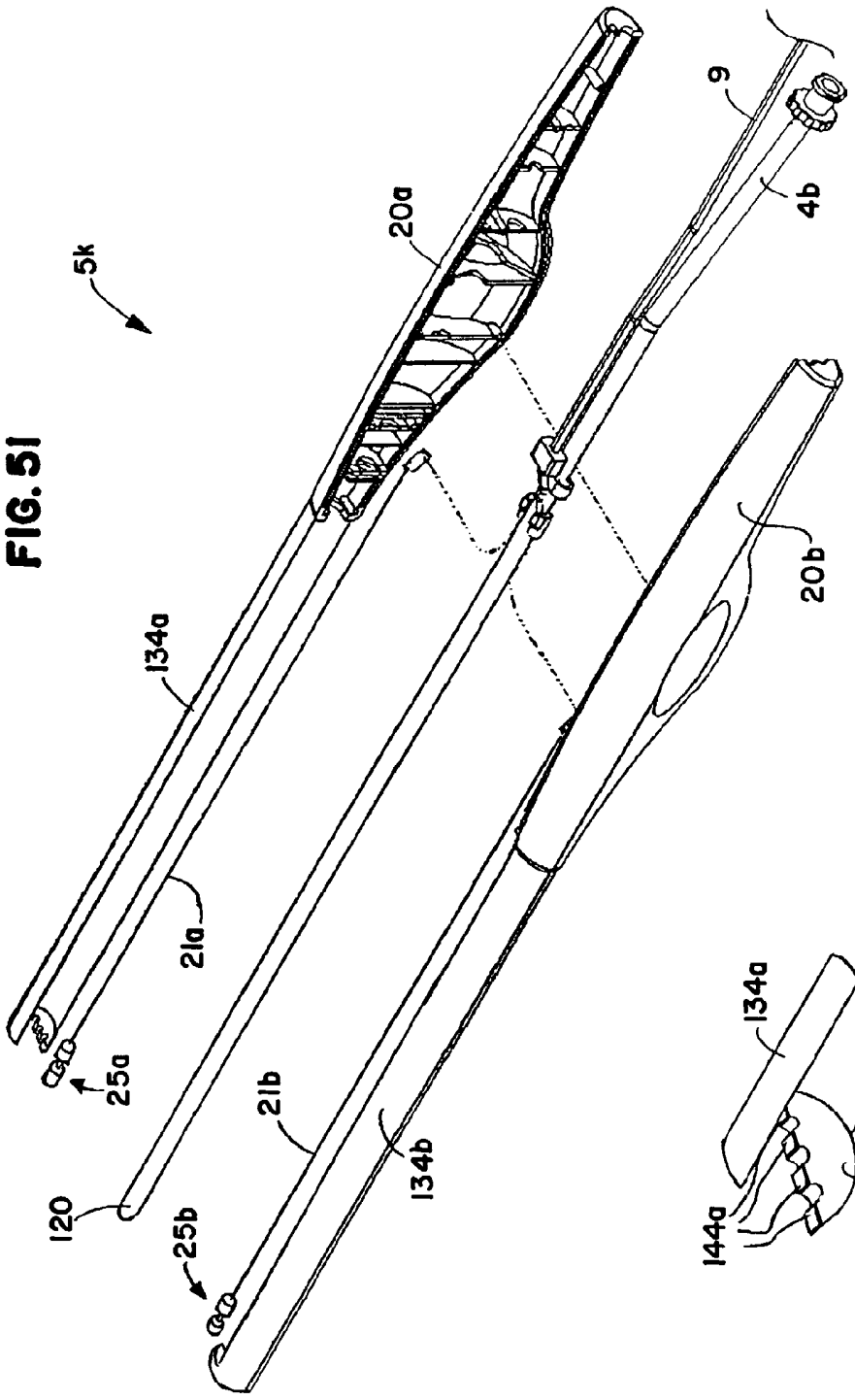



FIG. 51




FIG. 52

FIG. 53

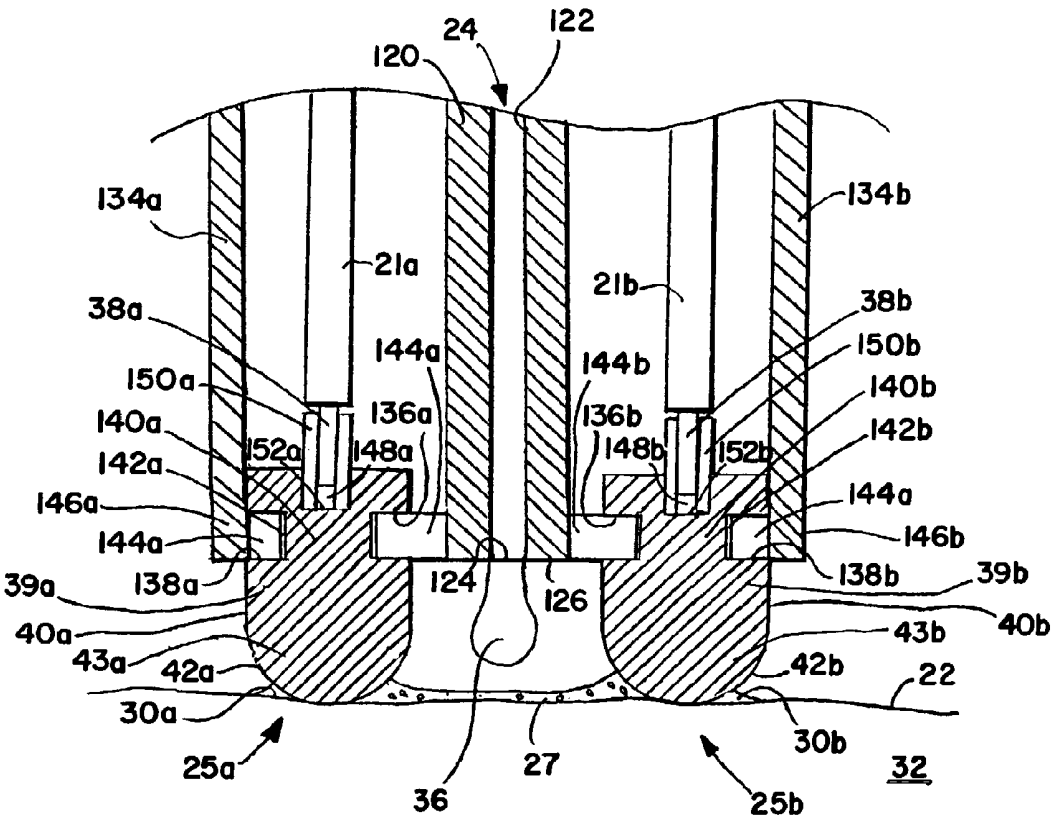
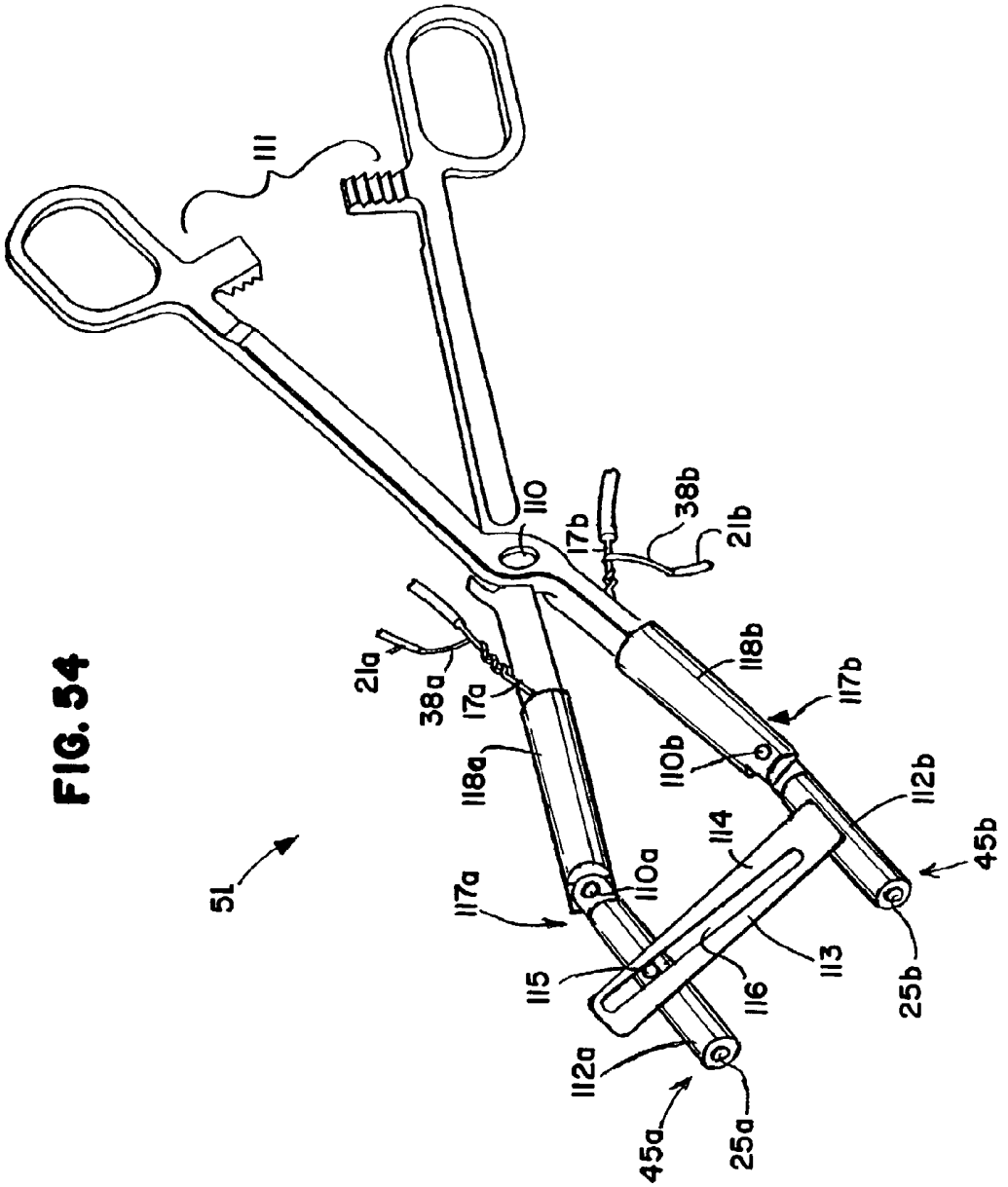

24
122
120
134a
134b
21a
21b
38a
38b
144a
144b
150a
150b
136a
136b
140a
140b
152a
148a
148b
152b
142a
142b
146a
144a
144a
146b
138a
138b
39a
39b
124
126
40a
40b
43a
43b
42a
42b
22
30a
30b
25a
27
32
36
25b

FIG. 54


111
110
17b
38b
21b
21a
38a
17a
118b
117b
118a
110b
112b
114
45b
117a
110a
115
116
113
25b
112a
45a
25a
51

# FLUID-ASSISTED MEDICAL DEVICES, SYSTEMS AND METHODS

## CROSS REFERENCE TO RELATED APPLICATIONS

This patent application is a divisional application of U.S. patent application Ser. No. 10/365,170, filed on Feb. 11, 2003, which is incorporated herein by reference.

Priority under 35 U.S.C. §119(e) is claimed to United States provisional applications serial numbers 60/356,390, filed Feb. 12, 2002, and 60/368,177, filed Mar. 27, 2002, the entire disclosures of which are incorporated herein by reference.

This patent application is also a continuation-in-part of U.S. Pat. application Ser. No. 09/947,658, filed Sept. 5, 2001, now U.S. Pat. No. 7,115,139 which is a continuation-in-part of United States patent application Ser. No. 09/797,049, filed Mar. 1, 2001, now U.S. Pat. No. 6,702,810 which claimed priority to United States provisional application Ser. No. 60/187,114, filed Mar. 6, 2000.

The entire disclosure of each of these patent applications is incorporated herein by reference to the extent it is consistent.

## FIELD

This invention relates generally to the field of medical devices and methods for use upon a body during surgery. More particularly, the invention relates to electrosurgical devices, systems and methods for use upon tissues of a human body during surgery, particularly open surgery and minimally invasive surgery such as laparoscopic surgery.

## BACKGROUND

Electrosurgical devices configured for use with a dry tip use electrical energy, often radio frequency (RF) energy, to cut tissue or to cauterize blood vessels. During use, a voltage gradient is created at the tip of the device, thereby inducing current flow and related heat generation in the tissue. With sufficiently high levels of electrical energy, the heat generated is sufficient to cut the tissue and, advantageously, to stop the bleeding from severed blood vessels.

Current dry tip electrosurgical devices can cause the temperature of tissue being treated to rise significantly higher than 100° C., resulting in tissue desiccation, tissue sticking to the electrodes, tissue perforation, char formation and smoke generation. Peak tissue temperatures as a result of RF treatment of target tissue can be as high as 320° C., and such high temperatures can be transmitted to adjacent tissue via thermal diffusion. Undesirable results of such transmission to adjacent tissue include unintended thermal damage to the tissue.

The use of saline inhibits such undesirable effects as sticking, desiccation, smoke production and char formation. One key factor is inhibiting tissue desiccation, which occurs when tissue temperature exceeds 100° C. and all of the intracellular water boils away, leaving the tissue extremely dry and much less electrically conductive. However, an uncontrolled or abundant flow rate of saline can provide too much cooling at the electrode/tissue interface. This cooling reduces the temperature of the target tissue being treated, and the rate at which tissue thermal coagulation occurs is determined by tissue temperature. This, in turn, can result in longer treatment time to achieve the desired tissue temperature for treatment of the tissue. Long treatment times are undesirable for surgeons since it is in the best interest of the patient, physician and hospital, to perform surgical procedures as quickly as possible.



RF energy delivered to tissue can be unpredictable and often not optimal when using general-purpose generators. Most general-purpose RF generators have modes for different waveforms (e.g., cut, coagulation, or a blend of these two) and device types (e.g., monopolar, bipolar), as well as power levels that can be set in watts. However, once these settings are chosen, the actual power delivered to tissue and associated heat generated can vary dramatically over time as tissue impedance changes over the course of RF treatment. This is because the power delivered by most generators is a function of tissue impedance, with the power ramping down as impedance either decreases toward zero or increases significantly to several thousand ohms. Current dry tip electrosurgical devices are not configured to address a change in power provided by the generator as tissue impedance changes or the associated effect on tissue and rely on the surgeon's expertise to overcome this limitation.

## SUMMARY OF THE INVENTION

The invention is directed to various embodiments of electrosurgical devices. In one preferred embodiment, an electrosurgical device has a proximal end and a distal end, with the device having a handle and a shaft extending from the handle, an electrode tip having an electrode surface, at least a portion of the electrode tip extending distally beyond the distal end of the shaft, with the electrode tip extending distally beyond the distal end of the shaft comprising a cylindrical side surface and a domed distal end surface. The device also has a fluid passage connectable to a fluid source, and at least one fluid outlet opening in fluid communication with the fluid passage, the fluid outlet opening located proximal to the domed distal end surface of the electrode tip and arranged to provide a fluid from the fluid source to the cylindrical side surface of the electrode tip.

In another preferred embodiment, the electrode tip extending distally beyond the distal end of the shaft has a neck portion and an enlarged end portion, the enlarged end portion located distal to the neck portion and comprising a cylindrical side surface and a domed distal end surface.

The electrosurgical device may have one or multiple fluid outlet openings, for example four, which can be located at or adjacent the distal end of the shaft. The openings may be equally spaced. These fluid outlet opening(s) may be arranged to provide the fluid from the fluid source around the cylindrical side surface of the electrode tip.

Various other embodiments have a portion of the electrode surface forming a contact angle ($\theta$) with the fluid from the fluid source of less than 90 degrees. Generally, this fluid at least partially wets that portion of the electrode surface that forms the contact angle ($\theta$).

The devices of the invention may include one or multiple recesses provided in the electrode tip, the recess providing a fluid flow channel for a flow of the fluid distally along the electrode tip. This recess or recesses are in fluid communication with the at least one fluid outlet opening. Preferably, the number of recesses is equal to the number of fluid outlet openings.

The invention is also directed to a surgical method for treating tissue. The method includes providing tissue having a tissue surface, providing radio frequency power at a power level, providing an electrically conductive fluid at a fluid flow rate, providing an surgical device configured to simultaneously provide the radio frequency electrical power and the

electrically conductive fluid to tissue, providing the electrically conductive fluid to the tissue at the tissue surface, forming a fluid coupling comprising the electrically conductive fluid which couples the tissue and the surgical device, providing the radio frequency power to the tissue at the tissue surface and below the tissue surface into the tissue through the fluid coupling, coagulating the tissue without cutting the tissue, and blunt dissecting the tissue after coagulating the tissue.

The fluid from the electrosurgical device can be a coupling that is used to cool the tissue or dissipate heat from the tissue by transferring heat to the fluid. The fluid coupling can dissipate heat from the tissue by boiling. The radio frequency power level, the conductive fluid flow rate, or both can be adjusted based on the boiling. The tissue is generally protected from desiccation by the fluid coupling.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing one embodiment of a control system of the invention, and an electrosurgical device;

FIG. **2** is a schematic graph that describes the relationship between RF power to tissue (P), flow rate of saline (Q), and tissue temperature (T) when heat conduction to adjacent tissue is considered;

FIG. **3** is schematic graph that describes the relationship between RF power to tissue (P), flow rate of saline (Q), and tissue temperature (T) when heat conduction to adjacent tissue is neglected;

FIG. **4** is a schematic graph that describes the relationship between RF power to tissue (P), flow rate of saline (Q), and tissue temperature (T) when the heat required to warm the tissue to the peak temperature (T) **68** is considered;

FIG. **5** is a graph showing the relationship of percentage saline boiling and saline flow rate (cc/min) for an exemplary RF generator output of **75** watts;

FIG. **6** is a schematic graph that describes the relationship of load impedance (Z, in ohms) and generator output power (P, in watts), for an exemplary generator output of 75 watts in a bipolar mode;

FIG. **7** is a schematic graph that describes the relationship of time (t, in seconds) and tissue impedance (Z, in ohms) after RF activation;

FIG. **8** is a schematic perspective view of a cannula which may be used with an electrosurgical device according to the present invention;

FIG. **9** is a schematic exploded perspective view of an assembly of an electrosurgical device according to the present invention;

FIG. **10** is a schematic longitudinal cross-sectional side view of the tip and shaft of the device of FIG. **9** taken along line **10-10** of FIG. **12**;

FIG. **11** is a schematic close-up longitudinal cross-sectional side view of the tip portion of the device bounded by circle **45** shown in FIG. **10** taken along line **10-10** of FIG. **12**;

FIG. **12** is a schematic distal end view of the tip portion of the device bounded by circle **45** shown in FIG. **10**;

FIG. **13** is a schematic side view of the of the tip and shaft of the device of FIG. **9** with a fluid coupling to a tissue surface of tissue;

FIG. **14** is a schematic close-up cross-sectional side view of an alternative tip portion;

FIG. **15** is a schematic close-up section side view of the tip portion of FIG. **14** taken along line **15-15** of FIG. **14**;

FIG. **16** is a schematic close-up cross-sectional side view of the tip portion of FIG. **14** disposed in a tissue crevice;

FIG. **17** is a schematic graph of impedance Z versus time t showing changes in impedance represented by impedance spikes;

FIG. **18** is a schematic graph of the impedance Z versus boiling of fluid %;

FIG. **19** is schematic close-up cross-sectional view of the sleeve taken along line **19-19** of FIG. **15**;

FIG. **20** is a schematic close-up perspective view of an alternative tip portion;

FIG. **21** is a schematic close-up section side view of the tip portion of FIG. **20** taken along line **21-21** of FIG. **20**;

FIG. **22** is a schematic close-up cross-sectional side view of the tip portion of FIG. **20** disposed in a tissue crevice;

FIG. **23** is a schematic close-up front perspective view of the electrode for the tip portion of FIG. **20**;

FIG. **24** is a schematic close-up rear perspective view of the electrode for the tip portion of FIG. **20**;

FIG. **25** is a schematic close up cross-sectional view of a porous electrode with recesses;

FIG. **26** is schematic close up cross-sectional view of an electrode with semi-circular recesses;

FIG. **27** is schematic close up cross-sectional view of an electrode with V-shaped recesses;

FIG. **28** is schematic close up cross-sectional view of an electrode with U-shaped recesses;

FIG. **29** is a schematic close-up perspective view of an alternative tip portion;

FIG. **30** is a schematic close-up section side view of the tip portion of FIG. **29** taken along line **30-30** of FIG. **29**;

FIG. **31** is a schematic close-up front perspective view of the electrode for the tip portion of FIG. **29**;

FIG. **32** is a schematic close-up rear perspective view of the electrode for the tip portion of FIG. **29**;

FIG. **33** is a schematic close-up perspective view of an alternative tip portion;

FIG. **34** is a schematic close-up section side view of the tip portion of FIG. **33** taken along line **34-34** of FIG. **33**;

FIG. **35** is a schematic close-up front perspective view of the electrode for the tip portion of FIG. **33**;

FIG. **36** is a schematic close-up rear perspective view of the electrode for the tip portion of FIG. **33**;

FIG. **37** is a schematic close-up perspective view of an alternative tip portion;

FIG. **38** is a schematic close-up section side view of the tip portion of FIG. **37** taken along line **38-38** of FIG. **37**;

FIG. **39** is a schematic close-up perspective view of an alternative tip portion;

FIG. **40** is a schematic close-up section side view of the tip portion of FIG. **39** taken along line **40-40** of FIG. **39**;

FIG. **41** is a schematic close-up front posterior perspective view of the electrode for the tip portion of FIG. **39**;

FIG. **42** is a schematic close-up front anterior perspective view of the electrode for the tip portion of FIG. **39**;

FIG. **43** is a schematic side view of the tip portion of FIG. **39** with a fluid coupling to a tissue surface of tissue;

FIG. **44** is a schematic front view of the tip portion of FIG. **39** with a fluid coupling to a tissue surface of tissue;

FIG. **45** is a schematic side view of the tip portion of FIG. **39** with a fluid coupling to a tissue surface of tissue;

FIG. **46** is a schematic exploded perspective view of an assembly of an alternative electrosurgical device according to the present invention;

FIG. **47** is a schematic close-up cross-sectional side view of the tip portions of FIG. **46** assembled with a fluid coupling to a tissue surface of tissue;

FIG. **48** is a schematic close-up cross-sectional side view of the tip portions of FIG. **46** assembled with an alternative fluid coupling to a tissue surface of tissue;

FIG. **49** is a schematic exploded perspective view of an assembly of an alternative electrosurgical device according to the present invention;

FIG. **50** is a schematic close-up cross-sectional side view of the tip portions of FIG. **49** assembled with a fluid coupling to a tissue surface of tissue;

FIG. **51** is a schematic exploded perspective view of an assembly of an alternative electrosurgical device according to the present invention;

FIG. **52** is a schematic close-up perspective side view of a distal end portion of the device of FIG. **51**;

FIG. **53** is a schematic close-up cross-sectional side view of the tip portion of the device of FIG. **51** assembled with a fluid coupling to a tissue surface of tissue; and

FIG. **54** is a schematic perspective view of an alternative electrosurgical device according to the present invention.

## DETAILED DESCRIPTION

Throughout the description, like reference numerals and letters indicate corresponding structure throughout the several views, and such corresponding structure need not be separately discussed. Furthermore, any particular feature(s) of a particular exemplary embodiment may be equally applied to any other exemplary embodiment(s) of this specification as suitable. In other words, features between the various exemplary embodiments described herein are interchangeable as suitable, and not exclusive.

The invention provides devices, systems and methods that control tissue temperature at a tissue treatment site during a medical procedure. This is particularly useful during surgical procedures upon tissues of the body, where it is desirable to coagulate and shrink tissue, to occlude lumens of blood vessels (e.g., arteries, veins), airways (e.g., bronchi, bronchioles), bile ducts and lymphatic ducts.

The invention includes electrosurgical procedures, which preferably utilize RF power and electrically conductive fluid, to treat tissue. Preferably, a desired tissue temperature range is achieved by adjusting parameters, such as conductive fluid flow rate, to affect the temperature at the tissue/electrode interface.

In one embodiment, the invention provides a control device, the device comprising a flow rate controller that receives a signal indicating power applied to the system, and adjusts the flow rate of conductive fluid from a fluid source to the electrosurgical device. The invention also provides a control system comprising a flow rate controller, a measurement device that measures power applied to the system, and a pump that provides fluid at a selected flow rate.

The invention will be discussed generally with reference to FIG. **1**, which shows a block diagram of one exemplary embodiment of a system of the invention. Preferably, an electrically conductive fluid **24** is provided from a fluid source **1** through a fluid line **2** to a pump **3**, which has an outlet fluid line **4***a* that is connected as an input fluid line **4***b* to electrosurgical device **5**. In a preferred embodiment, outlet fluid line **4***a* and input fluid line **4***b* are flexible and are made from a polymeric material, such as polyvinylchloride (PVC) or polyolefin (e.g., polypropylene, polyethylene) and the conductive fluid comprises a saline solution. More preferably, the saline comprises sterile, and even more preferably, normal saline. Although the description herein will specifically describe the use of saline as the fluid **24**, other electrically conductive fluids, as well as non-conductive fluids, can be used in accordance with the invention.

For example, in addition to the conductive fluid comprising physiologic saline (also known as "normal" saline, isotonic saline or 0.9% sodium chloride (NaCl) solution), the conductive fluid may comprise hypertonic saline solution, hypotonic saline solution, Ringers solution (a physiologic solution of distilled water containing specified amounts of sodium chloride, calcium chloride, and potassium chloride), lactated Ringer's solution (a crystalloid electrolyte sterile solution of distilled water containing specified amounts of calcium chloride, potassium chloride, sodium chloride, and sodium lactate), Locke-Ringer's solution (a buffered isotonic solution of distilled water containing specified amounts of sodium chloride, potassium chloride, calcium chloride, sodium bicarbonate, magnesium chloride, and dextrose), or any other electrolyte solution.

While a conductive fluid is preferred, as will become more apparent with further reading of this specification, fluid **24** may also comprise an electrically non-conductive fluid. The use of a non-conductive fluid is less preferred than a conductive fluid, however, the use of a non-conductive fluid still provides certain advantages over the use of a dry electrode including, for example, reduced occurrence of tissue sticking to the electrode of device **5**. Therefore, it is also within the scope of the invention to include the use of a non-conducting fluid, such as, for example, deionized water.

Returning to FIG. **1**, energy to heat tissue is provided from an energy source, such as an electrical generator **6** which preferably provides RF alternating current energy via a cable **7** to an energy source output measurement device, such as a power measurement device **8** that measures the RF alternating current electrical power. In one exemplary embodiment, preferably the power measurement device **8** does not turn the power off or on, or alter the power in any way. A power switch **15** connected to generator **6** is preferably provided by the generator manufacturer and is used to turn generator **6** on and off. The power switch **15** can comprise any switch to turn the power on and off, and is commonly provided in the form of a footswitch or other easily operated switch, such as a switch **15***a* mounted on electrosurgical device **5**. The power switch **15** or **15***a* may also function as a manually activated device for increasing or decreasing the rate of energy provided from device **5**. Alternatively, internal circuitry and other components of generator **6** may be used for automatically increasing or decreasing the rate of energy provided from device **5**. A cable **9** preferably provides RF energy from power measurement device **8** to electrosurgical device **5**. Power, or any other energy source output, is preferably measured before it reaches electrosurgical device **5**.

When capacitation and induction effects are negligibly small, from Ohm's law, power P, or the rate of energy delivery (e.g., joules/sec), may be expressed by the product of current times voltage (i.e., $I \times V$), the current squared times resistance (i.e., $I^2 \times R$), or the voltage squared divided by the resistance (i.e., $V^2/R$); where the current I may be measured in amperes, the voltage V may be measured in volts, the electrical resistance R may be measured in ohms, and the power P may be measured in watts (Joules/sec). Given that power P is a function of current I, voltage V, and resistance R as indicated above, it should be understood, that a change in power P is reflective of a change in at least one of the input variables. Thus, one may alternatively measure changes in such input variables themselves, rather than power P directly, with such changes in the input variables mathematically corresponding to a changes in power P as indicated above.

The RF electrical energy is preferably provided within a frequency band (i.e., a continuous range of frequencies extending between two limiting frequencies) in the range between and including about 9 kHz (kilohertz) to 300 GHz (gigahertz). More preferably, the RF energy is provided within a frequency band in the range between and including about 50 kHz (kilohertz) to 50 MHz (megahertz). Even more preferably, the RF energy is provided within a frequency band in the range between and including about 200 kHz (kilohertz) to 2 MHz (megahertz). Most preferably, RF energy is provided within a frequency band in the range between and including about 400 kHz (kilohertz) to 600 kHz (kilohertz). It should be understood that, for any frequency band identified above, the range of frequencies may be further narrowed in increments of 1 (one) hertz anywhere between the lower and upper limiting frequencies.

While RF electrical energy is preferred, it should be understood that the electrical energy (i.e., energy made available by the flow of electric charge, typically through a conductor or by self-propagating waves) may comprise any frequency of the electromagnetic spectrum (i.e., the entire range of radiation extending in frequency from $10^{23}$ hertz to 0 hertz) and including, but not limited to, gamma rays, x-rays, ultraviolet radiation, visible light, infrared radiation, microwaves, and any combinations thereof.

Heating of the tissue is preferably performed by electrical resistance heating. That is, the temperature of the tissue increases as a result of electric current flow through the tissue, with the electrical energy being absorbed from the voltage and transformed into thermal energy (i.e., heat) via accelerated movement of ions as a function of the tissue's electrical resistance.

Heating with electrical energy may also be performed by dielectric heating (capacitation). That is, the temperature of the tissue increases through the dissipation of electrical energy as a result of internal dielectric loss when the tissue is placed in a varying electric field, such as a high-frequency (e.g., microwave), alternating electromagnetic field. Dielectric loss is the electrical energy lost as heat in the polarization process in the presence of the applied electric field. In the case of an alternating current field, the energy is absorbed from the alternating current voltage and converted to heat during the polarization of the molecules.

However, it should be understood that energy provided to heat the tissue may be from surgical devices other than electrosurgical devices, energy sources other than generators, energy forms other than electrical energy and mechanisms other than resistance heating. For example, thermal energy can be provided to the tissue from an energy source having a higher temperature. Such may be provided, for example, by a heated device which heats tissue through direct contact (conduction), through contact with a flowing fluid (convection), or from a remote heat source (radiation).

Also, for example, providing energy to the tissue may be provided via mechanical energy which is transformed into thermal energy via accelerated movement of the molecules, such as by mechanical vibration provided, for example, by an energy source such as a transducer containing a piezoelectric substance (e.g., a quartz-crystal oscillator) that converts high-frequency electric current into vibrating ultrasonic waves which may be used by, for example, an ultrasonic surgical device.

Also, for example, energy can be provided to the tissue via radiant energy (i.e., energy which is transmitted by radiation/waves) which is transformed into thermal energy via absorption of the radiant energy by the tissue. Preferably the radiation/waves comprise electromagnetic radiation/waves which include, but are not limited to, radio waves, microwaves, infrared radiation, visible light radiation, ultraviolet radiation, x-rays and gamma rays. More preferably, such radiant energy comprises energy with a frequency of $3\times10^{11}$ hertz to $3\times10^{16}$ hertz (i.e., the infrared, visible, and ultraviolet frequency bands of the electromagnetic spectrum). Also preferably the electromagnetic waves are coherent and the electromagnetic radiation is emitted from energy source such as a laser device.

Referring again to FIG. **1**, a flow rate controller **11** preferably includes a selection switch **12** that can be set to achieve desired levels of percentage fluid boiling (for example, 100%, 98%, 80% boiling). Preferably, flow rate controller **11** receives an input signal **10** from power measurement device **8** and calculates an appropriate mathematically predetermined fluid flow rate based on percentage boiling indicated by the selection switch **12**. In a preferred embodiment, a fluid switch **13** is provided so that the fluid system can be primed (e.g., air eliminated) before turning on generator **6**. The output signal **16** of flow rate controller **11** is preferably sent to pump **3** motor to regulate the flow rate of conductive fluid, and thereby provide an appropriate fluid flow rate which corresponds to the amount of power being delivered.

In one embodiment, flow rate controller **11** is configured and arranged to be connected to a source of RF power (e.g., generator **6**), and a source of fluid (e.g., fluid source **1**), for example, a source of conductive fluid. The device of the invention receives information about the level of RF power applied to electrosurgical device **5**, and adjusts the flow rate of fluid **24** to electrosurgical device **5**, thereby controlling temperature at the tissue treatment site.

In another embodiment, elements of the system are physically included together in one electronic enclosure. One such embodiment is shown by enclosure within the outline box **14** of FIG. **1**. In the illustrated embodiment, pump **3**, flow rate controller **11**, and power measurement device **8** are enclosed within an enclosure, and these elements are connected through electrical connections to allow signal **10** to pass from power measurement device **8** to flow rate controller **11**, and signal **16** to pass from flow rate controller **11** to pump **3**. Other elements of a system can also be included within one enclosure, depending upon such factors as the desired application of the system, and the requirements of the user.

Pump **3** can be any suitable pump to provide saline or other fluid at a desired flow rate. Preferably, pump **3** is a peristaltic pump. With a rotary peristaltic pump, typically a fluid **24** is conveyed within the confines of a flexible tube (e.g., **4***a*) by waves of contraction placed externally on the tube which are produced mechanically, typically by rotating rollers which intermittently squeeze the flexible tubing against a support with a linear peristaltic pump, typically a fluid **24** is conveyed within the confines of a flexible tube by waves of contraction placed externally on the tube which are produced mechanically, typically by a series of compression fingers or pads which sequentially squeeze the flexible tubing against a support. Peristaltic pumps are generally preferred, as the electromechanical force mechanism (e.g., rollers driven by electric motor) does not make contact the fluid **24**, thus reducing the likelihood of inadvertent contamination.

Alternatively, pump **3** can be a "syringe pump", with a built-in fluid supply. With such a pump, typically a filled syringe is located on an electromechanical force mechanism (e.g., ram driven by electric motor) which acts on the plunger of the syringe to force delivery of the fluid **24** contained therein. The syringe pump may be a double-acting syringe pump with two syringes such that they can draw saline from a reservoir (e.g., of fluid source **1**), either simultaneously or

intermittently. With a double acting syringe pump, the pumping mechanism is generally capable of both infusion and withdrawal. Typically, while fluid **24** is being expelled from one syringe, the other syringe is receiving fluid **24** therein from a separate reservoir. In this manner, the delivery of fluid **24** remains continuous and uninterrupted as the syringes function in series. Alternatively, it should be understood that a multiple syringe pump with two syringes, or any number of syringes, may be used in accordance with the invention.

Furthermore, fluid **24**, such as conductive fluid, can also be provided from an intravenous (IV) bag full of saline (e.g., of fluid source **1**) that flows by gravity. Fluid **24** may flow directly to electrosurgical device **5**, or first to pump **3** located there between. Alternatively, fluid **24** from a fluid source **1** such as an IV bag can be provided through an IV flow controller that may provide a desired flow rate by adjusting the cross sectional area of a flow orifice (e.g., lumen of the connective tubing with the electrosurgical device **5**) while sensing the flow rate with a sensor such as an optical drop counter. Furthermore, fluid **24** from a fluid source **1** such as an IV bag can be provided through a manually or automatically activated device such as a flow controller, such as a roller clamp, which also adjusts the cross sectional area of a flow orifice and may be adjusted manually by, for example, the user of the device in response to their visual observation (e.g., fluid boiling) at the tissue treatment site or a pump.

Similar pumps can be used in connection with the invention, and the illustrated embodiments are exemplary only. The precise configuration of pump **3** is not critical to the invention. For example, pump **3** may include other types of infusion and withdrawal pumps. Furthermore, pump **3** may comprise pumps which may be categorized as piston pumps, rotary vane pumps (e.g., axial impeller, centrifugal impeller), cartridge pumps and diaphragm pumps. In some embodiments, pump **3** can be substituted with any type of flow controller, such as a manual roller clamp used in conjunction with an IV bag, or combined with the flow controller to allow the user to control the flow rate of conductive fluid to the device. Alternatively, a valve configuration can be substituted for pump **3**.

Furthermore, similar configurations of the system can be used in connection with the invention, and the illustrated embodiments are exemplary only. For example, the fluid source **1**, pump **3**, generator **6**, power measurement device **8** or flow rate controller **11**, or any other components of the system not expressly recited above, may be present as a part of the electrosurgical device **5**. For example, fluid source **1** may be a compartment of the electrosurgical device **5** which contains fluid **24**, as indicated at reference character **1***a*. In another exemplary embodiment, the compartment may be detachably connected to electrosurgical device **5**, such as a canister which may be attached via threaded engagement with device **5**. In yet another embodiment, the compartment may be configured to hold a pre-filled cartridge of fluid **24**, rather than the fluid directly.

Also for example, with regards to alternative for the generator **6**, an energy source, such as a direct current (DC) battery used in conjunction with inverter circuitry and a transformer to produce alternating current at a particular frequency, may comprise a portion of the electrosurgical device **5**, as indicated at reference character **6***a*. In one embodiment the battery element of the energy source may comprise a rechargeable battery. In yet another exemplary embodiment, the battery element may be detachably connected to the electrosurgical device **5**, such as for recharging. The components of the system will now be described in further detail. From the specification, it should be clear that any use of the terms "distal" and "proximal" are made in reference from the user of the device, and not the patient.

Flow rate controller **11** controls the rate of flow from the fluid source **1**. Preferably, the rate of fluid flow from fluid source **1** is based upon the amount of RF power provided from generator **6** to electrosurgical device **5**. Referring to FIG. **2**, there is illustrated a relationship between the rate of fluid flow Q and the RF power P. More precisely, as shown in FIG. **2**, the relationship between the rate of fluid flow Q and RF power P may be expressed as a direct, linear relationship. The flow rate Q of conductive fluid **24**, such as saline, interacts with the RF power P and various modes of heat transfer away from the target tissue, as described herein.

Throughout this disclosure, when the terms "boiling point of saline", "vaporization point of saline", and variations thereof are used, what is actually referenced for explanation purposes, is the boiling point of the water (i.e., 100° C.) in the saline solution given that the difference between the boiling point of normal saline (about 100.16° C.) and the boiling point of water is negligible.

FIG. **2** shows the relationship between the flow rate of saline, RF power to tissue, and regimes of boiling as detailed below. Based on a simple one-dimensional lumped parameter model of the heat transfer, the peak tissue temperature can be estimated, and once tissue temperature is estimated, it follows directly whether it is hot enough to boil saline. The total RF electrical power P that is converted into heat can be defined as:

$$P=\Delta T/R+\rho c_p Q_l \Delta T+\rho Q_l h_v \quad (1)$$

where P=the total RF electrical power that is converted into heat.

Conduction. The term [ΔT/R] in equation (1) is heat conducted to adjacent tissue, represented as **70** in FIG. **2**, where:

ΔT=(T−T$_\infty$) the difference in temperature between the peak tissue temperature (T) and the normal temperature (T$_\infty$) of the body tissue (° C.); normal temperature of the body tissue is generally 37° C.; and

R=Thermal resistance of surrounding tissue, the ratio of the temperature difference to the heat flow (° C./watt).

This thermal resistance can be estimated from published data gathered in experiments on human tissue (see for example, Phipps, J. H., "Thermometry studies with bipolar diathermy during hysterectomy," *Gynaecological Endoscopy,* 3:5-7 (1994)). As described by Phipps, Kleppinger bipolar forceps were used with an RF power of 50 watts, and the peak tissue temperature reached 320° C. For example, using the energy balance of equation (1), and assuming all the RF heat put into tissue is conducted away, then R can be estimated:

$$R=\Delta T/P=(320-37)/50=5.7\approx 6^\circ \text{ C./watt}$$

However, it is undesirable to allow the tissue temperature to reach 320° C., since tissue will become desiccated. At a temperature of 320° C., the fluid contained in the tissue is typically boiled away, resulting in the undesirable tissue effects described herein. Rather, it is preferred to keep the peak tissue temperature at no more than about 100° C. to inhibit desiccation of the tissue. Assuming that saline boils at about 100° C., the first term in equation (1)(ΔT/R) is equal to (100-37)/6=10.5 watts. Thus, based on this example, the maximum amount of heat conducted to adjacent tissue without any significant risk of tissue desiccation is 10.5 watts.

Referring again to FIG. **2**, RF power to tissue is represented on the X-axis as P (watts) and flow rate of saline (cc/min) is represented on the Y-axis as Q. When the flow rate of saline equals zero (Q=0), there is an "offset" RF power that shifts the

origin of the sloped lines **76**, **78**, and **80** to the right. This offset is the heat conducted to adjacent tissue. For example, using the calculation above for bipolar forceps, this offset RF power is about 10.5 watts. If the power is increased above this level with no saline flow, the peak tissue temperature can rise well above 100° C., resulting in tissue desiccation from the boiling off of water in the cells of the tissue.

Convection. The second term [$\rho c_\rho Q_1 \Delta T$] in equation (1) is heat used to warm up the saline without boiling the saline, represented as **72** in FIG. **2**, where:

- $\rho$=Density of the saline fluid that gets hot but does not boil (approximately 1.0 gm/cm$^3$);
- $c_\rho$=Specific heat of the saline (approximately 4.1 watt-sec/gm-° C.);
- $Q_1$=Flow rate of the saline that is heated (cm$^3$/sec); and
- $\Delta T$=Temperature rise of the saline. Assuming that the saline is heated to body temperature before it reaches the electrode, and that the peak saline temperature is similar to the peak tissue temperature, this is the same $\Delta T$ as for the conduction calculation above.

The onset of boiling can be predicted using equation (1) with the last term on the right set to zero (no boiling) ($\rho Q_b h_v$=0), and solving equation (1) for $Q_1$ leads to:

$$Q_1 = [P - \Delta T/R]/\rho c_\rho \Delta T \quad (2)$$

This equation defines the line shown in FIG. **2** as the line of onset of boiling **76**.

Boiling. The third term [$\rho Q_b h_v$] in equation (1) relates to heat that goes into converting the water in liquid saline to water vapor, and is represented as **74** in FIG. **2**, where:

- $Q_b$=Flow rate of saline that boils (cm$^3$/sec); and
- $h_v$=Heat of vaporization of saline (approximately 2,000 watt-sec/gm).

A flow rate of only 1 cc/min will absorb a significant amount of heat if it is completely boiled, or about $\rho Q_b h_v$=(1)(⅙0)(2,000)=33.3 watts. The heat needed to warm this flow rate from body temperature to 100° C. is much less, or $\rho c_\rho Q_1 \Delta T$=(1)(4.1)(⅙0)(100-37)=4.3 watts. In other words, the most significant factor contributing to heat transfer from a wet electrode device can be fractional boiling. The present invention recognizes this fact and exploits it.

Fractional boiling can be described by equation (3) below:

$$Q_1 = \frac{\{P - \Delta T / R\}}{\{\rho c_p \Delta T + \rho h_v Q_b / Q_1\}} \quad (3)$$

If the ratio of $Q_b/Q_1$ is 0.50 this is the 50% boiling line **78** shown in FIG. **2**. If the ratio is 1.0 this is the 100% boiling line **80** shown in FIG. **2**.

As indicated previously in the specification, use of a fluid to couple energy to tissue inhibits undesirable effects such as sticking, desiccation, smoke production and char formation. Tissue desiccation, which occurs if the tissue temperature exceeds 100° C. and all the intracellular water boils away, is particularly undesirable as it leaves the tissue extremely dry and much less electrically conductive.

As shown in FIG. **2**, one control strategy or mechanism which can be employed for the electrosurgical device **5** is to adjust the power P and flow rate Q such that the power P used at a corresponding flow rate Q is equal to or less than the power P required to boil 100% of the fluid and does not exceed the power P required to boil 100% of the fluid. This control strategy targets using the electrosurgical device **5** in the regions of FIG. **2** identified as T<100° C. and T=100° C., and includes the 100% boiling line **80**. That is, this control strategy targets not using the electrosurgical device **5** only in the region of FIG. **2** identified as T>>100° C.

Another control strategy that can be used for the electrosurgical device **5** is to operate device **5** in the region T<100° C., but at high enough temperature to shrink tissue containing Type I collagen (e.g., walls of blood vessels, bronchi, bile ducts, etc.), which shrinks when exposed to about 85° C. for an exposure time of 0.01 seconds, or when exposed to about 65° C. for an exposure time of 15 minutes. An exemplary target temperature/time for tissue shrinkage is about 75° C. with an exposure time of about 1 second. A determination of the high end of the scale (i.e., when the fluid reaches 100° C.) can be made by the phase change in the fluid from liquid to vapor. However, a determination at the low end of the scale (e.g., when the fluid reaches, for example, 75° C. for 1 second) requires a different mechanism as the temperature of the fluid is below the boiling temperature and no such phase change is apparent. In order to determine when the fluid reaches a temperature that will facilitate tissue shrinkage, for example 75° C., a thermochromic material, such as a thermochromic dye (e.g., leuco dye), may be added to the fluid. The dye can be formulated to provide a first predetermined color to the fluid at temperatures below a threshold temperature, such as 75° C., then, upon heating above 75° C., the dye provides a second color, such as clear, thus turning the fluid clear (i.e., no color or reduction in color). This color change may be gradual, incremental, or instant. Thus, a change in the color of the fluid, from a first color to a second color (or lack thereof) provides a visual indication to the user of the electrosurgical device **5** as to when a threshold fluid temperature below boiling has been achieved. Thermochromic dyes are available, for example, from Color Change Corporation, 1740 Cortland Court, Unit A, Addison, Ill. 60101.

It is also noted that the above mechanism (i.e., a change in the color of the fluid due to a dye) may also be used to detect when the fluid reaches a temperature which will facilitate tissue necrosis; this generally varies from about 60° C. for an exposure time of 0.01 seconds and decreasing to about 45° C. for an exposure time of 15 minutes. An exemplary target temperature/time for tissue necrosis is about 55° C. for an exposure time of about 1 second.

In order to reduce coagulation time, use of the electrosurgical device **5** in the region T=100° C. of FIG. **2** is preferable to use of the electrosurgical device **5** in the region T<100° C. Consequently, as shown in FIG. **2**, another control strategy which may be employed for the electrosurgical device **5** is to adjust the power P and flow rate Q such that the power P used at a corresponding flow rate Q is equal to or more than the power P required to initiate boiling of the fluid, but still less than the power P required to boil 100% of the fluid. This control strategy targets using the electrosurgical device **5** in the region of FIG. **2** identified as T=100° C., and includes the lines of the onset of boiling **76** and 100% boiling line **80**. That is, this control strategy targets using the electrosurgical device **5** on or between the lines of the onset of boiling **76** and 100% boiling line **80**, and not using the electrosurgical device **5** in the regions of FIG. **2** identified as T<100° C. and T>>100° C.

For consistent tissue effect, it is desirable to control the saline flow rate so that it is always on a "line of constant % boiling" as, for example, the line of the onset of boiling **76** or the 100% boiling line **80** or any line of constant % boiling located in between (e.g., 50% boiling line **78**) as shown in FIG. **2**. Consequently, another control strategy that can be used for the electrosurgical device **5** is to adjust power P and flow rate Q such that the power P used at a corresponding flow rate Q targets a line of constant % boiling.

It should be noted, from the preceding equations, that the slope of any line of constant % boiling is known. For example, for the line of the onset of boiling **76**, the slope of the line is given by ($\rho c_p \Delta T$), while the slope of the 100% boiling line **80** is given by $1/(\rho c_p \Delta T + \rho h_v)$. As for the 50% boiling line **78**, for example, the slope is given by $1/(\rho c_p \Delta T + \rho h_v 0.5)$.

If, upon application of the electrosurgical device **5** to the tissue, boiling of the fluid is not detected, such indicates that the temperature is less than 100° C. as indicated in the area of FIG. **2**, and the flow rate Q must be decreased to initiate boiling. The flow rate Q may then decreased until boiling of the fluid is first detected, at which time the line of the onset of boiling **76** is transgressed and the point of transgression on the line **76** is determined. From the determination of a point on the line of the onset of boiling **76** for a particular power P and flow rate Q, and the known slope of the line **76** as outlined above (i.e., $1/\rho c_p \Delta T$), it is also possible to determine the heat conducted to adjacent tissue **70**.

Conversely, if upon application of the electrosurgical device **5** to the tissue, boiling of the fluid is detected, such indicates that the temperature is approximately equal to 100° C. as indicated in the areas of FIG. **2**, and the flow rate Q must be increased to reduce boiling until boiling stops, at which time the line of the onset of boiling **76** is transgressed and the point of transgression on the line **76** determined. As with above, from the determination of a point on the line of the onset of boiling **76** for a particular power P and flow rate Q, and the known slope of the line **76**, it is also possible to determine the heat conducted to adjacent tissue **70**.

With regards to the detection of boiling of the fluid, such may be physically detected by the user (e.g., visually by the naked eye) in the form of either bubbles or steam evolving from the fluid coupling at the electrode/tissue interface. Alternatively, such a phase change (i.e., from liquid to vapor or vice-versa) may be measured by a sensor which preferably senses either an absolute change (e.g., existence or non-existence of boiling with binary response such as yes or no) or a change in a physical quantity or intensity and converts the change into a useful input signal for an information-gathering system. For example, the phase change associated with the onset of boiling may be detected by a pressure sensor, such as a pressure transducer, located on the electrosurgical device **5**. Alternatively, the phase change associated with the onset of boiling may be detected by a temperature sensor, such as a thermistor or thermocouple, located on the electrosurgical device **5**, such as adjacent to the electrode. Also alternatively, the phase change associated with the onset of boiling may be detected by a change in the electric properties of the fluid itself. For example, a change in the electrical resistance of the fluid may be detected by an ohm meter; a change in the amperage may be measured by an amp meter; a change in the voltage may be detected by a volt meter; and a change in the power may be determined by a power meter.

Yet another control strategy which may be employed for the electrosurgical device **5** is to eliminate the heat conduction term of equation (1) (i.e., $\Delta T/R$). Since the amount of heat conducted away to adjacent tissue can be difficult to precisely predict, as it may vary, for example, by tissue type, it may be preferable, from a control point of view, to assume the worst case situation of zero heat conduction, and provide enough saline so that if necessary, all the RF power could be used to heat up and boil the saline, thus providing that the peak tissue temperature will not go over 100° C. significantly. This is shown in the schematic graph of FIG. **3**.

Stated another way, if the heat conducted to adjacent tissue **70** is overestimated, the power P required to intersect the 100% boiling line **80** will, in turn, be overestimated and the 100% boiling line **80** will be transgressed into the T>>100° C. region of FIG. **2**, which is undesirable as established above. Thus, assuming the worse case situation of zero heat conduction provides a "safety factor" to avoid transgressing the 100% boiling line **80**. Assuming heat conduction to adjacent tissue **70** to be zero also provides the advantage of eliminating the only term from equation (1) which is tissue dependent, i.e., depends on tissue type. Thus, provided $\rho$, $c_p$, $\Delta T$, and $h_v$ are known as indicated above, the equation of the line for any line of constant % boiling is known. Thus, for example, the 98% boiling line, 80% boiling line, etc. can be determined in response to a corresponding input from selection switch **12**. In order to promote flexibility, it should be understood that the input from the selection switch preferably may comprise any percentage of boiling. Preferably the percentage of boiling can be selected in single percent increments (i.e., 100%, 99%, 98%, etc.).

Upon determination of the line of the onset of boiling **76**, the 100% boiling line **80** or any line of constant % boiling there between, it is generally desirable to control the flow rate Q so that it is always on a particular line of constant % boiling for consistent tissue effect. In such a situation, flow rate controller **11** will adjust the flow rate Q of the fluid **24** to reflect changes in power P provided by the generator **6**, as discussed in greater detail below. For such a use flow rate controller **11** may be set in a line of constant boiling mode, upon which the % boiling is then correspondingly selected.

As indicated above, it is desirable to control the saline flow rate Q so that it is always on a line of constant % boiling for consistent tissue effect. However, the preferred line of constant % boiling may vary based on the type of electrosurgical device **5**. For example, if with use of the device **5**, shunting through saline is not an issue, then it can be preferable to operate close to or directly on, but not over the line of the onset of boiling, such as **76***a* in FIG. **3**. This preferably keeps tissue as hot as possible without causing desiccation. Alternatively, if with use of the device **5** shunting of electrical energy (e.g., from one jaw to an opposing jaw of certain copative bipolar devices) through excess saline is an issue, then it can be preferable to operate along a line of constant boiling, such as line **78***a* in FIG. **3**, the 50% line. This simple proportional control will have the flow rate determined by equation (4), where K is the proportionality constant:

$$Q_1 = K \times P \tag{4}$$

In essence, when power P goes up, the flow rate Q will be proportionately increased. Conversely, when power P goes down, the flow rate Q will be proportionately decreased.

The proportionality constant K is primarily dependent on the fraction of saline that boils, as shown in equation (5), which is equation (3) solved for K after eliminating P using equation (4), and neglecting the conduction term ($\Delta T/R$):

$$K = \frac{1}{\{\rho c_p \Delta T + \rho h_v Q_b / Q_1\}} \tag{5}$$

Thus, the present invention provides a method of controlling boiling of fluid, such as a conductive fluid, at the tissue/electrode interface. In a preferred embodiment, this provides a method of treating tissue without use of tissue sensors, such as temperature or impedance sensors. Preferably, the invention can control boiling of conductive fluid at the tissue/electrode interface and thereby control tissue temperature without the use of feedback loops.

In describing the control strategy of the present invention described thus far, focus has been drawn to a steady state condition. However, the heat required to warm the tissue to the peak temperature (T) may be incorporated into equation (1) as follows:

$$P=\Delta T/R+\rho c_p Q_1 \Delta T+\rho Q_b h_v+\rho c_p V \Delta T/\Delta t \quad (6)$$

where $\rho c_\rho V\Delta T/\Delta t$ represents the heat required to warm the tissue to the peak temperature (T) **68** and where:

- $\rho$=Density of the saline fluid that gets hot but does not boil (approximately 1.0 gm/cm$^3$);
- $c_\rho$=Specific heat of the saline (approximately 4.1 watt-sec/gm-° C.);
- V=Volume of treated tissue
- $\Delta T=(T-T_\infty)$ the difference in temperature between the peak tissue temperature (T) and the normal temperature ($T_\infty$) of the body tissue (° C.). Normal temperature of the body tissue is generally 37° C.; and
- $\Delta t=(t-t_\infty)$ the difference in time to achieve peak tissue temperature (T) and the normal temperature ($T_\infty$) of the body tissue (° C.).

The inclusion of the heat required to warm the tissue to the peak temperature (T) in the control strategy is graphically represented at **68** in FIG. **4**. With respect to the control strategy, the effects of the heat required to warm the tissue to the peak temperature (T) **68** should be taken into account before flow rate Q adjustment being undertaken to detect the location of the line of onset of boiling **76**. In other words, the flow rate Q should not be decreased in response to a lack of boiling before at least a quasi-steady state has been achieved as the location of the line of onset of boiling **76** will continue to move during the transitory period. Otherwise, if the flow rate Q is decreased during the transitory period, it may be possible to decrease the flow Q to a point past the line of onset of boiling **76** and continue past the 100% boiling line **80** which is undesirable. In other words, as temperature (T) is approached the heat **68** diminishes towards zero such that the lines of constant boiling shift to the left towards the Y-axis.

FIG. **5** is an exemplary graph of flow rate Q versus % boiling for a situation where the RF power P is 75 watts. The percent boiling % is represented on the X-axis, and the saline flow rate Q (cc/min) is represented on the Y-axis. According to this example, at 100% boiling the most desirable predetermined saline flow rate Q is 2 cc/min. Also according to this example, flow rate Q versus % boiling at the remaining points of the graft illustrates a non-linear relationship as follows:

TABLE 1

| % Boiling | and Flow Rate Q (cc/min) at RF Power P of 75 watts |
|---|---|
| 0% | 17.4 |
| 10% | 9.8 |
| 20% | 6.8 |
| 30% | 5.2 |
| 40% | 4.3 |
| 50% | 3.6 |
| 60% | 3.1 |
| 70% | 2.7 |
| 80% | 2.4 |
| 90% | 2.2 |
| 100% | 2.0 |

Typical RF generators used in the field have a power selector switch to 300 watts of power, and on occasion some have been found to be selectable up to 400 watts of power. In conformance with the above methodology, at 0% boiling with a corresponding power of 300 watts, the calculated flow rate Q is 69.7 cc/min and with a corresponding power of 400 watts the calculated flow rate Q is 92.9 cc/min. Thus, when used with typical RF generators in the field, a fluid flow rate Q of about 100 cc/min or less with the present invention is expected to suffice for the vast majority of applications.

As discussed herein, RF energy delivery to tissue can be unpredictable and vary with time, even though the generator has been "set" to a fixed wattage. The schematic graph of FIG. **6** shows the general trends of the output curve of a typical general-purpose generator, with the output power changing as load (tissue plus cables) impedance Z changes. Load impedance Z (in ohms) is represented on the X-axis, and generator output power P (in watts) is represented on the Y-axis. In the illustrated embodiment, the electrosurgical power (RF) is set to 75 watts in a bipolar mode. As shown in the figure, the power will remain constant as it was set as long as the impedance Z stays between two cut-offs, low and high, of impedance, that is, for example, between 50 ohms and 300 ohms in the illustrated embodiment. Below load impedance Z of 50 ohms, the power P will decrease, as shown by the low impedance ramp **28***a*. Above load impedance Z of 300 ohms, the power P will decrease, as shown by the high impedance ramp **28***b*. Of particular interest to saline-enhanced electrosurgery is the low impedance cut-off (low impedance ramp **28***a*), where power starts to ramp down as impedance Z drops further. This change in output is invisible to the user of the generator and not evident when the generator is in use, such as in an operating room.

FIG. **7** shows the general trend of how tissue impedance generally changes with time for saline-enhanced electrosurgery. As tissue heats up, the temperature coefficient of the tissue and saline in the cells is such that the tissue impedance decreases until a steady-state temperature is reached upon which time the impedance remains constant. Thus, as tissue heats up, the load impedance Z decreases, potentially approaching the impedance Z cut-off of 50 ohms. If tissue is sufficiently heated, such that the low impedance cut-off is passed, the power P decreases along the lines of the low impedance ramp **28***a* of FIG. **6**.

Combining the effects shown in FIG. **6** and FIG. **7**, it becomes clear that when using a general-purpose generator set to a "fixed" power, the actual power delivered can change dramatically over time as tissue heats up and impedance drops. Looking at FIG. **6**, if the impedance Z drops from 100 to 75 ohms over time, the power output would not change because the curve is "flat" in that region of impedances. If, however, the impedance Z drops from 75 to 30 ohms one would transgress the low impedance cut-off and "turn the corner" onto the low impedance ramp **28***a* portion of the curve and the power output would decrease dramatically.

According to one exemplary embodiment of the invention, the control device, such as flow rate controller **11**, receives a signal indicating the drop in actual power delivered to the tissue and adjusts the flow rate Q of saline to maintain the tissue/electrode interface at a desired temperature. In a preferred embodiment, the drop in actual power P delivered is sensed by the power measurement device **8** (shown in FIG. **1**), and the flow rate Q of saline is decreased by flow rate controller **11** (also shown in FIG. **1**). Preferably, this reduction in saline flow rate Q allows the tissue temperature to stay as hot as possible without desiccation. If the control device was not in operation and the flow rate Q allowed to remain higher, the tissue would be over-cooled at the lower power input. This would result in decreasing the temperature of the tissue at the treatment site.

Flow rate controller **11** of FIG. **1** can be a simple "hard-wired" analog or digital device that requires no programming by the user or the manufacturer. Flow rate controller **11** can

alternatively include a processor, with or without a storage medium, in which the determination procedure is performed by software, hardware, or a combination thereof. In another embodiment, flow rate controller **11** can include semi-programmable hardware configured, for example, using a hardware descriptive language, such as Verilog. In another embodiment, flow rate controller **11** of FIG. **1** is a computer, microprocessor-driven controller with software embedded. In yet another embodiment, flow rate controller **11** can include additional features, such as a delay mechanism, such as a timer, to automatically keep the saline flow on for several seconds after the RF is turned off to provide a post-coagulation cooling of the tissue or "quench," which can increase the strength of the tissue seal. Flow rate controller **11** can include a delay mechanism, such as a timer, to automatically turn on the saline flow several seconds before the RF is turned on to inhibit the possibility of undesirable effects as sticking, desiccation, smoke production and char formation. Optionally, flow rate controller **11** can include a low level flow standby mechanism, such as a valve, which continues the saline flow at a standby flow level (which prevents the flow rate from going to zero when the RF power is turned off) below the surgical flow level ordinarily encountered during use of the electrosurgical device **5**.

An exemplary electrosurgical device of the present invention which may be used in conjunction with the system of the present invention is shown at reference character **5***a* in FIG. **9**, and more particularly in FIGS. **9-13**. While various electrosurgical devices of the present invention are described with reference to use with the remainder of the system of the invention, it should be understood that the description of the combination is for purposes of illustrating the remainder of the system of the invention only. Consequently, it should be understood that the electrosurgical devices of the present invention can be used alone, or in conjunction with the remainder of the system of the invention, or that a wide variety of electrosurgical devices can be used in connection with the remainder of the system of the invention. The electrosurgical devices disclosed herein are preferably further configured for both open and laparoscopic surgery. For laparoscopic surgery, the devices are preferably configured to fit through either a 5 mm or 12 mm trocar cannula.

As shown in FIG. **8**, electrosurgical device **5***a* may be used in conjunction with a cannula as illustrated at reference character **19**, during laparoscopic surgery such as, for example, a laparoscopic cholecystectomy. Cannula **19** comprises a proximal portion **19***a* separated from a distal portion **19***b* by an elongated rigid shaft portion **19***c*. Proximal portion **19***a* of cannula **19** preferably comprises a head portion **19***d* connected to rigid shaft portion **19***c*, preferably by threaded engagement. Most importantly, cannula **19** has a working channel **19***e* which extends through head portion **19***d* and shaft portion **19***c* from proximal portion **19***a* to distal portion **19***b* of cannula **19**. In one particular embodiment, during insertion into cannula **19**, electrosurgical device **5***a* is configured to enter the proximal end of working channel **19***e*, move along the channel **19***e* distally, and then be extended from the distal end of the working channel **19***e*. In the same embodiment, during retraction from cannula **19**, electrosurgical device **5***a* is configured to enter the distal end of working channel **19***e*, move along the channel **19***e* proximally, and then be removed from the proximal end of working channel **19***e*.

Referring back to FIG. **9**, as shown electrosurgical device **5***a* is a monopolar electrosurgical device. Electrosurgical device **5***a* preferably includes a rigid, self-supporting, hollow shaft **17**, a proximal handle comprising mating handle portions **20***a*, **20***b* and a tip portion as shown by circle **45**. Handle **20***a*, **20***b* is preferably made of a sterilizable, rigid, non-conductive material, such as a polymer (e.g., polycarbonate). As shown in FIGS. **10** and **11**, tip portion **45** includes a contact element preferably comprising an electrode **25**. Tip portion **45** also comprises a sleeve **82** having a uniform diameter along its longitudinal length, a spring **88** and a distal portion of shaft **17**. As shown in FIG. **10**, the longitudinal axis **31** of the tip portion **45** may be configured at an angle A relative to the longitudinal axis **29** of the proximal remainder of shaft **17**. Preferably, angle A is about 5 degrees to 90 degrees, and more preferably, angle A is about 8 degrees to 45 degrees.

As shown in FIGS. **10** and **11**, for electrosurgical device **5***a*, electrode **25** generally has a spherical shape with a corresponding spherical surface, a portion **42** of which is exposed to tissue **32** at the distal end of device **5***a*. When electrode **25** is in the form of a sphere, the sphere may have any suitable diameter. Typically, the sphere has a diameter in the range between and including about 1 mm to about 7 mm, although it has been found that when a sphere is larger than about 4 mm or less than about 2 mm tissue treatment can be adversely effected (particularly tissue treatment time) due to an electrode surface that is respectively either to large or to small. Thus, preferably the sphere has a diameter in the range between and including about 2.5 mm to about 3.5 mm, more preferably, about 3 mm.

It is understood that shapes other than a sphere can be used for the contact element. Examples of such shapes include oblong or elongated shapes. However, as shown in FIGS. **10** and **11**, preferably a distal end surface of electrosurgical device **5***a* provides a blunt, rounded surface which is non-pointed and non-sharp as shown by electrode **25**.

As shown in FIGS. **10** and **11**, electrode **25**, is preferably located in a cavity **81** of a cylindrical sleeve **82** providing a receptacle for electrode **25**. Among other things, sleeve **82** guides movement of electrode **25**. Among other things, sleeve **82** also functions as a housing for retaining electrode **25**.

Also as shown in FIG. **11**, a portion **44** of electrode **25**, is retained within cavity **81** while another portion **43** extends distally through the fluid outlet opening provided by circular fluid exit hole **26**. Also as shown, sleeve **82** is connected, preferably via welding with silver solder, to the distal end **53** of shaft **17**. For device **5***a*, electrode **25**, sleeve **82** and shaft **17** preferably include, and more preferably are made at least almost essentially of, an electrically conductive metal, which is also preferably non-corrosive. A preferred material is stainless steel. Other suitable metals include titanium, gold, silver and platinum. Shaft **17** preferably is stainless steel hypotubing.

As for cavity **81**, the internal diameter of cavity **81** surrounding electrode **25** is preferably slightly larger than the diameter of the sphere, typically by about 0.25 mm. This permits the sphere to freely rotate within cavity **81**. Consequently, cavity **81** of sleeve **82** also preferably has a diameter in the range of about 1 mm to about 7 mm.

As best shown in FIGS. **11** and **12**, in order to retain electrode **25**, within the cavity **81** of sleeve **82**, preferably the fluid exit hole **26**, which ultimately provides a fluid outlet opening, of cavity **81** at its distal end **83** comprises a distal pinched region **86** which is reduced to a size smaller than the diameter of electrode **25**, to inhibit escape of electrode **25** from sleeve **82**. More preferably, the fluid exit hole **26** has a diameter smaller than the diameter of electrode **25**.

As best shown in FIG. **12**, fluid exit hole **26** preferably has a diameter smaller than the diameter of electrode **25**, which can be accomplished by at least one crimp **84** located at the distal end **83** of sleeve **82** which is directed towards the

interior of sleeve **82** and distal to the portion **44** of electrode **25** confined in cavity **81**. Where one crimp **84** is employed, crimp **84** may comprise a single continuous circular rim pattern. In this manner, the contact element portion extending distally through the fluid outlet opening (i.e., electrode portion **43**) provided by fluid exit hole **26** has a complementary shape to the fluid outlet opening provided by fluid exit hole **26**, here both circular.

As shown in FIG. **12**, crimp **84** may have a discontinuous circular rim pattern where crimp **84** is interrupted by at least one rectangular hole slot **85** formed at the distal end **83** of sleeve **82**. Thus, the fluid outlet opening located at the distal end of the device **5***a* may comprise a first portion (e.g., the circular fluid exit hole portion **26**) and a second portion (e.g., the slot fluid exit hole portion **85**). As shown in FIG. **12**, preferably, crimp **84** comprises at least four crimp sections forming a circular rim pattern separated by four discrete slots **85** radially located there between at 90 degrees relative to one another and equally positioned around the fluid outlet opening first portion. Slots **85** are preferably used to provide a fluid outlet opening or exit adjacent electrode **25**, when electrode **25** is fully seated (as discussed below) and/or when electrode **25** is not in use (i.e., not electrically charged) to keep surface portion **42** of the electrode surface of electrode **25** wet. Preferably, slots **85** have a width in the range between and including about 0.1 mm to 1 mm, and more preferably about 0.2 mm to 0.3 mm. As for length, slots **85** preferably have a length in the range between and including about 0.1 mm to 1 mm, and more preferably bout 0.4 mm to 0.6 mm.

As shown in FIG. **12**, the contact element portion extending distally through the fluid outlet opening (i.e., electrode portion **43**) extends distally through the fluid outlet opening first portion (e.g., the circular fluid exit hole portion **26**) and does not extend distally through the fluid outlet opening second portion (e.g., the slot fluid exit hole portion **85**). In this manner an edge **91** of slot **85** remains exposed to tissue **32** to provide a tissue separating edge as discussed below.

It should be understood that the particular geometry of fluid outlet opening provided by the fluid exit hole located at the distal end of device **5***a* to the electrode is not critical to the invention, and all that is required is the presence of a fluid exit hole which provides fluid **24** as required. For example, fluid exit hole **26** may have an oval shape while electrode **25** has a different shape, such as a round shape.

As shown in FIG. **12**, in addition to slot **85** providing a fluid exit, at least one edge **91** of slot **85** may provide a tissue separating edge adjacent a blunt surface (e.g., surface portion **42** of electrode **25**) which may be used for blunt dissection when the electrosurgical device **5***a* is manipulated, particularly by rotating (e.g., twirling), abrading or impacting. When edge **91** is used in such regard, it is preferred that the edge comprise a sharp edge with a sharp angle which has not been rounded by, for example, a fillet.

Turning to the proximal end of the tip (comprising electrode **25**, spring **88** and sleeve **82**) of the device **5***a* and electrode **25**, as shown in FIG. **11**, preferably the portion of sleeve **82** proximal to electrode **25**, also has a proximal pinched region **87** which retains electrode **25** in the cavity **81** of sleeve **82** and inhibits escape of electrode **25** from the cavity **81** of sleeve **82**, such as a diameter smaller than the diameter of electrode **25**.

While distal pinched region **86** and proximal pinched region **87** may be used solely to support electrode **25**, in its position of use, the electrode may be further supported by a compression spring **88** as shown in FIG. **11**. The use of spring **88** is preferred to provide a variable length support within the working length of the spring **88** for overcoming manufacturing tolerances (e.g., length) between the fixed supports (i.e., pinched regions **86** and **87**) of sleeve **82**. As for maintaining proper location of the spring **88**, sleeve **82** also comprises a lumen **89** as shown in FIG. **11** (i.e., the cavity of an elongated hollow structure, such as a tube or tube like structure; typically cylindrical), which, in addition to providing a direct passage for fluid, provides a guide tube for spring **88**. Furthermore, the surface portion **60** of electrode **25**, which contacts spring **88** may have a flat surface rather than a curvilinear surface to better seat the spring against electrode **25**.

In addition to the above, spring **88** provides a multitude of functions and advantages. For example, the configuration of the distal pinched region **86**, proximal pinched region **87** and spring **88** offers the ability to move electrode **25** distally and proximally within sleeve **82**. As shown in FIG. **11**, spring **88** is located proximal to electrode **25** between a first load bearing surface comprising the electrode surface **60** and a second load bearing surface comprising the distal end **53** of shaft **17**. In this manner, spring **88** can be configured to provide a decompression force to seat electrode **25** against the distal pinched region **86**, in this case the perimeter edge **92** of crimp **84**, prior to use of electrosurgical device **5***a*.

Conversely, upon application of electrode **25** against surface **22** of tissue **32** with sufficient force to overcome the compression force of the spring **88**, spring **88** compresses and electrode **25** retracts proximally away from distal pinched region **86**, in this case perimeter edge **92** of crimp **84**, changing the position thereof. In the above manner, the contact element comprising electrode **25** is retractable into the cavity **81** of the housing provided by sleeve **82** upon the application of a proximally directed force against surface **42** of the portion **43** of electrode **25** extending distally beyond the distal opening **26** located at the distal end **83** of the housing and spring **88** functions as a retraction biasing member.

By making electrode **25** positionable in the above manner via spring **88**, electrosurgical device **5***a* can be provided with a damper mechanism which dampens the force of electrode **25** on tissue **32** being treated.

Furthermore, electrode **25** which can be positioned as outlined above can comprise a fluid flow rate adjustment mechanism which incrementally increases the area of fluid exit hole **26** and the corresponding fluid flow rate in response to the incremental proximal retraction of electrode **25**. In such an instance, electrode **25** functions as a valve by regulating flow of fluid **24** through fluid exit hole **26**.

In various embodiments, spring **88** may be used in conjunction with the distal pinched region **86** (e.g., crimp **84** comprising a single continuous circular pattern) to provide a fluid seal between electrode **25** and the distal pinched region **86** which stops fluid flow from the electrosurgical device **5***a*. In this manner, the electrosurgical device **5***a* may be used to provide both a wet electrode and dry electrode (i.e., when the fluid flow is on and off, respectively) with the energy and fluid provided sequentially in addition to simultaneously. The incorporation of a dry electrode function into the device may be desirable to provide a mechanism for electrosurgical cutting.

Furthermore, in various embodiments of electrosurgical device **5***a*, an electrode **25** which can be positioned as outlined above can include a declogging mechanism. Such a mechanism can retract to provide access for unclogging fluid exit holes (e.g., **26** and **85**), which may become flow restricted as a result of loose debris (e.g., tissue, blood) becoming lodged therein. For example, when a biasing force, such as from a handheld cleaning device (e.g., brush) or from pushing the distal tip against a hard surface such as a retractor, is applied to surface **42** of electrode **25** which overcomes the compres-

sion force of the spring **88** causing the spring **88** to compress and electrode **25** to retract, the tip of the handheld cleaning device may by extended into the fluid exit hole **26** for cleaning the fluid exit hole **26**, perimeter edge **92**, slot **85** and edge **91**. Stated another way, electrode **25**, which can be positioned as outlined, provides a methodology for declogging a fluid exit hole by increasing the cross-sectional area of the fluid exit hole to provide access thereto.

Additionally, in various embodiments of device **5***a*, spring **88** comprises an electrical conductor, particularly when electrode **25**, is retracted to a non-contact position (i.e., not in contact) with sleeve **82**.

In other embodiments, proximal pinched region **87** may comprise one or more crimps similar to distal pinched region **86**, such that electrode **25** is retained in sleeve **82** both distally and proximally by the crimps. Also, in other embodiments, sleeve **82** may be disposed within shaft **17** rather than being connected to the distal end **53** of shaft **17**. Also, in still other embodiments, sleeve **82** may be formed unitarily (i.e., as a single piece or unit) with shaft **17** as a unitary piece.

As best shown in FIGS. **10** and **11**, electrode **25** is retained in sleeve **82** with a portion **43** of electrode **25** extending distally beyond distal end **83** of sleeve **82**. As shown, preferably the surface **42** of this exposed portion **43** of electrode **25** is blunt and does not have any sharp corners. Also, the portion **43** of electrode **25** which extends distally beyond the distal end **83** of sleeve **82** is controlled by the shape of the fluid exit hole **26** in sleeve **82** in relation to the shape of electrode **25**. In other words, the portion **43** of electrode **25** that extends distally beyond distal end **83** of sleeve **82** is controlled by the contact of the electrode surface with the edge **92**.

In locations where shaft **17** and sleeve **82** are electrically conductive (for device **5***a*, preferably shaft **17** and sleeve **82** are completely electrically conductive and do not comprise non-conductive portions) an electrical insulator **90** (i.e., comprising non-conductive or insulating material) preferably surrounds shaft **17** and sleeve **82** along substantially its entire exposed length (e.g., the portion outside the confines of the handle **20**), terminating a short distance (e.g., at the proximal onset of crimp **84** or less than about 3 mm) from distal end **83** of sleeve **82**. Insulator **90** preferably comprises a shrink wrap polymer tubing.

As with the other electrosurgical devices described within, a input fluid line **4***b* and a power source, preferably comprising generator **6** preferably providing RF power via cable **9**, are preferably fluidly and electrically coupled, respectively, to the tip portion **45** of the electrosurgical device **5***a*.

As indicated above, device **5***a* comprises a monopolar device. A monopolar device has a first electrode, often referred to as the active electrode, and a second electrode, often referred to as the indifferent or return electrode. For electrosurgical device **5***a*, electrode **25** is the first electrode, and a ground pad dispersive electrode located on the patient, typically on the back or other suitable anatomical location, is the second electrode. Preferably, both electrodes are electrically coupled to generator **6** to form an electrical circuit. Preferably the active electrode is coupled to generator **6** via a wire conductor from insulated wire cable **9** to the outer surface **18** of shaft **17** within the confines of handle **20***a*, **20***b*, typically through a switch **15***a*.

In some embodiments, shaft **17** may be made of an electrical non-conducting material except for a portion at its distal end **53** that comes in contact with sleeve **82**. This portion of shaft **17** that contacts sleeve **82** should be electrically conducting. In this embodiment, the wire conductor from insulated wire cable **9** extends to this electrically conducting portion of shaft **17**. In still other embodiments, shaft **17** may completely comprise a non-conducting material as where the wire conductor from insulated wire cable **9** extends directly to sleeve **82**.

With respect to the fluid coupling, fluid **24** from the fluid source **1** preferably is communicated from fluid source **1** through a flexible, polyvinylchloride (PVC) outlet fluid line **4***a* to a flexible, polyvinylchloride (PVC) inlet fluid line **4***b* connected to electrosurgical device **5***a*. Outlet fluid line **4***a* and inlet fluid line **4***b* are preferably connected via a male and female mechanical fastener configuration; a preferred such connection is a Luer-Lok® connection from Becton, Dickinson and Company. The lumen of the inlet line is then preferably interference fit over the outside diameter of shaft **17** to provide a press fit seal there between. An adhesive may be used there between to strengthen the seal. Fluid **24** is then communicated down lumen **23** of shaft **17** through lumen **89** and cavity **81** of sleeve **82** where it is expelled from around and on the exposed surface **42** of electrode **25**. This provides a wet electrode for performing electrosurgery.

As shown in FIG. **13**, during use of electrosurgical device **5***a*, typically a fluid coupling **30** preferably comprising a discrete, localized web and more preferably comprising a triangular shaped web or bead portion providing a film of fluid **24** is provided between surface **22** of tissue **32** and electrode **25**. When the user of electrosurgical device **5***a* places electrode **25** at a tissue treatment site and moves electrode **25** across the surface **22** of the tissue **32**, fluid **24** is expelled around and on surface **42** of electrode **25** at the distal end **83** of sleeve **82** and onto the surface **22** of the tissue **32** via coupling **30**. The fluid **24**, in addition to providing an electrical coupling between electrosurgical device **5***a* and tissue **32**, lubricates surface **22** of tissue **32** and facilitates the movement of electrode **25** across surface **22** of tissue **32**. During movement of electrode **25**, electrode **25** typically slides across surface **22** of tissue **32**, but also may rotate as electrode **25** moves across surface **22** of tissue **32**. Typically the user of the electrosurgical device **5***a* slides the electrode across surface **22** of tissue **32** back and forth with a painting motion while using fluid **24** as, among other things, a lubricating coating. Preferably the thickness of the fluid **24** between the distal end surface of electrode **25** and surface **22** of tissue **32** at the outer edge of the coupling **30** is in the range between and including about 0.05 mm to 1.5 mm, more preferably in the range between and including about 0.1 mm to 0.3 mm. Also preferably, in certain embodiments, the distal end tip of electrode **25** contacts surface **22** of tissue **32** without any fluid **24** in between.

Another exemplary electrosurgical device is shown at reference character **5***b* in FIGS. **14-16**. In this embodiment, electrical insulator **90** preferably terminates proximally to sleeve **82** where sleeve **82** is connected to the distal end **53** of shaft **17**. In certain embodiments where sleeve **82** is formed unitary shaft **17**, electrical insulator **90** preferably terminates proximally to proximal pinched region **87**. In this manner, in addition to the spherical surface portion **42** of electrode **25** and the narrowing surface portion **41**, here conical, of sleeve **82** being used for treating tissue **32** when exposed thereto, a cylindrical surface **40** of a cylindrical portion **39** of sleeve **82** and a broadening surface portion **47** of broadening portion **54**, here both conical, of sleeve **82** also function as electrode surfaces for treating tissue. Thus, the electrode exposed to tissue **32** now comprises a cylindrical surface portion **40** and a broadening surface portion **47** in addition to the spherical surface portion **42** and the narrowing surface portion **41**, with the cylindrical surface portion **40** substantially increasing the surface area of the electrode. As a result, electrode **25** has surfaces which are parallel and perpendicular to the longitu-

dinal axis **31** of tip portion **45**, and more particularly, sleeve **82** of electrosurgical device **5***b*. In the above manner, front end use (e.g., surfaces **41** and **42**), sideways use (e.g., surface **40** and **47**), or oblique use (e.g., surfaces **40**, **41** and **42**) of electrosurgical device **5***b* is facilitated.

In the above manner, tip portion **45** now includes a first tissue treating surface (e.g., distal end spherical surface **42**) and a second tissue treating surface (e.g., side surface **40**). As discussed above, preferably the first tissue treating surface is configured for blunt dissection while the second tissue treating surface is configured for coagulation. Additionally, tip portion **45** also has a third tissue treating surface (e.g., surface **41**) located between the first tissue treating surface (e.g., surface **42**) and a second tissue treating surface (e.g., surface **39**). Furthermore, tip portion **45** also has a fourth tissue treating surface (e.g., surface **47**) located proximal and adjacent to surface **39**.

With device **5***a*, when electrode **25** is placed directly in contact with surface **22** of tissue **32**, tissue **32** may occlude fluid flow from fluid exit holes **26**, **85** located at the distal end of device **5***a*. Consequently, for device **5***b* fluid exit holes **93**, **94** may be located in the cylindrical side portion **39** of sleeve **82**, either proximal or adjacent to electrode **25**, and either in addition to or as an alternative to fluid exit holes **26**, **85**.

As shown in FIGS. **14** and **15**, at least one fluid exit hole **93** is preferably formed in the cylindrical longitudinal side surface **40** and through the wall of side portion **39** of sleeve **82** adjacent to electrode **25** when electrode **25** is fully seated. Furthermore, preferably at least one fluid exit hole **94** is formed in the cylindrical side portion **39** of sleeve **82** proximal to electrode **25** when electrode **25** is fully seated.

Preferably, holes **93**, **94** each comprise more than one hole which are equally spaced radially in a circular pattern around the longitudinal axis **31** of tip portion **45**, and more particularly sleeve **82**. More preferably, holes **93**, **94** each comprise four discrete holes equally spaced 90 degrees around the cylindrical side portion **39** of sleeve **82**. Preferably holes **93**, **94** have a diameter in the range between and including about 0.1 mm to 1.0 mm, and more preferably have a length in the range between and including about 0.2 mm to 0.6 mm.

Electrode **25**, which can be positioned as outlined above, can comprise not only a valve for regulating fluid flow from the fluid exit holes, such as fluid exit hole **26**, but also comprise a valve which while opening one fluid flow exit simultaneously closes another fluid flow exit. For example, as electrode **25** retracts proximally, fluid exit hole **26** is opened while fluid exit hole **93** is closed. Stated another way, an electrode **25** which can be positioned as outlined above can provide a mechanism for altering the size and/or location of the fluid exit holes during use of electrosurgical device **5***b* which may be necessary, for example, to direct fluid to a particular tissue location or balance fluid flow among the fluid exit outlets.

Thus, as shown in FIGS. **14** and **15**, surfaces **40**, **41** and **47** of sleeve **82**, and surface **42** of electrode **25** are all active electrode surfaces and can provide electrical energy to tissue **32**. Portions of this combined electrode surface can be wet by fluid flow from holes **26**, **94** or **93**, as well as from the hole slots **85** in crimp **84** adjacent electrode **25**.

The holes **94**, **93** in the cylindrical sleeve **82** of the overall electrode surface are intended to assure that fluid **24** is provided to the smooth, less rough, atraumatic sides of the electrode that are used to produce tissue coagulation and hemostasis (e.g., surfaces **40** and **47**) rather than blunt dissection (e.g., surfaces **41** and **42**). The most distal portion of the device may have a more rough, but also wetted, electrode surface that can blunt dissect as well as coagulate tissue.

The electrode configuration shown in FIGS. **14** and **15** is particularly useful to a surgeon performing a liver resection. Once the outer capsule of the liver is scored with a dry bovie blade along the planned line of resection the distal tip of tip portion **45** is painted back and forth along the line, resulting in coagulation of the liver parenchyma. As the tissue is coagulated under and around the electrode surfaces **40**, **41** and **42**, the electrode is used to blunt dissect into the coagulated parenchyma, with edge **91** of slots **85** around crimp **84** providing roughness elements that aid in disrupting the tissue **32** and enabling the parting of tissue **32**.

As shown in FIG. **16**, the device **5***b* can be used deeply in a crevice **97** of tissue **32** to blunt dissect tissue **32** and coagulate it at the same time. Blunt dissection is preferred over sharp dissection, such as with a blade or scissors, since blunt dissection is less likely to tear or damage the larger blood vessels or other vessels. Once identified by blunt dissection, larger vessels can be safely clipped, tied with suture or sealed with some other device. If the larger vessels are not thus first "skeletonized" without being damaged by blunt dissection, they may bleed profusely and require much more time to stop the bleeding. The device can also be used to coagulate first without simultaneous blunt dissection, and then blunt dissect in a separate step.

This technique can also be used on other parenchymal organs such as the pancreas, the kidney, and the lung. In addition, it may also be useful on muscle tissue and subcutaneous fat. It's use can also extend to benign tumors, cysts or other tissue masses found in the urological or gynecological areas. It would also enable the removal of highly vascularized tumors such as hemangiomas.

In FIG. **16** the zone **99** identifies the part of the electrode that has the ability to blunt dissect and coagulate, and the zone **98** identifies the part that is intended primarily for coagulation and hemostasis. The line **100** indicates the depth of the zone of tissue that is coagulated, typically from 3 mm to 5 mm deep.

For the devices disclosed herein, the presence of various fractions of boiling can be visually estimated by the naked eye, or by detecting changes in electrical impedance. FIG. **17** shows a plot of electrical impedance Z versus time t. The impedance spikes **101** shown in FIG. **17** occur at a frequency of about 1 cycle per second and with an amplitude that is on the same order as the baseline impedance. This frequency is shown in FIG. **17** as the interval **102** between successive impedance spikes. Impedance is directly measurable by dividing the voltage by the current as previously described. The use of electrical impedance to detect the onset of tissue dessication when impedance rises dramatically as a result of being heated to the point of smoking and charring, but not to detect the presence of boiling, is described above. As shown in FIG. **17**, the impedance Z may change from a level of about 100 ohms with no boiling, to a level of about 400 ohms or more with a large fraction of the conductive fluid boiling. The percentages of boiling shown are exemplary as are the levels of impedance.

Shown in FIG. **18** is the qualitative nature of the boiling as the % boiling increases, indicated by the small figures for each of five exemplary "regimes" of boiling. In each small figure a portion of the tip of the tip portion **45** of device **5***a* is shown in close proximity to tissue **32**. As boiling begins in regime **104**, there are few small bubbles **37** of vapor in the conductive fluid **24**, here saline, of coupling **30**. As the percentage of boiling increases at regime **106** there are a larger number of small bubbles **37**. As the percentage boiling increases further at regime **107**, the bubbles **37** become much larger. At even higher percentage boiling at regime **108** inter-

mittent threads of saline form and are quickly boiled off. Finally, at the highest level of regime **109**, drops **36** of saline are instantly boiled upon contacting the hot surface **22** of tissue **32** and arcing occurs from the metal to tissue **32**.

Returning to FIGS. **14** and **15**, fluid outlet openings are provided by substantially linear through holes **93**, **94** which provide conductive fluid **24** to the treatment site. However, in an alternative embodiment, as shown in FIG. **19**, fluid outlet openings in sleeve **82** may be provided by holes in the form of tortuous and interconnected pathways **59**, which are formed in a material pervious to the passage of fluid **24**, therethrough, such as a porous material. The discrete, linear through holes **93**, **94** may be either supplemented with or replaced by a plurality of tortuous, interconnected pathways **59** formed in the porous material which, among other things, provides porous surfaces **40**, **41** and **47** to more evenly distribute fluid flow and provide the conductive fluid **24** to tissue **32** at the treatment site. According to the invention, all or a portion of sleeve **82** may comprise a material pervious to the passage of fluid **24** therethrough as disclosed herein.

In certain embodiments, the contact element, here electrode **25** may also comprise a material pervious to the passage of fluid **24**, therethrough, such as a porous material (e.g., metal, polymer or ceramic) to provide the tortuous pathways **59**. In these embodiments, the porous structure of electrode **25** allows fluid **24** to not only pass around electrode **25** on the outer porous surface **42** to be expelled, but also allows fluid **24** to pass through electrode **25**, to be expelled. According to the invention, all or a portion of the electrodes or any particular electrodes for treating tissue **32** may comprise a material pervious to the passage of fluid **24** therethrough as disclosed herein.

Where the contact element and sleeve provide electrodes for treating tissue and compromise a porous material, preferably the porous material further comprises porous metal. Porous sintered metal is available in many materials (such as, for example, **316**L stainless steel, titanium, Ni-Chrome) and shapes (such as cylinders, discs, plugs) from companies such as Porvair, located in Henderson, N.C.

Porous metal components can be formed by a sintered metal powder process or by injection molding a two-part combination of metal and a material that can be burned off to form pores that connect (open cell) to each other. With sintering, for example, typically solid particles of material are placed in a mold under heat and pressure such that the outer surface of the particles soften and bond to one another with the pores comprising the interstices between the particles. Alternatively, when porosity is formed by burning off material, it is not the interstice between the particles which provides the porosity as with sintering, but rather a partial evisceration of the material generally provided by the removal of a component with a lower melt temperature than the bum off temperature.

While the electrode provided by contact element and/or sleeve preferably comprises an electrically conductive material such as metal, a non-electrically conductive porous contact element and/or sleeve, such as porous polymers and ceramics, can be used to replace an electrically conductive contact element and/or sleeve. While the porous polymers and ceramics are generally non-conductive, they may also be used to conduct the RF energy through the porous polymer and ceramic thickness and porous surface to the tissue to be treated by virtue of conductive fluid **24** contained within the plurality of interconnected tortuous pathways **59**.

Preferably the tortuous passages in the porous materials have a pore size (cross-sectional dimension) in the range between and including about 2.5 micrometers (0.0025 mm) to 500 micrometers (0.5 mm) and more preferably has pore size in the range between and including about 10 micrometers (0.01 mm) to 120 micrometers (0.12 mm). Even more preferably, the porous material has a pore size in the range between and including about 20 micrometers (0.02 mm) to 80 micrometers (0.08 mm).

In addition to possibly providing a more uniform distribution of fluid **24**, the porous materials also may provide other advantages. For example, when the electrode surfaces, such as surfaces **40**, **41**, **42** and **47**, in contact with the surface **22** of tissue **32** are porous and dissipate fluid **24**, tissue **32** is less apt to stick to surfaces **40**, **41**, **42** and **47** of the electrode as compared to the situation where the surfaces **40**, **41**, **42** and **47** are not porous. In addition, by providing fluid **24** to surfaces **40**, **41**, **42** and **47** through tortuous pathways **59**, heated and/or electrified fluid **24** can now be provided more uniformly to surfaces **40**, **41**, **42** and **47**, which may result in a wider tissue treatment region as compared to when the surfaces are not porous.

Preferably the porous material provides for the wicking (i.e., drawing in of fluid by capillary action or capillarity) of the fluid **24** into the pores of the porous material. In order to promote wicking of the fluid **24** into the pores of the porous material, preferably the porous material, and in particular the surface of the tortuous pathways, is hydrophilic. The porous material may be hydrophilic with or without post treating (e.g., plasma surface treatment such as hypercleaning, etching or micro-roughening, plasma surface modification of the molecular structure, surface chemical activation or crosslinking), or made hydrophilic by a coating provided thereto, such as a surfactant.

Though not preferable, it is not necessary that fluid coupling **30** of fluid **24** be present in between the metal electrode surfaces (e.g., **40**, **41**, **42**) and tissue **32** at all locations of tissue treatment and there may be points of direct tissue contact by the electrode surfaces without any fluid coupling **30** therebetween. In such an instance, the convective cooling of the metal electrode by flowing saline is often sufficient to keep the metal electrode and tissue contacting the metal electrode at or below a temperature of 100° C. In other words, heat may be also first dissipated from tissue **32** to the electrodes by conduction, then dissipated from the electrodes to the fluid **24** by convection.

Preferably the relationship between the material for electrodes particularly their surfaces (e.g., **40**, **41**, **42**, **47**), and fluid **24** throughout the various embodiments should be such that the fluid **24** wets the surface of the electrodes to form a continuous thin film coating thereon (for example, see FIG. **19**A) and does not form isolated rivulets or circular beads (e.g., with a contact angle, θ greater than 90 degrees) which freely run off the surface of the electrode. Contact angle, θ, is a quantitative measure of the wetting of a solid by a liquid. It is defined geometrically as the angle formed by a liquid at the three phase boundary where a liquid, gas and solid intersect. In terms of the thermodynamics of the materials involved, contact angle θ involves the interfacial free energies between the three phases given by the equation $\gamma_{LV} \cos \theta = \gamma_{SV} - \gamma_{SL}$ where $\gamma_{LV}$, $\gamma_{sv}$ and $\gamma_{SL}$ refer to the interfacial energies of the liquid/vapor, solid/vapor and solid/liquid interfaces, respectively. If the contact angle θ is less than 90 degrees the liquid is said to wet the solid. If the contact angle is greater than 90 degrees the liquid is non-wetting. A zero contact angle θ represents complete wetting. Thus, preferably the contact angle is less than 90 degrees.

For clarification, while it is known that the contact angle θ may be defined by the preceding equation, in reality contact angle θ is determined by a various models to an approxima-

tion. According to publication entitled "Surface Energy Calculations" (dated Sep. 13, 2001) from First Ten Angstroms (465 Dinwiddie Street, Portsmouth, Va. 23704), there are five models which are widely used to approximate contact angle θ and a number of others which have small followings. The five predominate models and their synonyms are: (1) Zisman critical wetting tension; (2) Girifalco, Good, Fowkes, Young combining rule; (3) Owens, Wendt geometric mean; (4) Wu harmonic mean; and (5) Lewis acid/base theory. Also according to the First Ten Angstroms publication, for well-known, well characterized surfaces, there can be a 25% difference in the answers provided for the contact angle θ by the models. Also for clarification, any one of the five predominate models above which calculates a contact angle θ within a particular range of contact angles θ or the contact angle θ required of a particular embodiment of the invention should be considered as fulfilling the requirements of the embodiment, even if the remaining four models calculate a contact angle θ which does not fulfill the requirements of the embodiment.

The effects of gravity and surface tension tend to wick the fluid **24**, here saline, around the circumference of the cylindrical sleeve **82** to preferably cover the entire active electrode surface. More specifically, the effects of gravity and surface tension on fluid **24** which is located on the electrode surfaces may be modeled by the Bond number $N_{BO}$. Bond number $N_{BO}$ measures the relationship of gravitational forces to surface tension forces and may be expressed as:

$N_{BO}$=gravitational force/surface tension force

$N_{BO}=\rho L^2 g/\sigma$

where:

ρ=Density of the saline fluid (approximately 1.0 gm/cm$^3$);

L=droplet diameter (cm)

g=Gravitational acceleration (980 cm/s$^2$)

σ=Surface tension (approximately 72.8 dynes/cm (20° C.)

For a Bond number $N_{BO}$=1, the droplet diameter is equal to about 0.273 cm or about 2.7 mm, which is in the same order of magnitude as the preferred size of the electrode. For the purposes of the present invention, preferably Bond number $N_{BO}$ for a droplet of fluid **24** on a surface of electrode **25** is preferably less than 1.

Another tip portion of an exemplary electrosurgical device **5***c* of the present invention which may be used in conjunction with the system of the present invention is shown at reference character **45** in FIGS. **20-24**. As best shown in FIGS. **20** and **21**, the separate sleeve **82** of embodiments **5***a* and **5***b* has been eliminated from tip portion **45** of device **5***c*. Consequently, the contact element, still preferably comprising an electrode **25**, is assembled directly with the shaft **17**. Electrode **25** is preferably assembled (e.g., mechanically connected via press fit, mechanical connector, threaded, welded, adhesively bonded) adjacent the distal end **53** of shaft **17**. In certain embodiments, electrode **25** preferably is detachably assembled to the shaft **17** such that it may be removed from the shaft **17**, preferably manually by human hand, so that the shaft **17** may be used with multiple different contact elements/electrodes, or the shaft **17** may be reuseable and used with disposable contact elements/electrodes.

As shown in FIGS. **20-24**, electrode **25** preferably comprises a spherical portion **43** and a corresponding spherical surface portion **42** located at the distal end of the device **5***c* which provided a smooth, blunt contour outer surface. More specifically, as shown, the spherical portion **43** and spherical surface portion **42** further provide a domed, hemisphere (i.e., less than a full sphere) and hemispherical surface portion comprising preferably about 180 degrees.

Also as shown in FIGS. **20-24**, electrode **25** preferably also comprises a cylindrical portion **39** and a corresponding cylindrical surface portion **40** located proximal and adjacent to the spherical portion **43** and spherical surface portion **42**, respectively.

Further continuing with FIGS. **20-24**, electrode **25** preferably comprises a connector portion, preferably comprising a shank **46**, which connects the remainder of electrode **25** to the shaft **17**. Among other things, the connector portion of electrode **25** is preferably configured to form a connection with a mating connector portion of the shaft **17**. As shown, preferably the shank portion **46** is configured to extend into cavity **50** of shaft **17** which comprises a cylindrical receptacle and provides the mating connector portion for shank **46**. More preferably, surface **48** of the shank portion **46** is configured to mate against and form an interference fit with surface **52** of cavity **50** to provide the connection.

Continuing with FIGS. **20-24**, shank portion **46** is preferably cylindrical and located proximal and adjacent to a neck portion **56**. As shown, neck portion **56** comprises a cylindrical portion **57** (having a corresponding cylindrical surface portion **58**) and a broadening portion **54** (having a corresponding broadening surface portion **47**). Here broadening portion **54** and corresponding broadening surface portion **47** are both spherical, and more specifically comprise a domed, hemisphere and hemispherical surface portion comprising preferably about **180** degrees, located proximal and adjacent to the cylindrical portion **39** and cylindrical surface portion **40**.

As shown in FIGS. **20-24**, the cylindrical portion **57** of neck portion **56** preferably has a cross-sectional dimension, here diameter, greater than the cross-sectional dimension, here also diameter, of the shank **46**. In this manner, in certain embodiments, the proximal end of the neck portion **56** may be located adjacent and in contact with the distal end **53** of shaft **17**.

Also as shown in FIGS. **20-24**, electrode **25** comprises at least one recess **64** which provides an elongated fluid flow channel for the distribution of fluid **24**. The use of device **5***c*, and in particular recesses **64**, for the distribution of fluid **24** is generally preferred to the fluid exit holes **93**, **94** of device **5***b* in particularly deep tissue crevices **97** where tissue **32** can occlude fluid flow from the fluid exit holes located in the cylindrical portion **39** of electrode **25**.

As shown, electrode **25** preferably comprises a plurality of longitudinally directed recesses **64** and, more specifically, four recesses **64** equally spaced **90** degrees around the shank **46** and/or neck portion **56**, both proximal of cylindrical portion **39**. As best shown in FIG. **24**, in certain embodiments, the recess **64** may comprise a first side wall **64***a*, a second opposing side wall **64***b*, and a bottom wall **64***c*.

In use, when tissue **32** overlies and occludes the fluid outlet opening **55** of recess **64** for a portion of its longitudinal length, thus inhibiting fluid **24** from exiting therefrom, fluid **24** from recess **64** may still be expelled from the electrosurgical device **5***c* after flowing longitudinally in the channel **64** to a remote location where the channel **64** is unoccluded and uninhibited to fluid flow exiting therefrom.

However, in certain instances, it may be possible that the recess **64** may be occluded by tissue **32** completely along its longitudinal length, thus completely inhibiting fluid flow from exiting through opening **55**. In order to overcome this problem, at least a portion of electrode **25** may comprise a material pervious to the passage of fluid **24**, therethrough, such as a porous material described above.

As shown in FIG. **25**, in another embodiment of the electrosurgical device of the present invention, as shown at reference character **5***d* in FIG. **25**, the walls **64***a*, **64***b* of recess **64**, surface **48** of the shank portion **46**, and/or the surfaces of the neck portion **56** of electrode **25** may be porous and connected

by a plurality of tortuous pathways **59** in the porous material. Consequently, rather than flowing out of recess **64** from a direct fluid outlet opening **55**, which may be occluded by tissue **32**, the fluid **24** may exit indirectly from recess **64** by first flowing through tortuous pathways **59** of electrode **25** from side walls **64***a*, **64***b* of the recess **64** and then exit electrode **25** from surface **58**, which may be in unoccluded by tissue **32**. Alternatively, if adjacent surface **58** of electrode **25** is also occluded by tissue **32**, the fluid **24** may continue to flow through tortuous pathways **59** of electrode **25** and exit electrode **25** from a surface **64***a*, **64***b* of a recess **64** or surface such as **40**, **42**, **47** or **58** which may be in unoccluded by tissue **32**.

Where electrode **25** comprises a porous material, recess **64** may be either supplemented with or replaced by the plurality of tortuous, interconnected passages **59** formed in the porous material as shown in FIG. **25**, with porous surfaces such as **40**, **42**, **47** or **58** to more evenly distribute fluid flow and provide conductive fluid **24** to the tissue treatment site. All or a portion of the electrodes can be porous according to the invention.

In other embodiments of the invention, recess **64** may comprise cross-sectional shapes other than rectangular shapes. For example, as shown in FIGS. **26-28** recess **64** comprises a semi-circular shape, a V-shape, or a U-shape respectively, or any combination thereof.

Returning to FIG. **21**, in order to facilitate direct fluid communication of recess **64** with lumen **23** of shaft **17**, preferably recesses **64** of device **5***c* are initiated within the confines of shaft **17**. In other words, within the cavity **50** of shaft **17** proximal to distal end **53**. Preferably the configuration of the recesses **64** as provided by geometry (e.g., width, depth) and/or the material and/or surface treatment of electrode **25** may be arranged such that surface tension will act to retain fluid collected in the recess **64** where the force of gravity is acting to remove the fluid from the recess **64**. However, while it is desirable that a certain predetermined amount of surface tension act to retain fluid collected in the recess **64** in the presence of gravity, the surface tension must be balanced against the inhibition of fluid flow from the recess **64**.

As indicated above, the use of device **5***c*, and in particular recesses **64**, for the distribution of fluid **24** is generally preferred to the fluid exit holes **93**, **94** of device **5***b* in particularly deep tissue crevices **97** where tissue **32** can occlude fluid flow from the fluid exit holes **93**, **94** located in the cylindrical portion **39** of electrode **25**. Also, since holes **93**, **94** are not presented with a declogging mechanism, such as provided for such as fluid exit holes **26** and **85**, holes such as **93**, **94** that can be simply occluded by ordinary tissue/electrode contact will sooner or later become irreversibly clogged.

As shown in FIG. **21**, with device **5***c* fluid outlet openings **73** are provided by the structure of electrode **25** (i.e., recesses **64**) at the distal end **53** of the shaft **17** which are protected and sheltered from contact and occlusion from surface **22** of tissue **32**. Fluid outlet openings **73** of device **5***c* are protected from occlusion from surface **22** of tissue **32** as the structure of device **5***c* defining the openings **26** is at least partially configured for non-contact with surface **22** of tissue **32**. More specifically, here the structure of the device defining the openings **73** is completely configured for non-contact with surface **22** of tissue **32**. Stated another way, the openings **73** are provided on the device **5***c* at a location removed from the tissue surface **22**. Also, as shown, openings **26** are particularly sheltered from occlusion from surface by **22** of tissue **32** by a portion of the shaft **17**. Also as shown, when openings **73** are formed substantially perpendicular to the surface **22** of tissue **32**.

Another tip portion of an exemplary electrosurgical device **5***e* of the present invention which may be used in conjunction with the system of the present invention is shown at reference character **45** in FIGS. **29-32**. As best shown in FIGS. **31** and **32**, the broadening portion **54** has been eliminated and the cylindrical portion **39** has an equal cross-sectional dimension, here diameter, with the neck portion **56**. Conversely, for device **5***c*, the cylindrical portion **39** has a cross-sectional dimension, there also diameter, greater than the cross-sectional dimension, there also diameter, of the neck portion **56**.

Also as shown in FIGS. **31** and **32**, the cylindrical portion **39** further comprises a rectilinear cylindrical portion **39***a* having a rectilinear cylindrical surface portion **40***a* and a curvilinear cylindrical portion **39***b* having a curvilinear cylindrical surface portion **40***b*. As shown, device **5***e* comprises the shape of a hockey stick. The cylindrical portion **39** for device **5***c* may be similarly arranged.

Another tip portion of an exemplary electrosurgical device **5***f* of the present invention which may be used in conjunction with the system of the present invention is shown at reference character **45** in FIGS. **33-36**. As best shown in FIGS. **35** and **36**, the cylindrical portion **39** has a cross-sectional dimension, here diameter, less than the cross-sectional dimension, here also diameter, of the neck portion **56**. As shown the neck portion **56** includes a narrowing portion **49** with a corresponding narrowing surface portion **51**, here both conical.

Also as shown in FIG. **34**, the cylindrical portion **39** further comprises a rectilinear cylindrical portion **39***a* having a rectilinear cylindrical surface portion **40***a* and a curvilinear cylindrical portion **39***b* having a curvilinear cylindrical surface portion **40***b*. Furthermore, as shown, the cylindrical portion **39**, and more specifically at least one of the rectilinear cylindrical portion **39***a* and the curvilinear cylindrical portion **39***b*, comprises a portion of a hook. Preferably, as shown both the rectilinear cylindrical portion **39***a* and the curvilinear cylindrical portion **39***b* comprise portions of a hook. As shown in FIGS. **35** and **36**, the hook further comprises an L-hook.

Another tip portion of an exemplary electrosurgical device **5***g* of the present invention which may be used in conjunction with the system of the present invention is shown at reference character **45** in FIGS. **37-38**. As shown, for device **5***g* the cylindrical portion **39**, and more specifically both the rectilinear cylindrical portion **39***a* and the curvilinear cylindrical portion **39***b* comprise portions of a hook. Also as shown in FIGS. **37** and **38**, the hook further comprises an J-hook.

Another tip portion of an exemplary electrosurgical device **5***h* of the present invention which may be used in conjunction with the system of the present invention is shown at reference character **45** in FIGS. **39-42**. As shown in FIGS. **39** and **40**, electrode **25** preferably comprises a finger portion **65** (preferably comprising cylindrical portion **39** and cylindrical surface portion **40**) having a distal end (preferably comprising a spherical portion **43** and spherical surface portion **42**) which, among other things, is configured for blunt dissection or electrosurgical dissection of tissue **32**. Electrosurgical dissection occurs when tension or force is applied to tissue while also applying RF energy. The RF energy heats the tissue, thereby weakening it, and the tissue yields or breaks where desired. Surgeons may refer to this type of dissection with a hook-type electrode as "hook and cook". Furthermore, finger portion **65** is also preferably configured to function as a hook, particularly the anterior (i.e., front) surface portion **66** of finger portion **65** which is configured, among other things, to engage and restrain tissue **32**.

As shown, finger portion **65** is rectilinear and forms an L-hook with an angle of about 90 degrees relative to the longitudinal axis **31** of the tip portion **45**, particularly shank **45**. However, finger portion may be formed at angles other

than 90 degrees. For example finger portion **65** may be formed at any angle in the range between and including about 60 degrees relative to the tip portion **45** to about 180 degrees relative to the tip portion **45**, or any other range of angles or particular angle inclusive therein (e.g., 75°, 105°, 120°, 135°, 180°, 90°-135°,90°-180°).

Among other things, electrode **25** preferably comprises a knuckle portion **61** comprising a rounded protuberance having a raised prominence on the posterior (back) surface portion **62** of electrode **25**. Also as shown, knuckle portion **61** also comprises a rounded protuberance having a raised prominence on the lateral surface portion **75** of electrode **25**. Among other things, posterior knuckle surface portion **62** and lateral knuckle surface portion **75** formed by knuckle portion **61** are configured for coagulation and stasis (e.g., hemostasis, aerostasis) of tissue **32**.

Key to device **5***g* is the cross-sectional dimension of the knuckle Z to the cross-section dimension of the finger F. When comparing the functions of blunt or electrosurgical dissection and coagulation/hemostasis, the coagulation/hemostasis portion of electrode **25** preferably comprises a greater surface area than the blunt or electrosurgical dissection portion of electrode **25**.

As shown in FIG. **36**, preferably the cross-sectional dimension Z, of the knuckle portion **61** is greater than cross-section dimension F of the finger portion **65**. Here, as shown, the cross-sectional dimensions Z and F comprise diameters. However, in other embodiments where the cross-sectional dimension Z and/or F could not properly be considered to comprise a diameter, the cross-sectional dimension Z and/or F could comprise a width or thickness.

Preferably, the cross-sectional dimension Z of the knuckle portion **61** is in the range between and including about 1.6 to 3.3 times greater than the cross-section dimension F of the finger portion **65**, with typical dimensions comprising the ratios of 2.5 mm to 1.5 mm (1.6 times) and 2.5 mm to 0.75 mm (3.3 times). Even more preferably, the cross-sectional dimension Z of the knuckle portion **61** is in the range between and including about 2 to 2.5 times greater than the cross-section dimension F of the finger portion **65**, with typical dimensions comprising the ratios of 2.5 mm to 1.25 mm (2 times) and 2.5 mm to 1 mm (2.5 times).

From the above dimensions, the ratio of the surface area of the knuckle portion **61** to the surface area of the distal end (e.g., surface **42**) of the finger portion **65** may be determined to an approximation using a formula for half the area of a sphere. For the above dimensions, preferably the surface area of the knuckle portion **61** is in the range between and including about 2.8 times to 11 times greater than the surface area the distal end of the finger portion **65**. More preferably, the surface area of the knuckle portion **61** is in the range between and including about 4 times to 6.2 times greater than the surface area the distal end of the finger portion **65**.

Also as shown in FIGS. **39** and **40**, neck portion **56** preferably comprises a cylindrical portion **57** and a spatula portion **67**. As shown, spatula portion **67** comprises a substantially flat anterior surface portion **69** of electrode **25**. In certain embodiments, electrode **25** may comprise one, any combination of, or all of the features of finger portion **65**, knuckle portion **61** and spatula portion **67**.

Turning to use of the devices, similar to device **5***b*, device **5***c* is particularly useful to a surgeon performing a liver resection. Once the outer capsule of the liver is scored with a dry bovie blade along the planned line of resection the distal tip of tip portion **45** is painted back and forth along the line, with radio frequency power and the flow of fluid **24** on, resulting in coagulation of the liver parenchyma. Once the tissue is coagulated under and around the electrode surface **42** and, as the device **5***c* enters a crevice **97**, surface **40**, surface **42** of electrode **25** is used to blunt dissect the coagulated parenchyma. Blunt dissection of the coagulated parenchyma is performed by continuous abrading or splitting apart of the parenchyma with the substantially the same back and forth motion as coagulation and with the device **5***c* being held substantially in the same orientation as for coagulation of the liver parenchyma. However, with blunt dissection, the surgeon typically applies more force to the tissue. In various embodiments, once the liver parenchyma is coagulated, blunt dissection may be performed with or without the radio frequency power (i.e., on or off) and/or with or without the presence of fluid **24**.

In addition to liver resections, device **5***h* are particularly useful to a surgeon performing a laparoscopic cholecystectomy (abbr. "lap chole") for the case of, for instance, either acute cholecystitis or an intrahepatic gallbladder in that the device provides multi-functional uses. More particularly, device **5***h* is useful to the surgeon for coagulation and dissection of an inflamed serosal layer of tissue **32** between the liver and gallbladder, which may include tough, fibrous, highly vascular connecting tissue between the organs.

For coagulation, device **5***h* may be positioned in at least three different orientations. For the first orientation, as shown in FIG. **43**, coagulation may be performed with posterior knuckle surface portion **62** formed by knuckle portion **61**. Similar to device **5***c*, coagulation with device **5***h* is performed with radio frequency power and the flow of fluid **24** on. Preferably power is applied in the coagulation mode of the generator and at a power level in the range between and including about 10 watts to 60 watts. More preferably, the power level is in the range between and including about 20 watts to 50 watts. Even more preferably, the power level is in the range between and including about 30 watts to 40 watts. With respect to motion of surface portion **62** during coagulation, coagulation may be performed with surface portion **62** stationary, or with a painting motion by moving surface portion **62** back and forth substantially along the longitudinal axis **29** or laterally side to side.

For the second orientation, as shown in FIG. **44**, coagulation may be performed with a combination of lateral knuckle surface portion **75** formed by knuckle portion **61** and cylindrical surface portion **40**, and more specifically a lateral cylindrical surface portion of cylindrical surface portion, of finger portion **65**. For the third orientation, as shown in FIG. **45**, coagulation may be performed also with another combination of knuckle portion **61** and finger portion **65**. As shown in FIG. **45**, coagulation may be performed with a posterior cylindrical surface portion of cylindrical surface portion **40** and a posterior surface of knuckle portion **61**. In the various orientations, coagulation may be used to stop active bleeding (e.g., such as a spleen injury comprising a splenic capsule tear) or pre-coagulation of tissue before dissection for bloodless surgery.

Where the surgeon has pre-coagulated tissue **32**, the surgeon may dissect tissue **32** with simultaneous mechanical traction (i.e., the process of drawing or pulling of tissue **32** with a mechanical device) with anterior (i.e., front) surface portion **66** of finger portion **65** which is configured, among other things, to engage and restrain tissue **32**. More specifically, the surgeon may hook tissue **32** for dissection against the surface portion **66** of finger portion **65** and apply traction to tissue **32**, then dissect tissue **32**.

Since tissue **32** has been coagulated, dissection may be performed with or without the radio frequency power (i.e., on or off) and/or with or without the presence of fluid **24**. Where tissue **32** is dissected without fluid **24**, but with the radio frequency power on and with the generator set to the coagu-

lation mode, the process of dissecting may be referred to as "hook and cook" in the art. While dissecting in this manner is fast, it suffers from the problems of significant arcing, the production of smoke and char, and the possibility of inadvertent perforation of the gall bladder wall. Alternatively, dissecting without the radio frequency power on may eliminate the problems of arcing, the production of smoke and char, and the possibility of inadvertent perforation, but may result in bleeding if tissue **32** is not sufficiently coagulated. In order to overcome the aforementioned issues, dissection of tissue **32** with traction may be performed similar to coagulation (i.e., in the presence of both radio frequency power and fluid **24**). However, this alternative typically requires more time than "hook and cook".

With regards to the sequence of events for dissect tissue **32** with traction and using the "hook and cook" technique (i.e., without fluid **24**), the surgeon first engages tissue **32** on the surface portion **66** of finger portion **65**. The surgeon then applies traction to the engaged tissue **32**. Once complete, the surgeon checks for proper position then applies the radio frequency power. Upon application of the radio frequency power, tissue **32** yields, separates and breaks. The surgeon then turns the radio frequency power off. This process may then be repeated numerous times as the surgeon incrementally dissects tissue **32** along a length in step-wise fashion.

Certain embodiments of the invention may be particularly configured for bipolar devices. For example, an exemplary bipolar electrosurgical device of the present invention which may be used in conjunction with the system of the present invention is shown at reference character **5***i* in FIGS. **46-48**. With a bipolar device, the ground pad electrode located on the patient is eliminated and replaced with a second electrical pole as part of the device. An alternating current electrical circuit is then created between the first and second electrical poles of the device. Consequently, alternating current no longer flows through the patient's body to the ground pad electrode, but rather through a localized portion of tissue preferably between the poles of the bipolar device.

In certain embodiments, an exemplary bipolar surgical device of the present invention may comprise, among other things, multiple, substantially parallel, arms. As shown in FIG. **46**, electrosurgical device **5***i* preferably includes two arms comprising rigid, self-supporting, hollow shafts **17***a*, **17***b*, a proximal handle comprising mating handle portions **20***a*, **20***b* and arm tip portions as shown by circles **45***a*, **45***b*. In this embodiment, shafts **17***a*, **17***b* preferably comprise thick walled hypo-tubing. In this manner, the shafts **17***a*, **17***b* have sufficient rigidity to maintain their form during use of the device without kinking or significant bending.

Preferably the arms of device **5***i* (comprising shafts **17***a*, **17***b*) are retained in position relative to each other by a mechanical coupling device comprising a collar **95** and inhibited from separating relative to each other. Collar **95** preferably comprises a polymer (e.g., acrylonitrile-butadiene-styrene or polycarbonate) and is preferably located on the distal portion of the arms. More preferably, the collar **95** is located proximal the distal ends **53***a*, **53***b* of the shafts **17***a*, **17***b*. Preferably the collar **95** comprises two apertures **96***a*, **96***b*, preferably comprising opposing C-shapes, configured to receive a portion of the shafts **17***a*, **17***b* which are preferably snap-fit therein. Once the collar **95** is connected to the shafts **17***a*, **17***b*, preferably by a snap-fit connection, the collar **95** may be configured to slide along the length of the shafts **17***a*, **17***b* as to adjust or vary the location of the collar **95** on the shafts **17***a*, **17***b*. Alternatively, the location of the collar **95** may be fixed relative to the shafts **17***a*, **17***b* by welding, for example.

Device **5***i* comprises a first arm tip portion **45***a* and a second arm tip portion **45***b*. As shown, preferably both first arm tip portion **45***a* and second arm tip portion **45***b* are each individually configured identical to tip portion **45** of device **5***a*. As a result, device **5***i* has two separate, spatially separated (by empty space) contact elements preferably comprising electrodes **25***a*, **25***b*.

As shown in FIG. **47**, when device **5***i* is in use electrodes **25***a*, **25***b* are laterally spaced adjacent tissue surface **22** of tissue **32**. Electrodes **25***a*, **25***b* are connected to a source of alternating electrical current and alternating current electrical field is created between electrodes **25***a* and **25***b*. In the presence of alternating current, the electrodes alternate polarity between positive and negative charges with current flow from the positive to negative charge.

Similar to device **5***a*, for device **5***i* fluid **24** is communicated from a fluid source **1** within the lumens **23***a*, **23***b* of the shafts **17***a*, **17***b* through the lumens **89***a*, **89***b* and cavities **81***a*, **81***b* of the sleeves **82***a*, **82***b* where it is expelled from around and on the surface **42***a*, **42***b* of the electrodes **25***a*, **25***b*.

As with use of device **5***a*, with use of device **5***i* fluid couplings **30***a*, **30***b* preferably comprising discrete, localized webs and more preferably comprising a triangular shaped web or bead portion providing a film of fluid **24** is provided between surface **22** of tissue **32** and electrodes **25***a*, **25***a*. When the user of electrosurgical device **5***i* places electrodes **25***a*, **25***b* at a tissue treatment site and moves electrodes **25***a*, **25***b* across surface **22** of tissue **32**, fluid **24** is expelled around and on surfaces **42***a*, **42***b* of electrodes **25***a*, **25***b* at the distal ends **83***a*, **83***b* of sleeves **82***a*, **82***b* and onto surface **22** of tissue **32** via couplings **30***a*, **30***b*. At the same time, RF electrical energy, shown by electrical field lines **130**, is provided to tissue **32** at tissue surface **22** and below tissue surface **22** into tissue **32** through fluid couplings **25***a*, **25***b*.

As with device **5***a*, the fluid **24**, in addition to providing an electrical coupling between the electrosurgical device **5***i* and tissue **32**, lubricates surface **22** of tissue **32** and facilitates the movement of electrodes **25***a*, **25***b* across surface **22** of tissue **32**. During movement of electrodes **25***a*, **25***b*, electrodes **25***a*, **25***b* typically slide across the surface **22** of tissue **32**, but also may rotate as electrodes **25***a*, **25***b* move across surface **22** of the tissue **32**. Typically the user of electrosurgical device **5***i* slides electrodes **25***a*, **25***b* across surface **22** of tissue **32** back and forth with a painting motion while using fluid **24** as, among other things, a lubricating coating. Preferably the thickness of the fluid **24** between the distal end surface of electrodes **25***a*, **25***b* and surface **22** of tissue **32** at the outer edge of couplings **30***a*, **30***b* is in the range between and including about 0.05 mm to 1.5 mm. More preferably, fluid **24** between the distal end surface of electrodes **25***a*, **25***b* and surface **22** of tissue **32** at the outer edge of coupling **30***a*, **30***b* is in the range between and including about 0.1 mm to 0.3 mm. Also preferably, in certain embodiments, the distal end tip of electrode **25** contacts surface **22** of tissue **32** without any fluid **24** in between.

As shown in FIG. **48**, the fluid coupling for device **5***i* may comprise a conductive fluid bridge **27** between electrodes **25***a*, **25***b* which rests on surface **22** of tissue **32** and forms a shunt between electrodes **25***a*, **25***b*. Given this scenario, a certain amount of RF energy may be diverted from going into tissue **32** and actually pass between electrodes **25***a*, **25***b* via the conductive fluid bridge **27**. This loss of RF energy may slow down the process of coagulating tissue and producing the desired hemostasis or aerostasis of the tissue.

In order to counteract the loss of energy through bridge **27**, once enough energy has entered bridge **27** to boil fluid **24** of bridge **27**, the loss of RF energy correspondingly decreases

with the loss of bridge **27**. Preferably energy is provided into fluid **24** of bridge **27** by means of heat dissipating from tissue **32**.

Thus, where a high % boiling of conductive fluid **24** of bridge **24** is created, the loss of RF energy through bridge **27** may either be reduced or eliminated because all the fluid **24** of bridge **27** boils off or a large fraction of boiling creates enough disruption in the continuity of bridge **27** to disrupt the electrical circuit through bridge **27**. Thus, one control strategy of the present invention is to reduce the presence of a conductive fluid shunt by increasing the % boiling of the conductive fluid.

Another embodiment of a bipolar device is shown at **5***j* in FIGS. **49** and **50**. Similar to device **5***i*, electrosurgical device **5***j* preferably includes two arms comprising rigid, self-supporting, shafts **17***a*, **17***b*, a proximal handle comprising mating handle portions **20***a*, **20***b* and first and second arm tip portions as shown by circles **45***a*, **45***b*. However, as shown in FIG. **50**, unlike device **5***i*, for device **5***j* shafts **17***a*, **17***b* may comprise solid rods (i.e., do not have lumens) which provide for electrical connection to a power source but do not have lumens for providing conductive fluid through sleeves **82***a*, **82***b*. Rather conductive fluid **24** is preferably provided by means of a lumen **122** of a separate fluid line **120**, preferably comprising either a metal (e.g., stainless steel hypo-tubing) or polymer (e.g., PVC tubing) material, extending distally and substantially parallel to the arms along side shafts **17***a*, **17***b*. In order to minimize the risk of clogging of the lumen **122** at the distal end outlet opening **124** of the fluid line **120**, as shown, preferably the distal end **126** of the fluid line **120** is located proximal to the distal end of the device **5***j* and more preferably, proximal to spherical surface portions **42***a*, **42***b* of electrodes **25***a*, **25***b*, or other tissue treating surfaces of electrodes as the electrode configurations vary.

Also as shown for device **5***j*, outlet opening **124** for fluid line **120** is preferably spaced uniformly between electrodes **25***a*, **25***b* such that conductive fluid **24** expelled from outlet opening **124** may form a fluid coupling comprising bridge **27** between tissue surface **22** surface **42***a*, **42***b* of each of electrodes **25***a*, **25***b*. If a collar **95** is used with device **5***j* preferably the collar contains a third C-shaped aperture to accommodate fluid line **120** there through.

In certain embodiments, at least a portion of the length of the two arms (comprising shafts **17***a*, **17***b* and sleeves **82***a*, **82***b*) or the two arms and fluid line **120** of device **5***j* may be located and housed within the cavity **132**, typically a lumen, of an elongated hollow tubular enclosure **128** as shown in FIG. **49**. The elongated tubular enclosure **128** may or may not be connected to the handle portions **20***a*, **20***b*. Where the tubular enclosure is not connected to the handle portions **20***a*, **20***b*, similar to collar **95**, tubular enclosure **128** may be configured to slide along the length of shafts **17***b*, **17***c* as to adjust or vary the location of enclosure **128** on shafts **17***a*, **17***b* or, alternatively, may be fixed relative to shafts **17***a*, **17***b* by welding, for example.

The elongated tubular enclosure **128** may comprise, for example a wrapping, such as shrink wrap polymer film or shrink wrap polymer tubing, which may be formed and located with the surface of cavity **132** against insulators **90***a*, **90***b* upon the application of heat thereto. In this manner, elongated members shafts **17***a*, **17***b* or shafts **17***a*, **17***b* and fluid line **120**, are retained in position relative to each other and inhibited from separating relative to each other.

Another embodiment of a bipolar device is shown at **5***k* in FIGS. **51-53**. As shown in FIGS. **51** and **53**, electrosurgical device **5***k* preferably includes a housing comprising mating handle portions **20***a*, **20***b* and mating elongated shaft portions **134***a*, **134***b* forming a hollow shaft. As best shown in FIG. **51**, shaft portions **134***a*, **134***b*, preferably comprise two semi-circular elongated portions which are connected to handle portions **20***a*, **20***b*, respectively, preferably as part of a unitary (i.e., single piece) polymer molding.

As best shown in FIG. **53**, electrodes **25***a*, **25***b* are preferably assembled directly with shaft portions **134***a*, **134***b* adjacent the distal end of shaft portions **134***a*, **134***b*. As shown, preferably electrodes **25***a*, **25***b* are mechanically assembled adjacent the distal end of shaft portions **134***a*, **134***b* via a spool configuration. More specifically, preferably electrodes **25***a*, **25***b* comprise locking portions comprising proximal circular flange portions **136***a*, **136***b* and distal circular flange portions **138***a*, **138***b* separated and connected by circular spindles **140***a*, **140***b* there between which form the respective spool configurations.

The circular recesses **142***a*, **142***b* formed between the proximal circular flange portions **136***a*, **136***b* and distal circular flange portions **138***a*, **138***b* provides a receptacle for receiving semi-circular interlocking tab portions **144***a*, **144***b* of distal end portions **146***a*, **146***b* of shaft portions **134***a*, **134***b*.

During assembly, the interlocking tab portions of one of the shaft portions are first located in a portion of recesses **142***a*, **142***b* of electrodes **25***a*, **25***b*. In other words, for example, electrodes **25***a*, **25***b* may be first assembled with semi-circular interlocking tab portions **144***a* of distal end portion **146***a* of shaft portion **134***a* which then occupy a first semi-circular portion of circular recesses **142***a*, **142***b*. Then, once electrodes **25***a*, **25***b* have been properly seated with respect to the first shaft portion, here **134***a*, the interlocking tab portions of the second shaft portion, here **144***b* of shaft **134***b*, are located in the remaining semi-circular portion of circular recesses **142***a*, **142***b*. After electrodes **25***a*, **25***b* have been properly seated with respect to both shaft portions **134***a*, **134***b* and all remaining components are properly located, shaft portions **134***a*, **134***b* and handle portions **20***a*, **20***b* may be assembled to one another by use of, for example an adhesive (e.g., cyanoacrylate) or welding.

As best shown in FIG. **53**, electrodes **25***a*, **25***b* of device **5***k* preferably comprise spherical portions **43***a*, **43***b* and a corresponding spherical surface portions **42***a*, **42***b* located at the distal end of the device which provided a smooth, blunt contour outer surface. More specifically, as shown, spherical portions **43***a*, **43***b* and spherical surface portion **42***a*, **42***b* further provide a domed, hemisphere (i.e., less than a full sphere) and hemispherical surface portion comprising preferably about 180 degrees. Also as shown in FIG. **53**, electrodes **25***a*, **25***b* preferably also comprise cylindrical portions **39***a*, **39***b* and a corresponding cylindrical surface portions **40***a*, **40***b* located proximal and adjacent to the spherical portions **43***a*, **43***b* and spherical surface portions **42***a*, **42***b*, respectively.

Electrodes **25***a*, **25***b* of device **5***k* are preferably coupled to generator **6** via wire conductors **38***a*, **38***b* of insulated wires **21***a*, **21***b*. At their distal ends, conductors **38***a*, **38***b* may be coupled to electrodes **25***a*, **25***b* by means of first being inserted into the lumens **148***a*, **148***b* of hollow metal tubes **150***a*, **150***b*, such as hypo-tubes, then crimping tubes **150***a*, **150***b*. Tubes **150***a*, **150***b* are then preferably inserted and retained in proximal end receptacles **152***a*, **152***b* of electrodes **25***a*, **25***b* by an interference fit. Alternatively, tubes **150***a*, **150***b* may be eliminated and wire conductors **38***a*, **38***b* may be coupled to electrodes **25***a*, **25***b* by welding.

For device **5***k*, conductive fluid **24** is preferably provided by means of a lumen **122** of a separate fluid line **120**, preferably comprising either a metal (e.g., stainless steel hypo-tubing) or

polymer (e.g., PVC tubing) material, extending distally and substantially parallel within the lumen of the shaft comprising shaft portions **134***a*, **134***b*.

Similar to device **5***j*, in order to minimize the risk of clogging lumen **122** at the distal end outlet opening **124** of fluid line **120**, as shown, preferably distal end **126** of fluid line **120** is located proximal to the distal end of device **5***k* and more preferably, proximal to spherical surface portions **42***a*, **42***b* and cylindrical surface portions **40***a*, **40***b* of electrodes **25***a*, **25***b*, or other tissue treating surfaces of electrodes as the electrode configurations vary.

Also similar to device **5***j*, for device **5***k* the outlet opening **124** for fluid line **120** is preferably spaced uniformly between electrodes **25***a*, **25***b* such that conductive fluid **24** expelled from outlet opening **124** may form a fluid coupling comprising bridge **27** between tissue surface **22** and surface **42***a*, **42***b* of each of electrodes **25***a*, **25***b*.

The effect of the bipolar devices of the present invention on tissue may be varied by changing the separation distance between the contact elements. Consequently, as shown in FIG. **54**, bipolar device **5***l* provides an adjustment mechanism for changing the separation distance (either increasing or decreasing) between electrodes **25***a*, **25***b*. As shown in FIG. **54**, the changing of the separation distance between electrodes **25***a*, **25***b* is provided by a scissors type adjustment mechanism with two arms **117***a*, **117***b* hinged relative to one another in the middle on a pivot **110** preferably comprising a pin. Device **5***l* may also comprise a latching mechanism **111** which fixes the position of electrodes **25***a*, **25***b* relative to one another during tissue treatment.

Furthermore, as shown, arms **117***a*, **117***b* themselves are preferably hinged or pivotal around pivots **110***a* and **110***b*, which preferably comprising pins, which divide arms **117***a*, **117***b* into proximal arm portions **118***a*, **118***b* and distal arm portions **112***a*, **112***b*. Distal arm portions **112***a*, **112***b* are preferably connected by a linkage **113** which keeps distal arm portions **112***a*, **112***b* substantially parallel to one another with use of the device **5***l*. As shown, linkage **113** comprises a bar **114** fixed to distal arm portion **112***b* and having an elongated opening **116** therein. Linkage also comprises a pin **115** fixed to distal arm portion **112***a* which moves along and within the opening **116** during use of the device **5***l* with the changing of the separation distance between electrodes **25***a*, **25***b*. For device **5***l*, tip portions **45***a*, **45***b* may particularly comprise the configuration disclosed with device **5***i*.

Bipolar devices **5***i*-**5***l* are particularly useful as non-coaptive tissue coagulators given they do not grasp tissue. Devices **5***i*-**5***l* are particularly useful to surgeons to achieve hemostasis after dissecting through soft tissue as part of hip or knee arthroplasty. The tip portions **45***a*, **45***b* can be painted over the raw, oozing surface **22** of tissue **32** to seal tissue **32** against bleeding, or focused on individual larger bleeding vessels to stop vessel bleeding. The devices **5***i*-**5***l* are also useful to stop bleeding from the surface of cut bone tissue as part of any orthopedic procedure that requires bone to be cut. Bipolar devices **5***i*-**5***l* are particularly useful for these applications over a monopolar device **5***a* as a much greater surface area **22** of tissue **32** may be treated in an equivalent period of time and with better controlled depth of the treatment.

One or more of the features of the previously described system can be built into a custom RF generator. This embodiment can provide one or more advantages. For example, this type of system can save space and reduce overall complexity for the user. This system can also enable the manufacturer to increase the power delivered into low impedance loads, thereby further reducing the time to achieve the desired tissue effects. This changes the curve of FIG. **5**, by eliminating or reducing the slope of the low impedance ramp **28***a* of power versus impedance.

To effectively treat thick tissues, it can be advantageous to have the ability to pulse the RF power on and off. Under some circumstances, the temperature deep in tissue can rise quickly past the 100° C. desiccation point even though the electrode/tissue interface is boiling at 100° C. This manifests itself as "popping," as steam generated deep in the tissue boils too fast and erupts toward the surface. In one embodiment of the invention, a switch is provided on the control device or custom generator to allow the user to select a "pulse" mode of the RF power. Preferably, the RF power system in this embodiment is further controlled by software.

It may be desirable to control the temperature of the conductive fluid before its release from the electrosurgical device. In one embodiment, a heat exchanger is provided for the outgoing saline flow to either heat or chill the saline. The heat exchanger may be provided as part of the electrosurgical device or as part of another part of the system, such as within enclosure **14**. Pre-heating the saline to a predetermined level below boiling reduces the transient warm-up time of the device as RF is initially turned on, thereby reducing the time to cause coagulation of tissue. Alternatively, pre-chilling the saline is useful when the surgeon desires to protect certain tissues at the electrode/tissue interface and treat only deeper tissue. One exemplary application of this embodiment is the treatment of varicose veins, where it is desirable to avoid thermal damage to the surface of the skin. At the same time, treatment is provided to shrink underlying blood vessels using thermal coagulation. The temperature of the conductive fluid prior to release from the surgical device can therefore be controlled, to provide the desired treatment effect.

In another embodiment, the flow rate controller is modified to provide for a saline flow rate that results in greater than 100% boiling at the tissue treatment site. For example, selection switch **12** of flow rate controller **11** (shown in FIG. **1**) can include settings that correspond to 110%, 120% and greater percentages of boiling. These higher settings can be of value to a surgeon in such situations as when encountering thick tissue, wherein the thickness of the tissue can increase conduction away from the electrode jaws. Since the basic control strategy neglects heat conduction, setting for 100% boiling can result in 80% of 90% boiling, depending upon the amount of conduction. Given the teachings herein, the switch of the flow rate controller can accommodate any desirable flow rate settings, to achieve the desired saline boiling at the tissue treatment site.

Some embodiments of the invention can provide one or more advantages over current electrosurgical techniques and devices. For example, the invention preferably achieves the desired tissue effect (for example, coagulation, cutting, and the like) in a fast manner. In a preferred embodiment, by actively controlling the flow rate of saline, both in quantity (Q vs. P) and location (for example, using gutters to direct fluid distally to tissue, using holes to direct flow of fluid, or other similar methods) the electrosurgical device can create a hot non-desiccating electrode/tissue interface and thus a fast thermally induced tissue coagulation effect.

The use of the disclosed devices can result in significantly lower blood loss during surgical procedures such as liver resections. Typical blood loss for a right hepatectomy can be in the range of 500-1,000 cubic centimeters. Use of the devices disclosed herein to perform pre-transection coagulation of the liver can result in blood loss in the range of 50-300 cubic centimeters. Such a reduction in blood loss can reduce or eliminate the need for blood transfusions, and thus the cost

and negative clinical consequences associated with blood transfusions, such as prolonged hospitalization and a greater likelihood of cancer recurrence. Use of the device can also provide improved sealing of bile ducts, and reduce the incidence of post-operative bile leakage, which is considered a major surgical complication.

The invention can, in some embodiments, deliver fast treatment of tissue without using a temperature sensor built into the device or a custom special-purpose generator. In a preferred embodiment, there is no built-in temperature sensor or other type of tissue sensor, nor is there any custom generator. Preferably, the invention provides a means for controlling the flow rate to the device such that the device and flow rate controller can be used with a wide variety of general-purpose generators. Any general-purpose generator is useable in connection with the fluid delivery system and flow rate controller to provide the desired power; the flow rate controller will accept the power and constantly adjust the saline flow rate according to the control strategy. Preferably, the generator is not actively controlled by the invention, so that standard generators are useable according to the invention. Preferably, there is no active feedback from the device and the control of the saline flow rate is "open loop." Thus, in this embodiment, the control of saline flow rate is not dependent on feedback, but rather the measurement of the RF power going out to the device.

For purposes of the appended claims, the term "tissue" includes, but is not limited to, organs (e.g., liver, lung, spleen, gallbladder), highly vascular tissues (e.g., liver, spleen), soft and hard tissues (e.g., adipose, areolar, bone, bronchus-associated lymphoid, cancellous, chondroid, chordal, chromaffin, cicatricial, connective, elastic, embryonic, endothelial, epithelial, erectile, fatty, fibrous, gelatiginous, glandular, granulation, homologous, indifferent, interstitial, lymphadenoid, lymphoid, mesenchymal, mucosa-associated lymphoid, mucous, muscular, myeloid, nerve, osseous, reticular, scar, sclerous, skeletal, splenic, subcutaneous) and tissue masses (e.g., tumors).

While a preferred embodiment of the present invention has been described, it should be understood that various changes, adaptations and modifications can be made therein without departing from the spirit of the invention and the scope of the appended claims. The scope of the invention should, therefore, be determined not with reference to the above description, but instead should be determined with reference to the appended claims along with their full scope of equivalents. Furthermore, it should be understood that the appended claims do not necessarily comprise the broadest scope of the invention which the Applicant is entitled to claim, or the only manner(s) in which the invention may be claimed, or that all recited features are necessary.

All publications and patent documents cited in this application are incorporated by reference in their entirety for all purposes.

We claim:

**1**. A surgical method for treating tissue comprising:
providing tissue having a tissue surface;
providing radio frequency power and an electrically conductive fluid to an electrosurgical device having a tip portion which simultaneously provides the radio frequency power and the electrically conductive fluid to a tissue treatment site, the tip portion comprising at least one fluid outlet opening and a non-porous blunt distal end provided by an exposed electrode;
providing an electrically conductive fluid from the electrosurgical device at a fluid flow rate;
forming a localized fluid coupling with the electrically conductive fluid which couples the tissue surface and the electrode, the fluid coupling localized at the tip portion of the electrosurgical device;
providing the radiofrequency power to the tissue;
moving the tip portion of the electrosurgical device along the tissue;
coagulating the tissue with the electrosurgical device without cutting the tissue; and
blunt dissecting the tissue with the tip portion of electrosurgical device after coagulating the tissue.

**2**. The method according to claim **1** wherein:
the tissue comprises parenchymal tissue.

**3**. The method according to claim **1** wherein:
the tissue comprises collagen.

**4**. The method according to claim **1** wherein:
the tissue comprises organ tissue.

**5**. The method according to claim **1** wherein:
the electrically conductive fluid comprises saline solution.

**6**. The method according to claim **1** wherein:
the exposed electrode comprises a domed portion.

**7**. The method according to claim **6** wherein:
the at least one fluid outlet opening is located proximal to the domed portion of the exposed electrode.

**8**. The method according to claim **6** wherein:
the exposed electrode further comprises a cylindrical portion proximal to the domed portion.

**9**. The method according to claim **8** wherein:
the at least one fluid outlet opening is arranged to provide fluid to the cylindrical portion of the exposed electrode.

**10**. The method according to claim **1** wherein:
the at least one fluid outlet opening is at least partially defined by the exposed electrode.

**11**. The method according to claim **1** further comprising:
a fluid passage in fluid communication with the at least one fluid outlet opening.

**12**. A surgical method comprising:
providing tissue;
providing an electrically conductive fluid and radiofrequency power to an electrosurgical device having a tip portion to treat the tissue, the tip portion comprising a sintered metal electrode;
placing the electrode on the tissue;
providing the electrically conductive fluid and the radiofrequency power simultaneously from the device to treat the tissue; and
blunt dissecting the tissue with the electrosurgical device.

**13**. The method of claim **12** wherein:
blunt dissecting the tissue is performed during a resection procedure.

**14**. The method of claim **13** wherein:
the resection procedure is to remove a portion of tissue, the portion of tissue removed comprising a tumor.

**15**. The method of claim **12** further comprising:
forming a localized fluid coupling with the electrically conductive fluid which couples the tissue and the electrode,
the fluid coupling localized at the tip portion of the device.

**16**. The method of claim **12** further comprising:
moving the electrode along the tissue.

**17**. The method of claim **12** further comprising:
moving the electrode along a line of resection.

**18**. The method of claim **12** further comprising:
treating the tissue along a line of resection.

**19**. The method of claim **12** further comprising:
treating the tissue within a crevice.

20. The method of claim 12 further comprising:
treating the tissue sufficiently to provide coagulation.
21. The method of claim 20 wherein:
blunt dissecting the tissue is performed at the same time as coagulation.
22. The method of claim 20 wherein:
blunt dissecting the tissue is performed after coagulation.
23. The method of claim 12 wherein:
the tissue comprises a blood vessel.
24. The method of claim 23 further comprising:
identifying the blood vessel in the tissue from blunt dissecting.
25. The method of claim 24 further comprising:
treating the tissue sufficiently to shrink the blood vessel.
26. The method of claim 12 wherein:
the tissue comprises collagen.
27. The method of claim 26 further comprising:
treating the tissue sufficiently to shrink the collagen.
28. The method of claim 12 further comprising:
removing a portion of tissue, the portion of tissue removed comprising a tumor.
29. The method of claim 12 wherein:
the tissue comprises organ tissue.
30. The method of claim 12 wherein:
the tissue comprises parenchymal tissue.
31. The method of claim 12 wherein:
the tissue comprises liver tissue.
32. The method of claim 12 wherein:
the tissue comprises at least one of lung, pancreas and kidney tissue.
33. The method of claim 12 wherein:
the electrically conductive fluid comprises saline.
34. The method of claim 32 wherein:
the saline is normal saline.
35. The method of claim 12 wherein:
the electrically conductive fluid comprises an electrolyte solution.
36. The method of claim 32 wherein:
the electrically conductive fluid is provided from a fluid source, the fluid source comprising a bag of saline.
37. The method of claim 12 wherein:
the electrosurgical device comprises:
a handle;
a rigid shaft extending distally beyond the handle, the shaft having a distal end;
the electrode extends distally beyond the distal end of the shaft,
a fluid delivery lumen; and
the electrode in fluid communication with the fluid delivery lumen.
38. The method of claim 12 wherein:
the sintered metal electrode is porous.
39. The method of claim 38 wherein:
the porous sintered metal electrode comprises a plurality of pores.
40. The method of claim 39 wherein:
the pores have a pore size in a range of 2.5 micrometers to 500 micrometers.
41. The method of claim 39 wherein:
the pores have a pore size in a range of 10 micrometers to 120 micrometers.
42. The method of claim 39 wherein:
the pores have a pore size and a range of 20 micrometers to 80 micrometers.
43. The method of claim 12 wherein:
the sintered metal electrode is pervious to the passage of the fluid.
44. The method of claim 12 wherein:
the sintered metal electrode at least partially defines a fluid outlet.
45. The method of claim 12 wherein:
the electrosurgical device has fluid flow adjustment mechanism.
46. The method of claim 12 wherein:
the electrosurgical device has a switch to activate the radiofrequency power.
47. The method of claim 12 wherein:
the electrosurgical device is a monopolar device.
48. The method of claim 12 wherein:
the electrosurgical device is a laparoscopic surgery device.
49. The method of claim 12 wherein:
the electrosurgical device is an open surgery device.
50. A surgical method comprising:
providing tissue;
providing an electrically conductive fluid and radiofrequency power to an electrosurgical device having a tip portion to treat the tissue, the tip portion comprising a metal electrode wherein the metal electrode comprises a porous structure and bonded metal particles;
placing the electrode on the tissue;
providing the electrically conductive fluid in the radiofrequency power simultaneously from the device to treat the tissue;
blunt dissecting the tissue with the electrosurgical device.

* * * * *

| | | | |
|---|---|---|---|
| 专利名称(译) | 流体辅助医疗设备，系统和方法 | | |
| 公开(公告)号 | US8568409 | 公开(公告)日 | 2013-10-29 |
| 申请号 | US11/931312 | 申请日 | 2007-10-31 |
| [标]申请(专利权)人(译) | TISSUELINK医疗 | | |
| 申请(专利权)人(译) | TISSUELINK MEDICAL，INC. | | |
| 当前申请(专利权)人(译) | 美敦力公司ADVANCED ENERGY LLC | | |
| [标]发明人 | OBRIEN SCOTT D<br>MCCLURKEN MICHAEL F<br>LUZZI ROBERT | | |
| 发明人 | O'BRIEN, SCOTT D.<br>MCCLURKEN, MICHAEL F.<br>LUZZI, ROBERT | | |
| IPC分类号 | A61B18/12 A61B A61B18/00 A61B18/04 A61B18/14 | | |
| CPC分类号 | A61B18/14 A61B18/1442 A61B18/1445 A61B18/1482 A61B2018/00029 A61B2018/00065 A61B2018/00404 A61B2018/00601 A61B2018/0063 A61B2018/00702 A61B2018/00791 A61B2018/00809 A61B2018/00875 A61B2018/1417 A61B2018/1422 A61B2018/1861 A61B2218/002 | | |
| 优先权 | 10/365170 2003-02-11 US<br>09/947658 2001-09-05 US<br>60/356390 2002-02-12 US<br>60/187114 2000-03-06 US<br>60/368177 2002-03-27 US<br>09/797049 2001-03-01 US | | |
| 其他公开文献 | US20080058796A1 | | |
| 外部链接 | USPTO | | |


摘要(译)

提供了用于治疗组织的手术装置。还提供了用于治疗组织的系统和治疗组织的方法。示例性外科手术装置具有手柄，可连接到流体源的流体通道，尖端部分和远端。尖端部分可以同时向组织提供RF功率和导电流体。尖端部分包括电极，该电极具有带圆顶表面的圆顶部分和具有圆柱表面的圆柱形部分。圆顶部分位于圆柱形部分的远侧，并占据手术装置的远端的至少一部分。该装置包括与流体通道流体连通的流体出口开口，该流体出口开口构造成将导电流体提供到靠近手术装置的远端表面的电极的表面。