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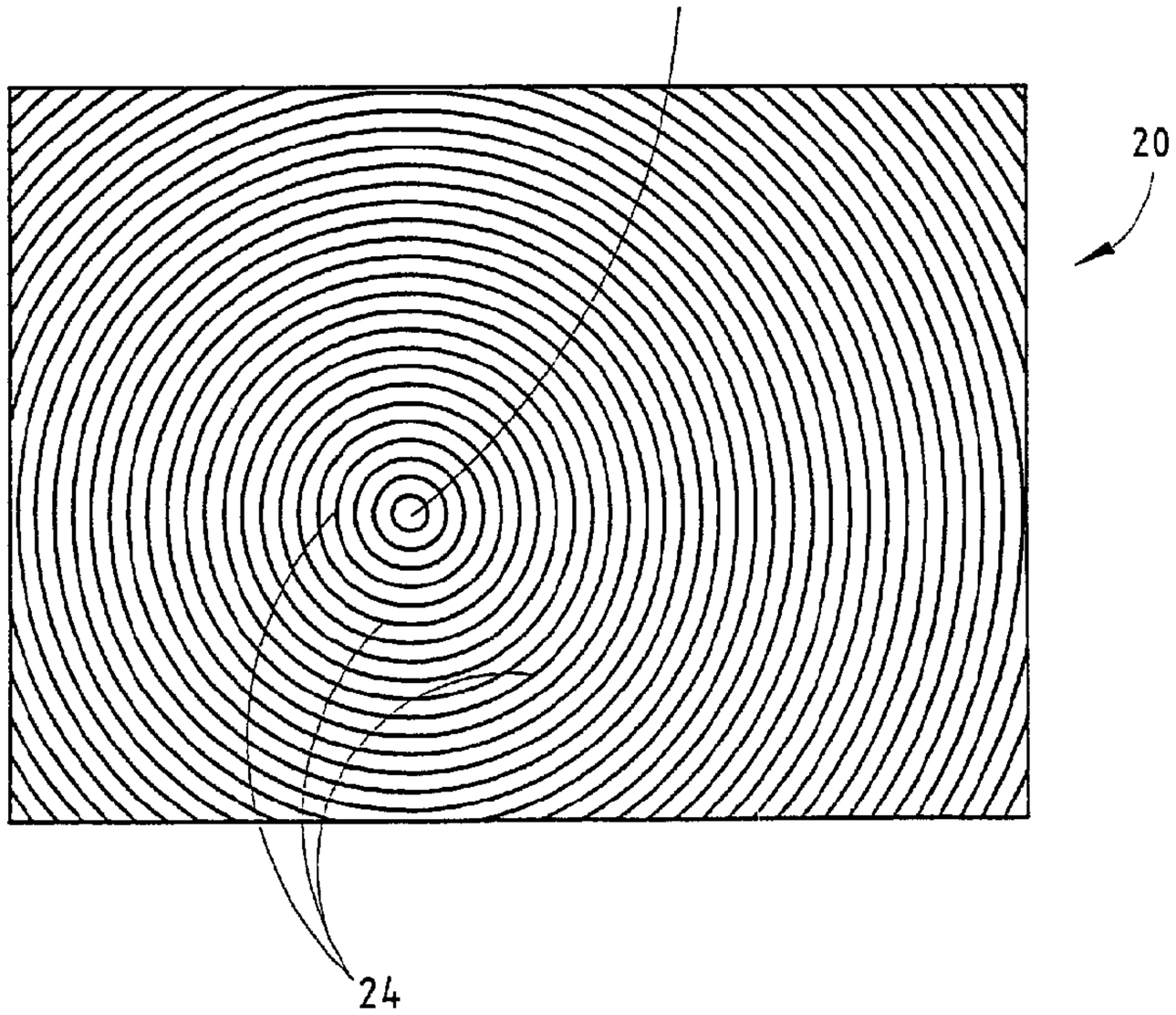
(54) Titre : FIBRE OPTIQUE ET PROCEDE DE FABRICATION DE FIBRE OPTIQUE A FAIBLE DISPERSION DE MODE-POLARISATION ET A FAIBLE ATTENUATION

(54) Title: AN OPTICAL FIBER AND A METHOD FOR FABRICATING A LOW POLARIZATION-MODE DISPERSION AND LOW ATTENUATION OPTICAL FIBER



(57) Abrégé/Abstract:
A method of fabricating an optical waveguide fiber that includes the steps of providing a cylindrical glass optical fiber preform having a longitudinally extending centerline hole, and closing the hole under conditions suitable to result in uniform and symmetric hole closure. The method may include first plugging a first end and a second end of the centerline hole to prevent gas flow therethrough. The method preferably involves closing the centerline hole of the preform by drawing the preform down into an optical waveguide fiber. An optical fiber produced by the method has a polarization mode dispersion (PMD) of <0.2 ps km-2.

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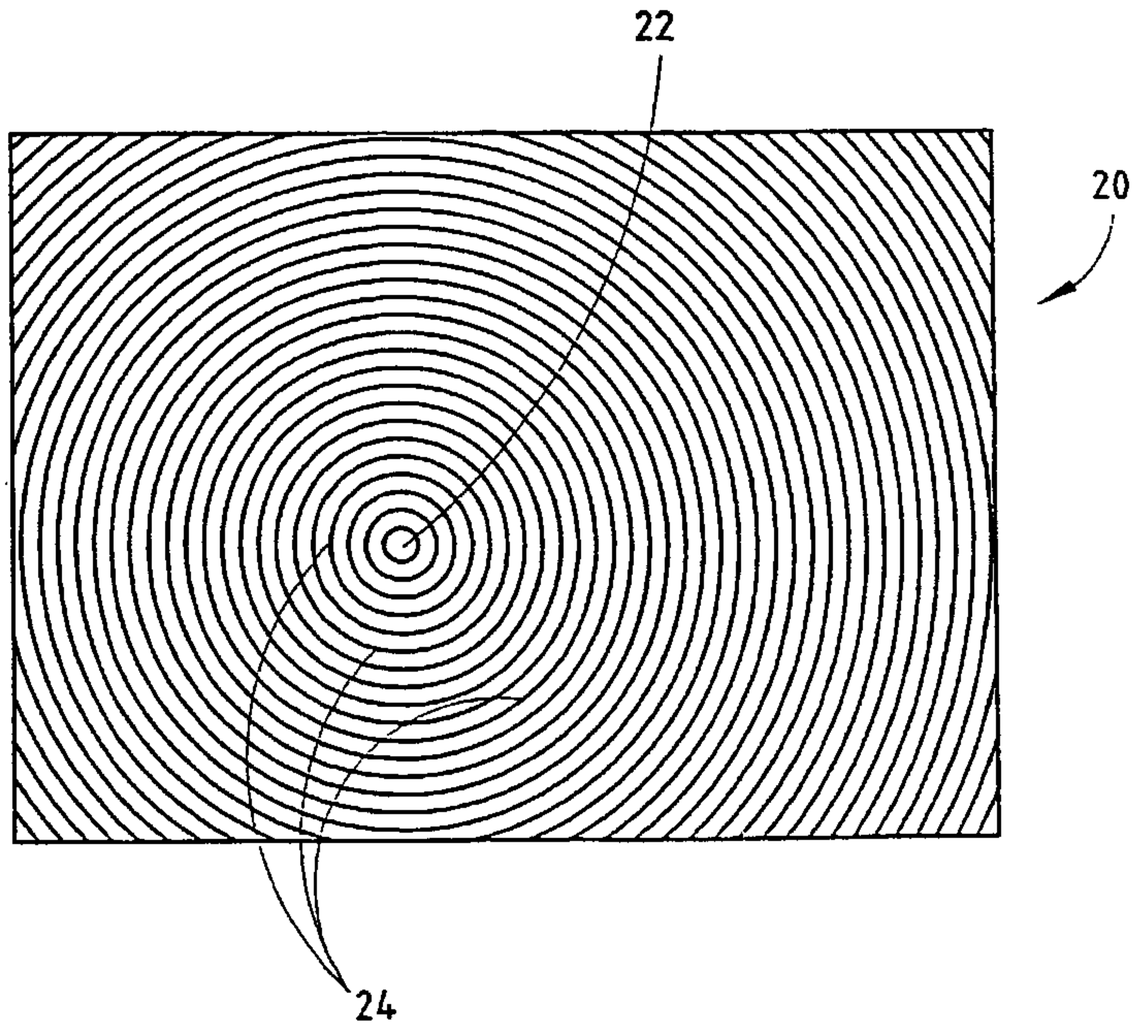
(54) Title: OPTICAL FIBER HAVING LOW POLARIZATION-MODE DISPERSION AND LOW ATTENUATION AND METHOD OF ITS MANUFACTURE



(57) Abstract: A method of fabricating an optical waveguide fiber that includes the steps of providing a cylindrical glass optical fiber preform having a longitudinally extending centerline hole, and closing the hole under conditions suitable to result in uniform and symmetric hole closure. The method may include first plugging a first end and a second end of the centerline hole to prevent gas flow therethrough. The method preferably involves closing the centerline hole of the preform by drawing the preform down into an optical waveguide fiber. An optical fiber produced by the method has a polarization mode dispersion (PMD) of <0.2 ps km-2.

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The invention claimed is:

1. A method of manufacturing an optical fiber, comprising the steps of:

providing an intermediate glass object for use in the manufacture of optical fiber, the glass object having a centerline hole therein;

heating the glass object to a temperature sufficient to reduce the outside diameter of the glass object;

applying a pressure of greater than or equal to about 760 Torr to the void; and

reducing the outside diameter of the glass object by at least 1/3 and causing the hole or annular void to close uniformly and symmetrically.

2. The method of claim 1, wherein said step of providing the intermediate glass object includes providing the intermediate glass object as an optical fiber preform to a draw furnace, and wherein said step of reducing the outside diameter of glass includes drawing an optical fiber from the optical fiber preform, and wherein the outside diameter of the optical fiber preform is sufficiently large with respect to the centerline hole so that during said drawing optical fiber step the centerline hole completely closes.

3. The method of claim 1, wherein said step of providing the glass object includes providing the glass object as a single mode optical fiber intermediate glass object, and wherein said step of reducing the outside diameter includes applying a pressure to the centerline hole which is great enough to achieve sufficiently symmetric layers of glass around the centerline of the fiber to result in a polarization mode dispersion value in the resultant optical fiber which is less than 0.2 psec/sqrt-km, when said fiber is in an unspun state.

4. The method of claim 3, wherein said step of providing the glass object includes providing the intermediate glass object as a single mode optical fiber intermediate glass object, and wherein said step of reducing the outside diameter includes applying a pressure to the centerline which is great enough to achieve sufficiently symmetric layers of glass around the centerline of the fiber to result in a polarization mode

dispersion value of less than 0.1 psec/sqrt-km when said exhibits less than 3 spin rotations over a longitudinal fiber length of 1 meter.

5. The method of claim 1, wherein said step of providing the glass object includes providing the intermediate glass object as a single mode optical fiber intermediate glass object, and wherein said step of reducing the outside diameter includes applying a pressure to the centerline hole which is great enough to achieve sufficiently symmetric layers of glass around the centerline of the fiber to result in a polarization mode dispersion value, in the resultant optical fiber, which is less than 0.05 psec/sqrt-km when said exhibits less than 3 spin rotations over a longitudinal fiber length of 1 meter.

6. The method of claim 2, wherein prior to said step of providing said preform to said draw furnace, at least one end of said centerline hole is plugged.

7. The method of claim 2, wherein said step of providing the glass object comprises providing a centerline hole that is plugged at both ends thereof preventing gas flow therethrough, and wherein, prior to said applying a pressure step, one end of the glass object is opened, thereby exposing the centerline hole to said pressure.

8. The method of claim 7, wherein the step of providing the glass object plugged at both ends protects the centerline of the glass object sufficiently such that the attenuation of the resultant optical waveguide fiber is equal to or less than 0.24 dB/km at 1550 nm.

9. The method of claim 7, wherein the attenuation of the resultant optical waveguide fiber is less than 0.22 dB/km at 1550 nm.

10. The method of claim 7, wherein the attenuation of the resultant optical waveguide fiber is less than 0.21 dB/km at 1550 nm.

11. The method of claim 2, further comprising:

forming the intermediate glass object by depositing glass or glass soot on the inside of a tube.

12. The method of claim 2, further comprising:

forming the intermediate glass object by depositing glass or glass soot onto the outside of a mandrel;

removing the mandrel to form the centerline hole; and

heating the soot core blank to form a glass core blank.

13. The method of claim 12, further comprising:

redrawing the glass core blank to form a core cane, and during said redrawing step maintaining the centerline hole in the core cane; and

forming the intermediate glass object from the core cane.

14. The method of claim 13, wherein said step of forming the intermediate glass object includes overlaying or depositing a cladding material onto the core cane.

15. The method of claim 14, further comprising:

sealing shut both ends of the cane subsequent to said redrawing step and prior to said overlaying or depositing step.

16. The method of claim 15, further comprising:

positioning the optical fiber preform in a draw furnace, and unsealing one end of said centerline hole prior to said drawing step, and drawing a fiber from the other end of said fiber preform.

17. The method of claim 14, further comprising:

sealing shut both ends of the glass core blank prior to said redrawing step.

18. The method of claim 1, wherein said step of providing the intermediate glass object includes providing the intermediate glass object as an intermediate glass object for making a multimode optical fiber.

19. The method of claim 18, further comprising:

providing a soot core blank;

consolidating the soot core blank into a glass body having a centerline hole therein; and

depositing additional soot onto said glass body.

20. The method of claim 19, further comprising:

redrawing the glass body into a more narrow diameter prior to the deposition of additional soot.

21. The method of claim 19, further comprising:

forming the intermediate glass object by depositing glass or glass soot onto the outside of a mandrel;

removing the mandrel to form the centerline hole; and

heating the soot core blank to form a glass core blank.

22. The method of claim 2, wherein the optical fiber has a centerline and has a substantially circular symmetry of glass layers along its centerline.

23. The method of claim 22, wherein at a distance of 0.1 microns from the centerline of said fiber, said fiber exhibits a radial symmetry of less than .025 microns.

24. A single mode optical fiber, comprising:

a fiber core of layers of glass, said fiber core having a centerline; and

a fiber cladding surrounding said fiber core, wherein the layers of glass surrounding the centerline are sufficiently circularly symmetric to result in a polarization mode dispersion of less than 0.2 psec/sqrt-km.

25. The optical fiber of claim 24, wherein said fiber has less than about 3 spin rotations over a longitudinal fiber length of 1 meter.

26. The fiber of claim 24, wherein said fiber is in a substantially unspun state.

27. The optical fiber of claim 24, wherein said fiber is comprised of:

concentric layers of glass; and

any glass layer between about .08 to about .15 microns from the centerline exhibits a change in radial dimension around its periphery which is less than .025 microns.

28. The optical fiber of claim 27, wherein said change in radial dimension is less than .015 microns.

29. The optical fiber in claim 27, wherein said optical fiber exhibits a polarization mode dispersion value of less than 0.2 psec/sqrt-km.

30. The optical fiber of claim 27, wherein said optical fiber exhibits a polarization mode dispersion value of less than 0.1 psec/sqrt-km.

31. A method of fabricating an optical waveguide fiber, comprising:

providing a cylindrical glass fiber preform having a longitudinally extending centerline hole;

plugging a first end and a second end of the centerline hole to prevent gas flow therethrough;

attaching an outer handle to the first end of the preform, the outer handle having a mating end;

providing an inner handle for coupling to a gas supply, the inner handle having a mating end and a fluid receiving end;

coupling the mating end of the outer handle with the mating end of the inner handle;

exposing the centerline hole of the preform to a gas;

heating the preform to a temperature sufficient to soften the preform; and

closing the centerline hole of the preform by drawing the preform into an optical waveguide fiber.

32. The method of claim 31, wherein the step of exposing the centerline hole of the preform includes breaking the first end of the glass body.

33. The method of claim 32, wherein the step of providing an inner handle includes providing a breaking tab within the inner handle to contact the bent tab of the preform when the outer handle and the inner handle rotate relative to one another, and wherein said step of exposing the centerline hole of the preform includes rotating the outer handle and the inner handle relative to one another until the breaking tab of the inner handle breaks the bent tab of the preform.

34. The method of claim 33, and further including:

drawing a vacuum on the outer handle and the exposed centerline hole of the preform subsequent to said step of exposing the centerline hole of the preform; and

backfilling the outer handle and the centerline hole of the preform with the gas.

35. The method of claim 34, and further including:

heating the glass body sufficiently to increase the gas pressure within the centerline hole of the glass body prior to said step of exposing the centerline hole of the preform.

36. The method of claim 34, and further including:

flooding the ambient air surrounding the fluid receiving end of the inner handle with the gas prior to said step of exposing the centerline hole of the preform; and

uncoupling the outer handle and the inner handle prior to said step of closing the centerline hole.

37. The method of claim 34, wherein the step of backfilling the outer handle and the centerline hole of the preform with the gas includes backfilling the inner and the outer handle and the centerline hole of the preform with a dry gas.

38. The method of claim 33, and further including:

heating the preform sufficiently to increase the gas pressure within the centerline hole of the preform.

39. The method of claim 33, and further including:

flooding the ambient air surrounding the fluid receiving end of the outer handle with a drying gas prior to said step of exposing the centerline hole of the preform; and

uncoupling the outer handle and the inner handle prior to said step of closing the centerline hole.

40. The method of claim 33, wherein the step of exposing the centerline hole of the glass body includes exposing the centerline hole of the glass body to a dry gas.

41. The method of claim 33, wherein the step of exposing the centerline hole of the glass body includes exposing the centerline hole of the glass body to a drying gas.

42. The method of claim 33, and further including:

drawing a vacuum on the inner handle prior to said step of exposing the centerline hole of the preform; and

backfilling the inner handle with a drying gas.

43. The method of claim 42, and further including:

heating the preform sufficiently to increase the gas pressure within the centerline hole of the glass body prior to said step of exposing the centerline hole of the preform.

44. The method of claim 42, further including:

flooding the ambient air surrounding the fluid receiving end of the outer handle with the gas prior to said step of exposing the centerline hole of the preform; and

uncoupling the outer handle and the inner handle prior to said step of closing the centerline hole.

45. The method according to claim 42, wherein the step of backfilling the outer handle with the gas includes providing the gas as a dry gas.

46. The method according to claim 42, wherein the step of backfilling the outer handle with the gas includes providing the gas as a drying gas.

47. The method of claim 42, wherein the step of backfilling the outer handle with the gas includes providing an exhaust port and passing the gas over the fluid receiving end of the inner handle enroute to the exhaust port.

48. The method of claim 47, and further including:

providing a one way valve in fluid communication with the exhaust port.

49. The method of claim 48, wherein said step of providing a one way flow valve includes providing a fluid filled bubbler.

50. The method of claim 48, wherein the step of providing a one way flow valve includes providing a tube sufficiently long so as to prevent back flow of ambient air from reaching the fluid receiving end of the inner handle.

51. The method of claim 50, wherein the step of backfilling the outer handle and the centerline hole of the glass body with the gas includes backfilling the outer handle and the centerline hole of the glass body with a drying gas.

52. The method of claim 50, wherein the step of plugging both ends of the centerline hole of the glass fiber preform sufficiently protects the centerline hole from contamination such that the attenuation of the resultant waveguide fiber is equal to or less than 0.24 dB/km at 1550 nm.

53. The method of claim 52, wherein the attenuation of the resultant optical waveguide fiber is less than 0.22 dB/km at 1550 nm.

54. The method of claim 53, wherein the attenuation of the resultant optical waveguide fiber is less than 0.21 dB/km at 1550 nm.

55. A preform for manufacturing an optical fiber comprising:

a cylindrical glass body having a longitudinally extending axial aperture;

a plug at a first end of said body to seal a first end of the axial aperture; and

a bent glass tab enclosing the opposite end of the axial aperture, said tab including a radially extending section and a longitudinally extending tip which can be fractured for exposing the axial aperture.

56. The preform of claim 55 and further including a generally cup-shaped handle integrally formed on said glass body with said tab within the handle.

57. The preform of claim 56 and further including a cylindrical conduit having an end mating with said cup-shaped handle and a radially inwardly extending breaking tab having a length which allows the breaking tab to engage and fracture the bent glass tab when the conduit and handle are rotated relative to one another.

58. An optical fiber including a fiber core constructed of layers of glass and having a centerline, and a fiber cladding surrounding the fiber core, wherein the layers of glass surrounding the centerline are sufficiently circularly symmetric to result in a polarization mode dispersion of less than 0.2 psec/sqrt-km, made in accordance with a method comprising the steps of:

providing an intermediate glass object for use in the manufacture of optical fiber, the glass object having a hole therein at least one end of which is plugged preventing gas flow therethrough;

heating the glass object to a temperature sufficient to reduce the outside diameter of the glass object;

applying a pressure of equal to greater than 8 Torr to the void; and

reducing the outside diameter of the glass object and causing the hole or annular void to close uniformly and symmetrically.

59. The optical fiber of claim 58, wherein said step of applying pressure includes applying a pressure of less than or equal to 100 Torr.

60. The optical fiber of claim 59, wherein said step of applying pressure includes applying a pressure of less than or equal to 500 Torr.

61. The optical fiber of claim 60, wherein said step of applying pressure includes applying a pressure of less than or equal to 750 Torr.

62. The optical fiber of claim 61, wherein said step of applying pressure includes applying a pressure of less than or equal to 760 Torr.

63. The optical fiber of claim 62, wherein said step of applying pressure includes applying a pressure of greater than 760 Torr.

64. The optical fiber of claim 58, wherein the fiber exhibits less than 3 spin rotations over a longitudinal fiber length of 1 meter.

65. The fiber of claim 58, wherein the fiber is in a substantially unspun state.

66. The optical fiber of claim 58, wherein the fiber is comprised of:

concentric layers of glass; and

any glass layer located between about .8 to about 1.5 microns from the centerline exhibits a radial thickness which is less than .25 microns.

67. The optical fiber of claim 66, wherein the radial thickness is less than .15 microns.

68. The optical fiber of claim 66, wherein the optical fiber has a polarization mode dispersion value of less than 0.2 psec/sqrt-km.

69. The optical fiber of claim 66, wherein the optical fiber has a polarization mode dispersion value of less than 0.1 psec/sqrt-km.

70. The optical fiber of claim 66, wherein the optical fiber has a polarization mode dispersion value of less than 0.05 psec/sqrt-km.

71. An optical fiber including a fiber core having an attenuation of less than or equal to 0.24 dB/km at 1550 nm, made in accordance with a method comprising the steps of:

providing an intermediate glass object for use in the manufacture of optical fiber, the glass object having a centerline hole therein each end of which is plugged preventing gas flow therethrough;

heating the glass object to a temperature sufficient to reduce the outside diameter of the glass object;

opening at least one end of the glass object while protecting the centerline hole from contamination; and

reducing the outside diameter of the glass object and causing the hole or annular void to close uniformly and symmetrically.

72. The optical fiber of claim 71, wherein the intermediate glass object was formed by a method which comprises:

forming a soot core blank by depositing glass or glass soot onto a mandrel;

removing the mandrel to form the centerline hole; and

heating the soot core blank to form a glass core blank.

73. The optical fiber of claim 72, wherein the method of forming the intermediate glass object further includes:

plugging both ends of the centerline hole of the soot core blank prior to heating the soot core blank to form a glass core blank.

74. The optical fiber of claim 73, wherein the attenuation is less than or equal to 0.22 dB/km at 1550 nm.

75. An optical fiber including a fiber core constructed of layers of glass and having a centerline, and a fiber cladding surrounding the fiber core, wherein the layers of glass surrounding the centerline are sufficiently circularly symmetric to result in a polarization mode dispersion of less than 0.2 psec/sqrt-km, and having an attenuation

of less than or equal to 0.24 dB/km at 1550 nm, made in accordance with a method comprising the steps of:

providing an intermediate glass object for use in the manufacture of optical fiber, the glass object having a centerline hole therein each end of which is plugged preventing gas flow therethrough;

heating the glass object to a temperature sufficient to reduce the outside diameter of the glass object;

opening at least one end of the glass object while protecting the centerline hole from contamination;

applying a pressure of equal to or greater than about 8 Torr to the void; and

reducing the outside diameter of the glass object and causing the hole or annular void to close uniformly and symmetrically.

76. The optical fiber of claim 75, wherein the step of applying the pressure includes applying a pressure of greater than or equal to 100 Torr.

77. The optical fiber of claim 76, wherein the step of applying the pressure includes applying a pressure of greater than or equal to 500 Torr.

78. The optical fiber of claim 77, wherein the step of applying the pressure includes applying a pressure of greater than or equal to 750 Torr.

79. The optical fiber of claim 78, wherein the step of applying the pressure includes applying a pressure of greater than 760 Torr.

80. The optical fiber of claim 79, wherein the fiber exhibits attenuation less than or equal to 0.22 dB/km at 1550 nm.

81. The optical fiber of claim 80, wherein the fiber exhibits attenuation less than or equal to 0.21 dB/km at 1550 nm.

82. The optical fiber of claim 75, wherein the fiber exhibits attenuation less than or equal to 0.21 dB/km at 1550 nm.

83. A method of making an optical fiber, comprising:

forming an optical fiber preform via a process which comprises deposition of glass soot onto a substrate, removing the substrate and consolidating the preform to form a intermediate glass object having a centerline hole therein for use in the manufacture of optical fiber, and closing the hole under conditions suitable to close the hole under a pressure inside said centerline hole which is greater than 1 Torr.

84. The method of claim 83, wherein the intermediate glass object is an optical fiber preform and the method, further comprising drawing said preform into an optical fiber.

85. The method of claim 84, wherein said hole closing step takes place during said step of drawing the preform into an optical fiber.

86. The method of claim 84, wherein the pressure inside the centerline hole is greater than 8 Torr.

87. The method of claim 84, wherein the pressure inside the centerline hole is greater than 100 Torr.

88. The method of claim 84, wherein the pressure inside the centerline hole is greater than 760 Torr.

89. The method of claim 83, wherein said hole closure step comprises closing the hole via a process which comprises exposure of said intermediate glass object to a heat source which symmetrical surrounds said intermediate glass object.

90. The method of claim 89, wherein said hole closing step comprises closing the hole in a cylindrical furnace.

91. The method of claim 89, wherein said hole closing step comprises closing the hole in a furnace which has a temperature gradient therein.

92. The method of claim 90, wherein said temperature gradient comprises a hotter zone and a cooler zone, the hotter zone located below the cooler zone, and the hole is closed by transporting said intermediate glass object from the cooler zone to the hotter zone.

93. The method of claim 92, wherein said hole closure step comprises transporting said intermediate glass object through a furnace which is vertically oriented.

94. The method of claim 83 wherein the intermediate glass object is a core cane.

95. The method of claim 83, wherein the intermediate glass object is a glass tube onto which glass deposited inside of said tube.

96. The method of claim 84, wherein, prior to said hole closure step, at least one end of said intermediate glass object is sealed.

97. The method of claim 96, wherein, prior to said hole closure step, both ends of said intermediate glass object are sealed.

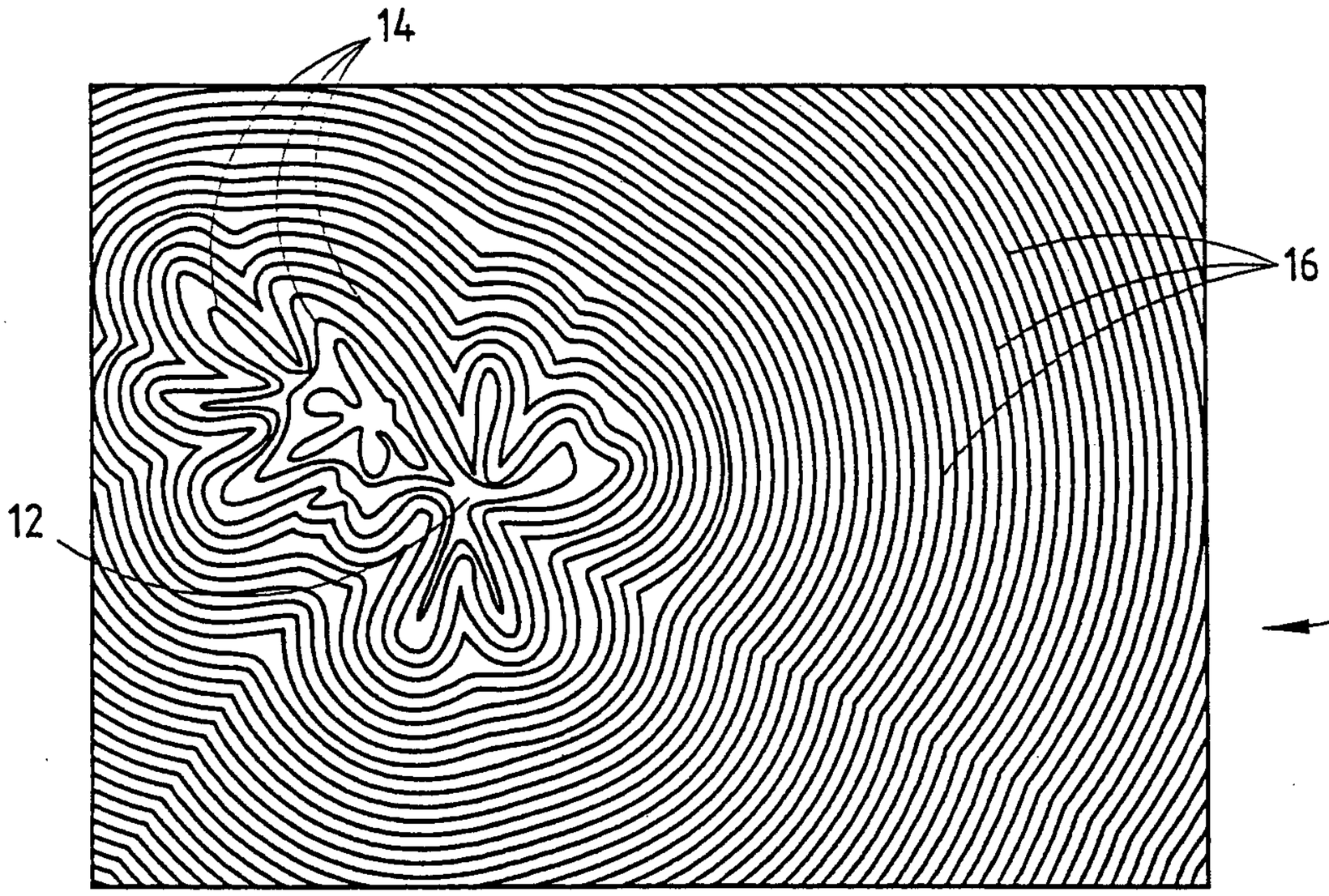

FIG. 1

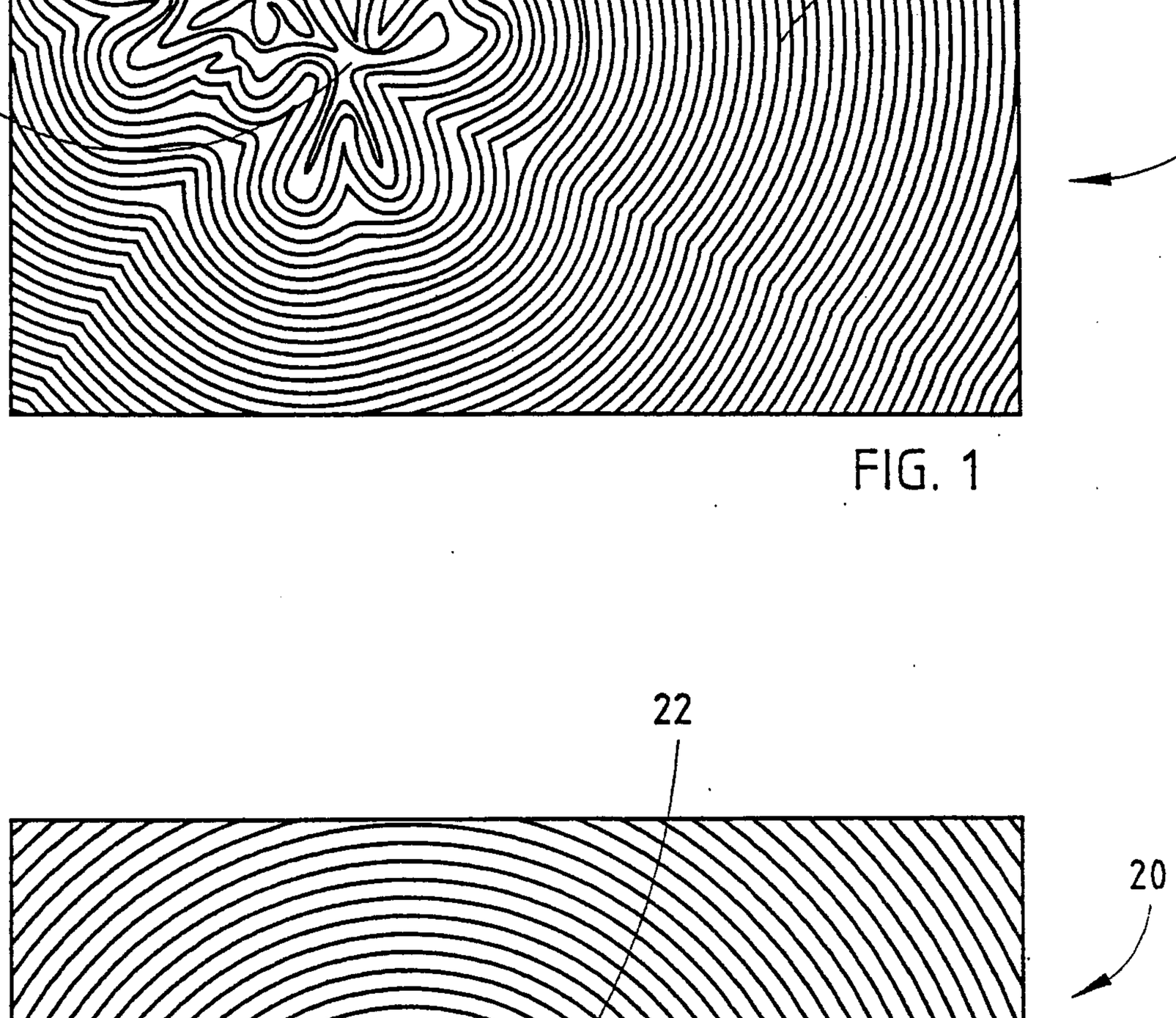

FIG. 14

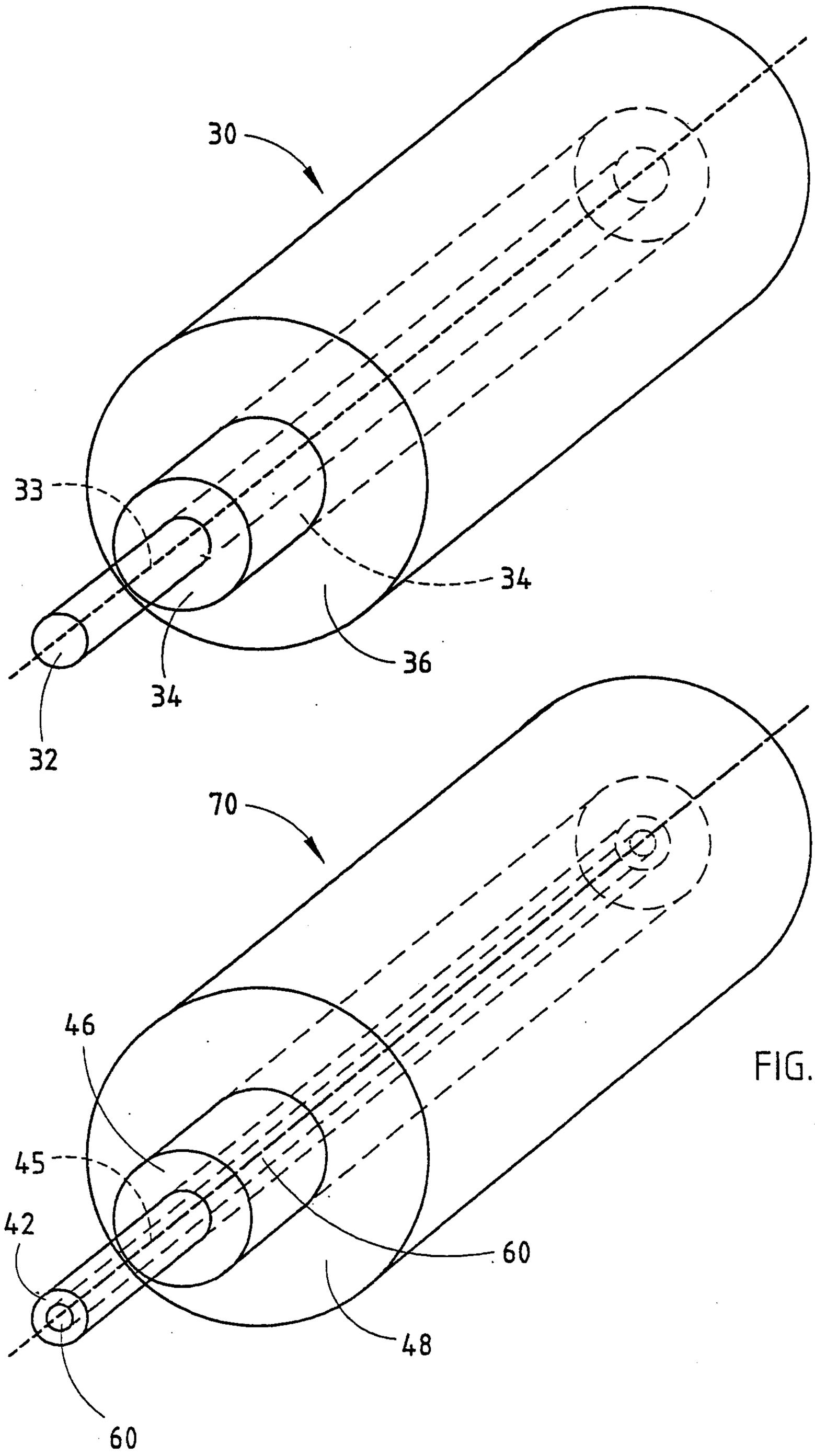

FIG. 2

FIG. 3

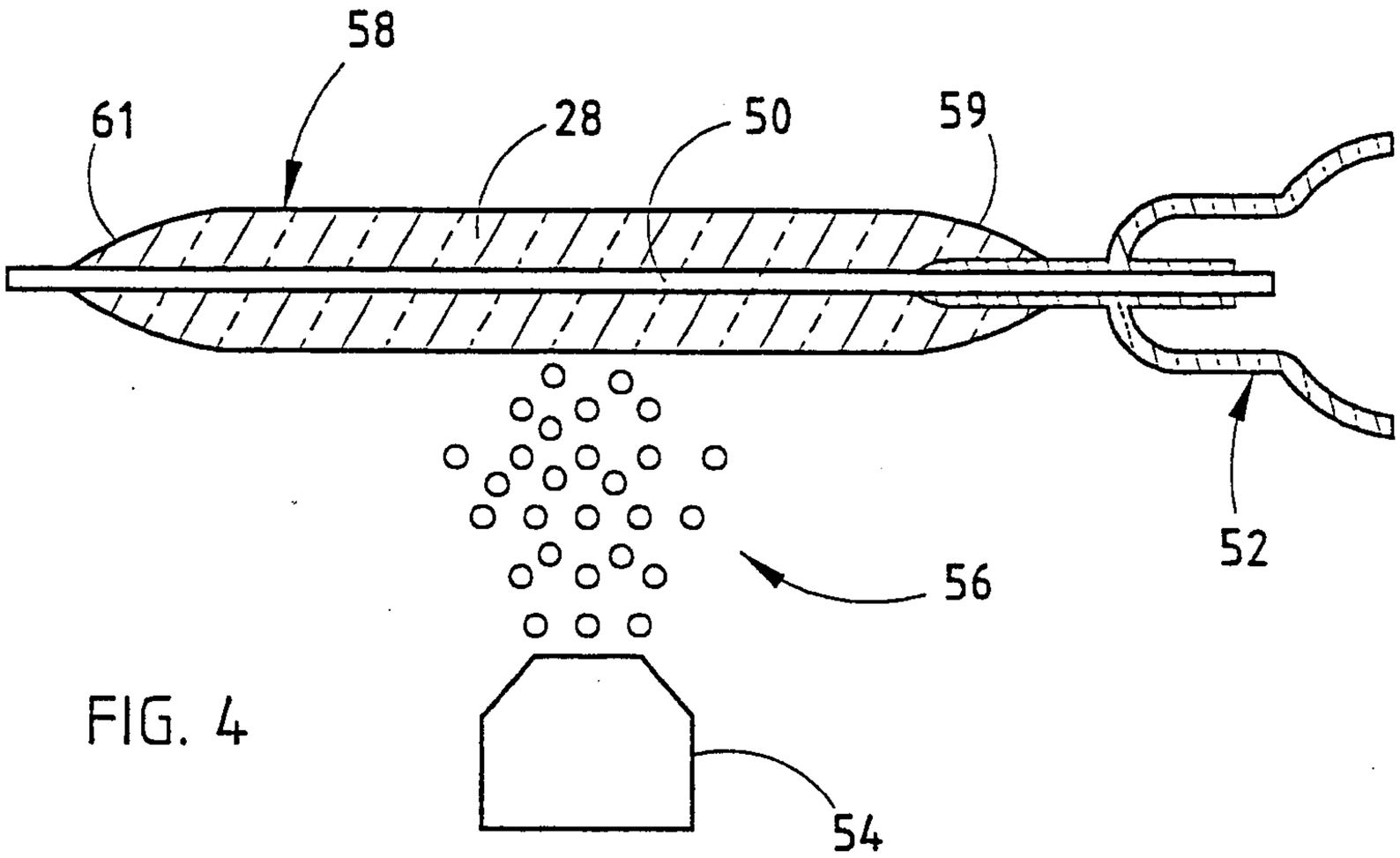

FIG. 4

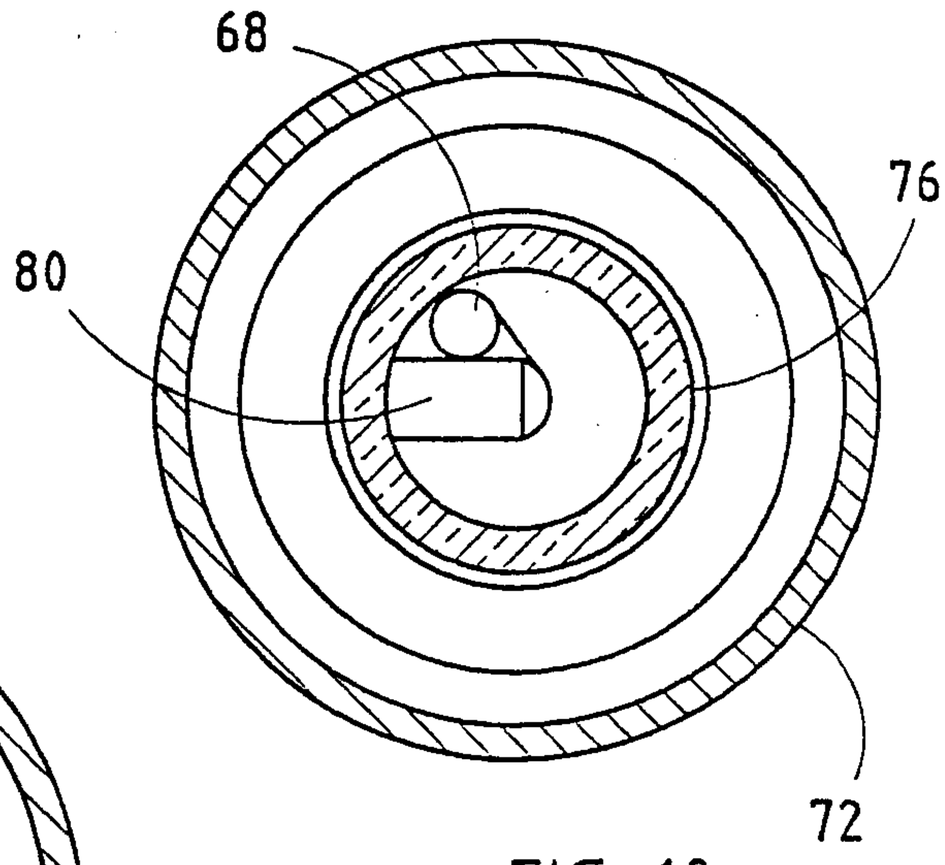

FIG. 10

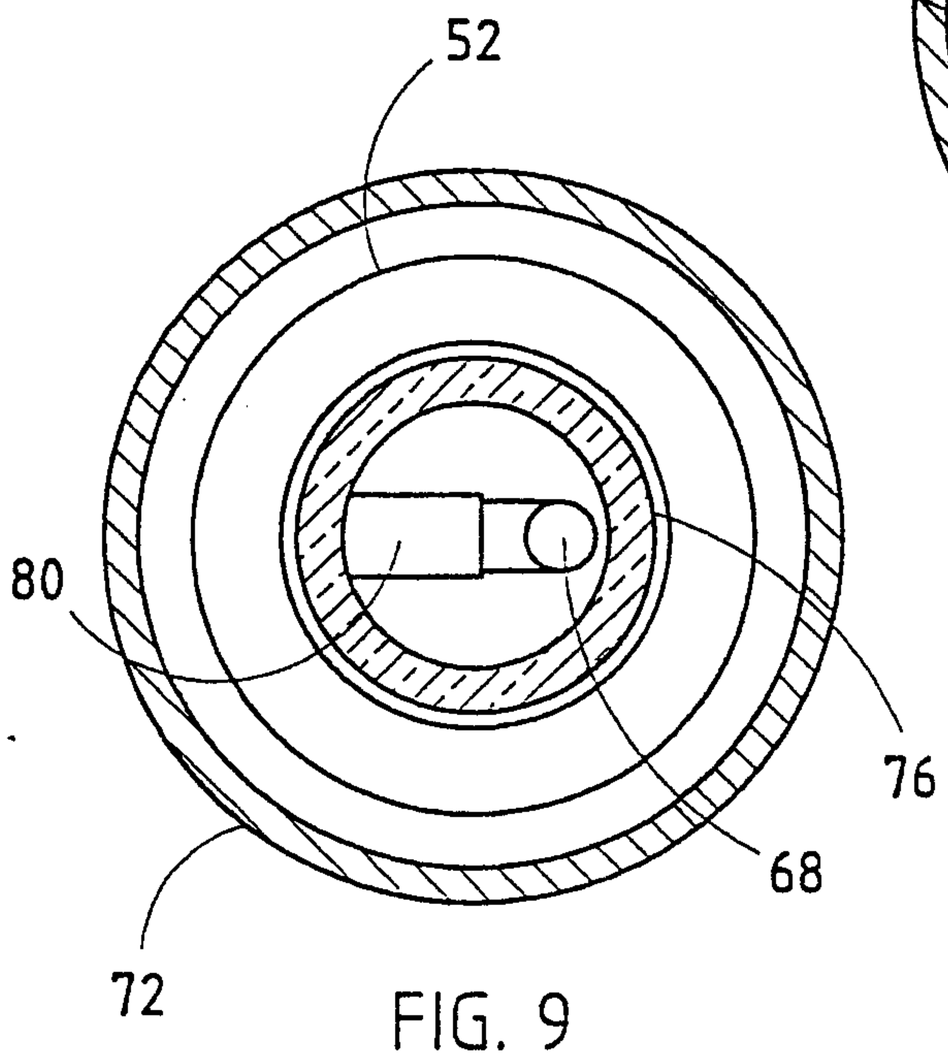

FIG. 9

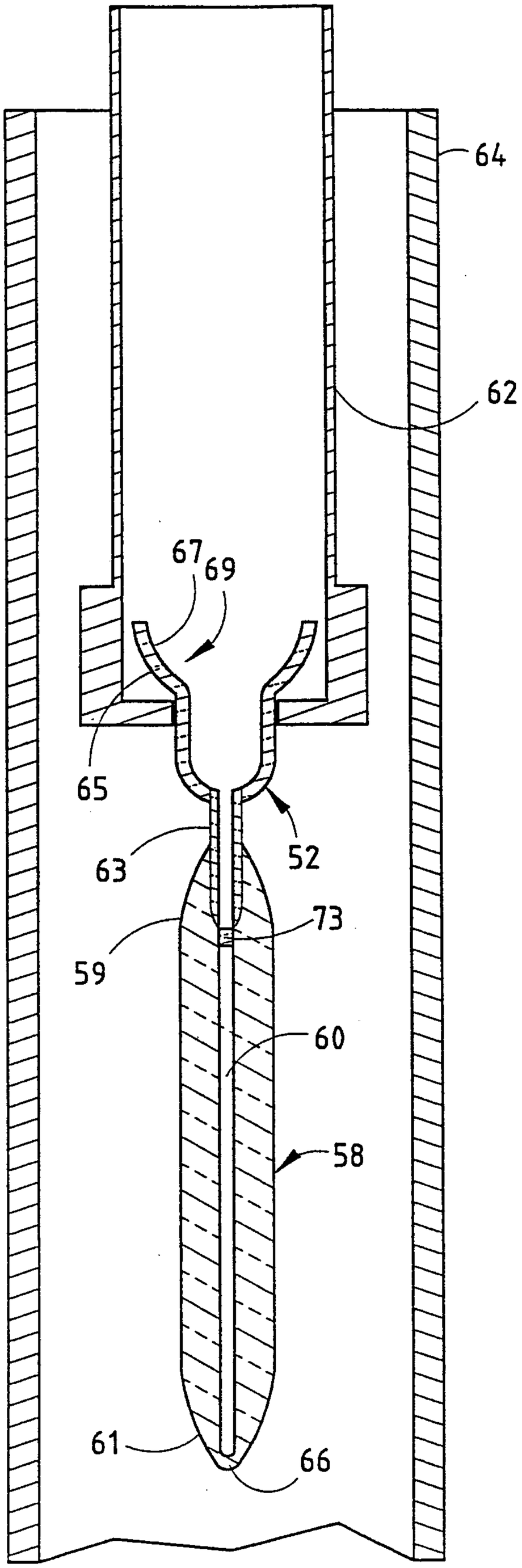
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FIG. 5

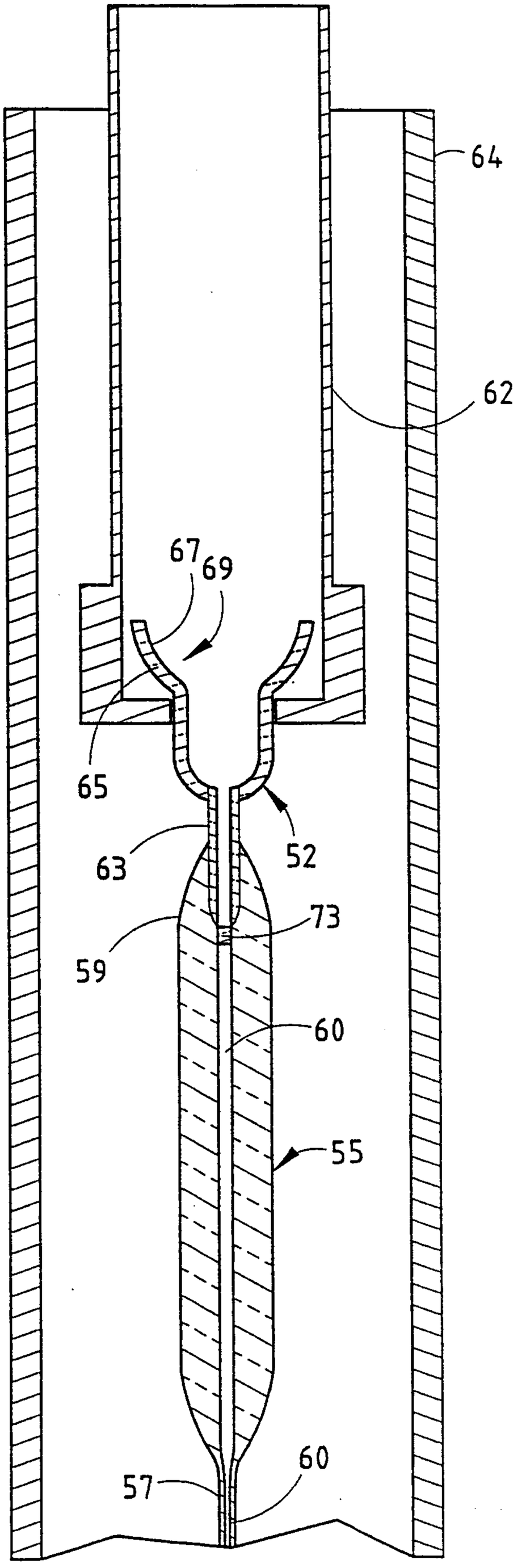
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FIG. 5A

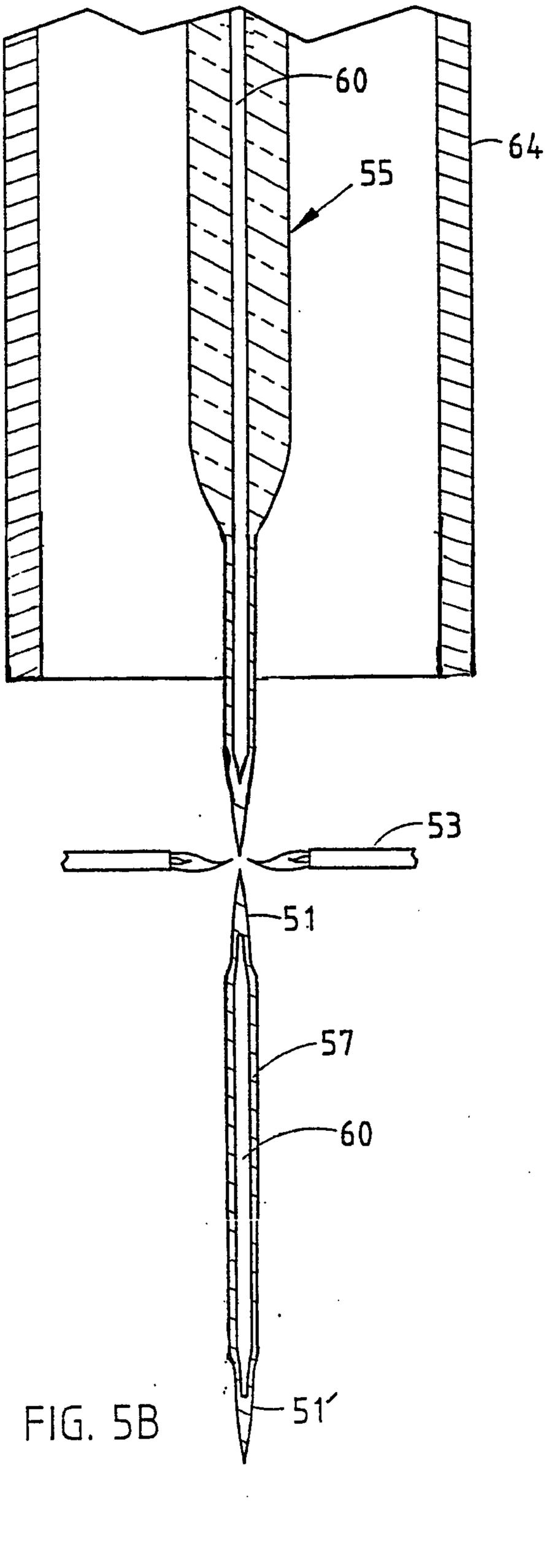


FIG. 5B

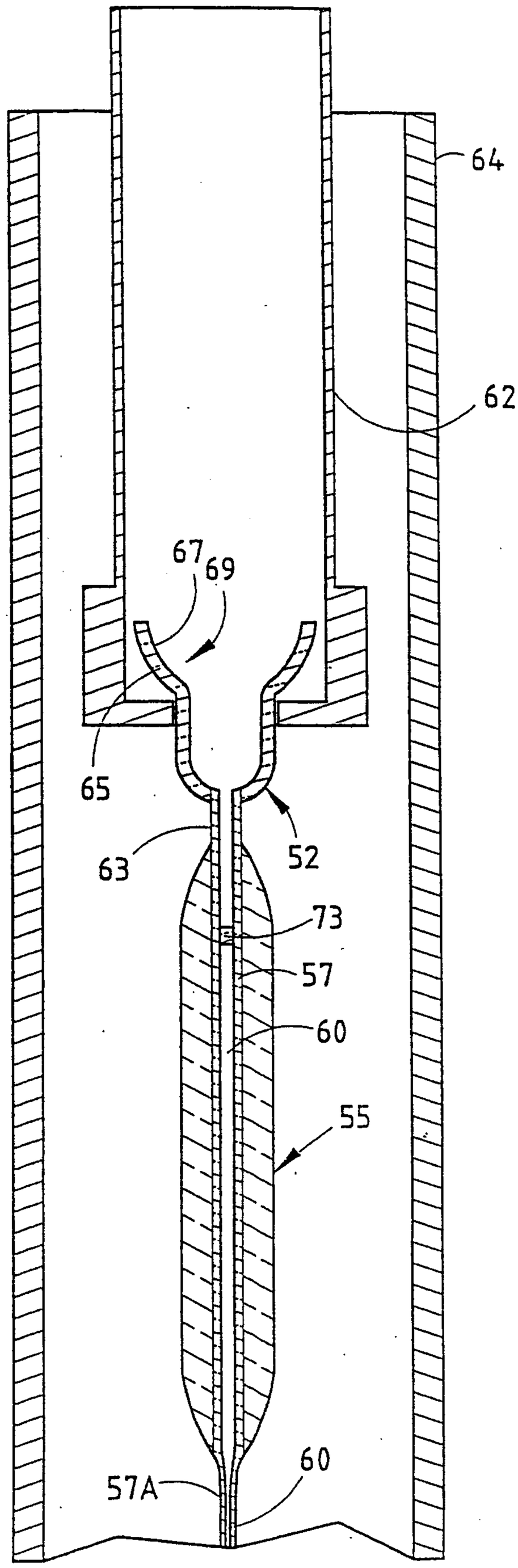
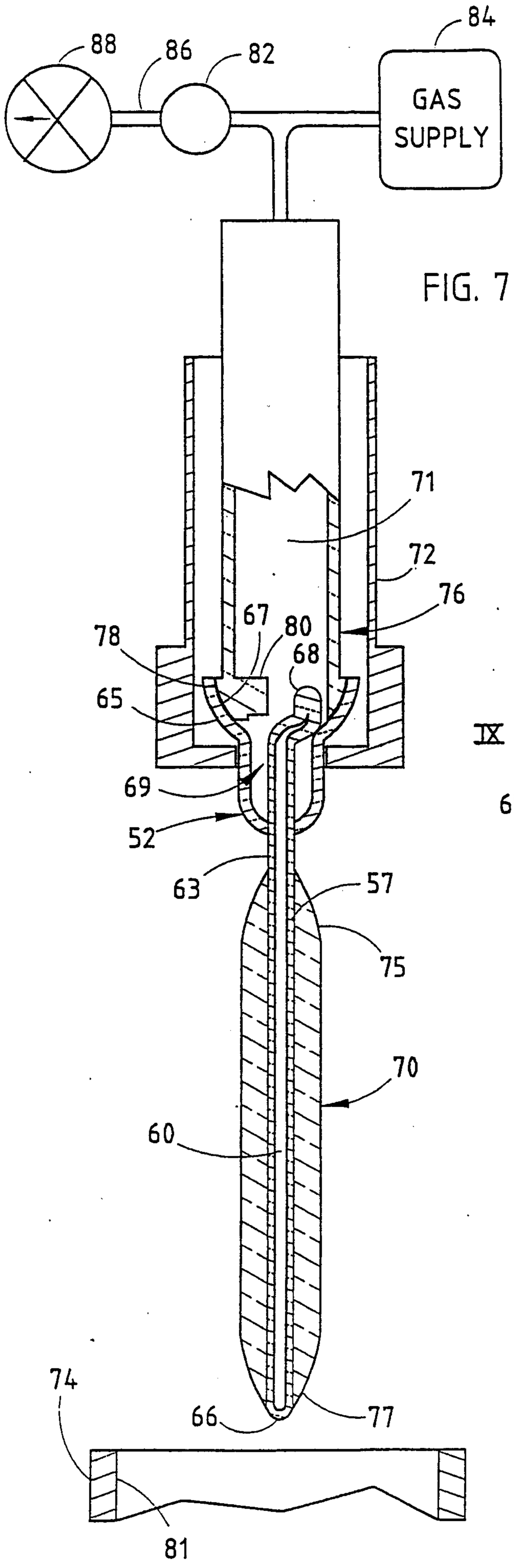


FIG. 6


84
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86
82
GAS SUPPLY
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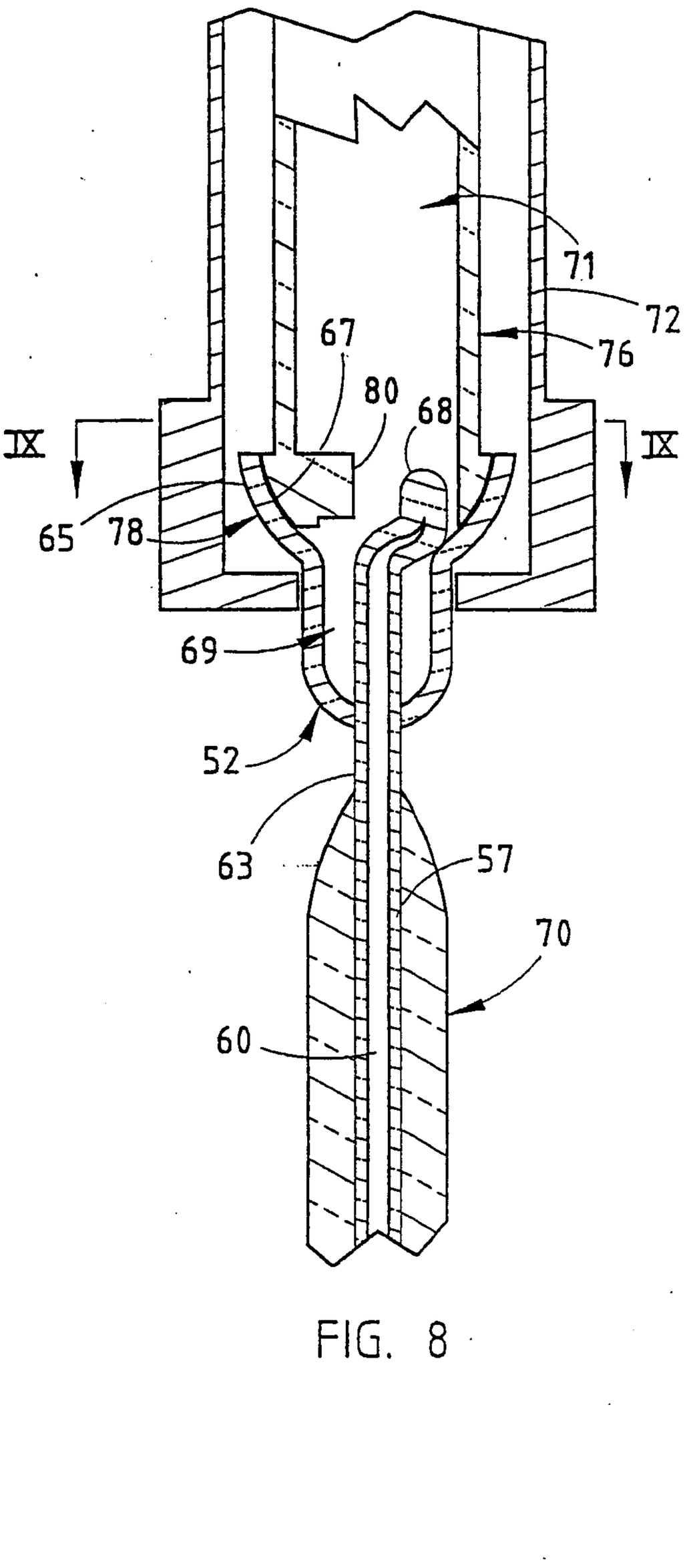
FIG. 7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80
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IX
IX
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FIG. 8

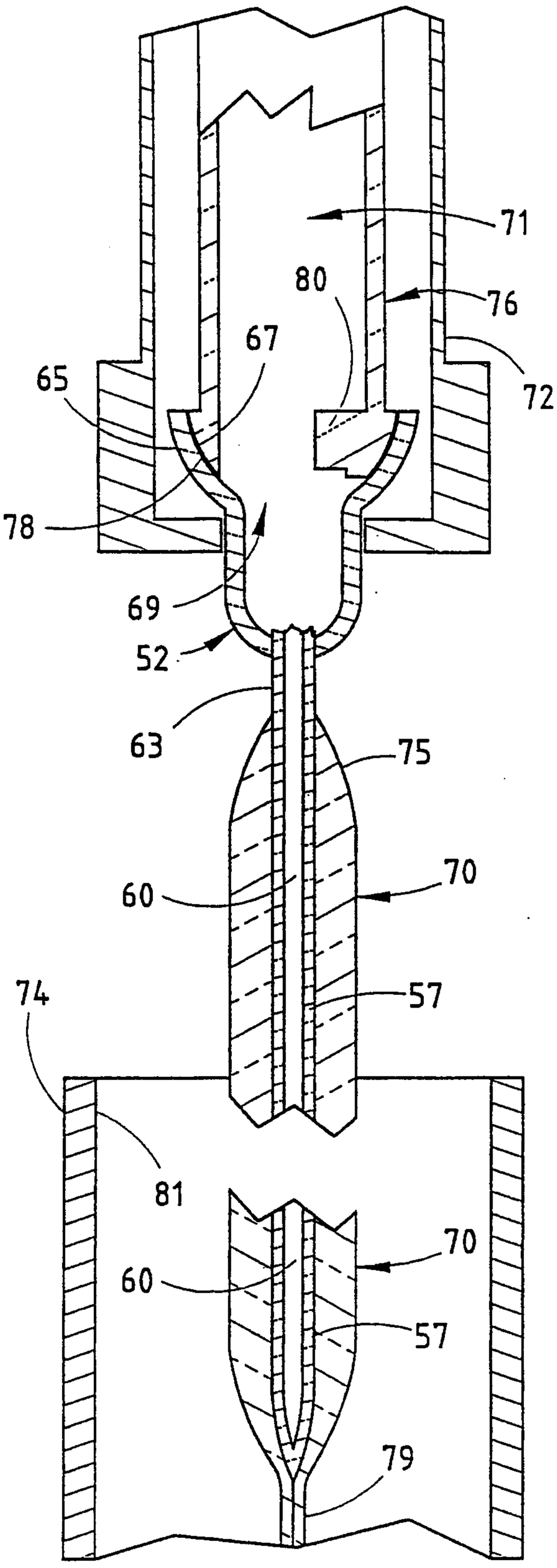
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FIG. 11

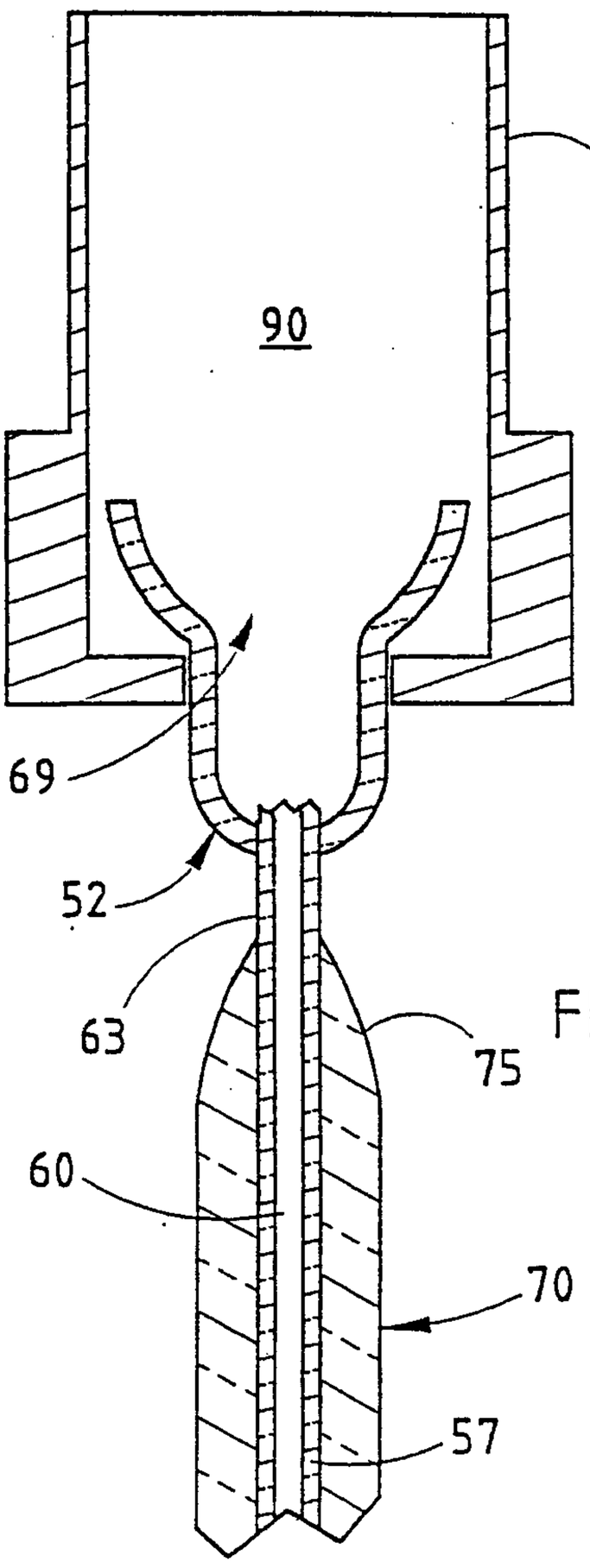
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FIG. 12

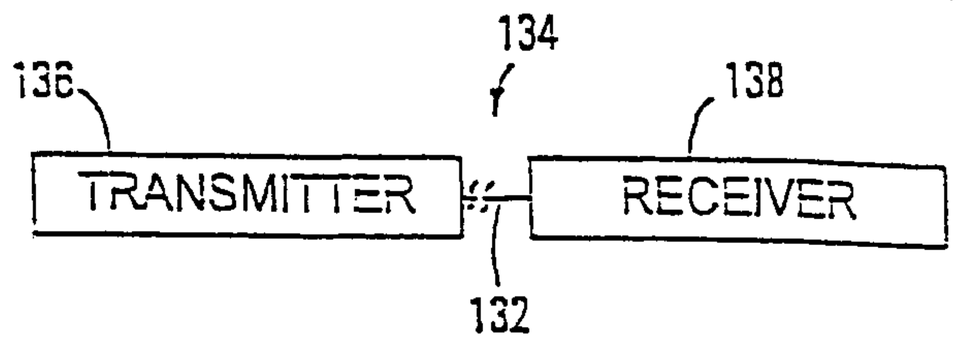
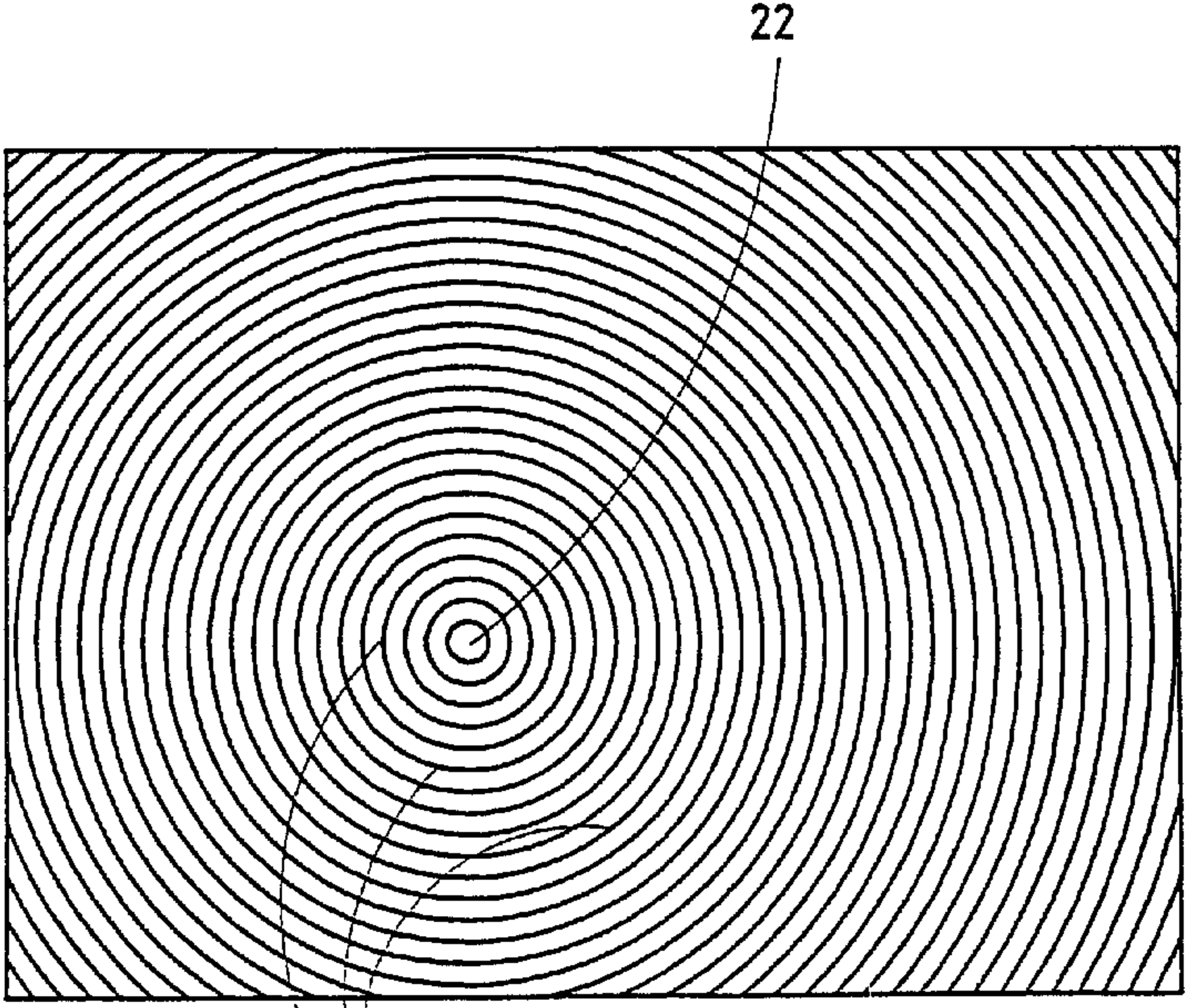

134
136
138
TRANSMITTER
RECEIVER
132

Fig. 15

FIG. 13

STEP 1: FORM GLASS PREFORM WITH CENTERLINE HOLE AND INTEGRALLY ATTACHED OUTER HANDLE
100
STEP 2: SUSPEND GLASS PREFORM WITHIN DRAWING MACHINE
102
STEP3: MATE OUTER HANDLE WITH INNER HANDLE
104
PLACE GLASS PREFORM IN HOTZONE?
NO
YES
106
STEP 4: PLACE GLASS PREFORM IN HOTZONE
REMOVE GLASS PREFORM FROM HOTZONE
NO
YES
108
STEP 5: REMOVE GLASS PREFORM IN HOTZONE
APPLY VACUUM TO INNER HANDLE?
NO
STEP 6a: SNAP CANE
120
APPLY VACUUM TO CENTERLINE?
NO
126
STEP 6b: EXPOSE CENTER-LINE TO DRY OR DRYING GAS
YES
110
STEP 6: APPLY VACUUM TO INNER HANDLE
YES
122
STEP 7a: APPLY VACUUM TO CENTERLINE
STEP 7: BACK FILL INNER HANDLE WITH DRY OR DRYING GAS
112
STEP 8: SNAP CANE
114
124
STEP 8a: BACKFILL CENTERLINE WITH DRY OR DRYING GAS
EXPOSE OUTER HANDLE AND CENTERLINE TO AMBIENT AIR?
NO
YES
128
STEP 9a: EXPOSE OUTER HANDLE AND CENTERLINE TO AMBIENT AIR
STEP 9: PASS DRY OR DRYING GAS OVER OUTER HANDLE AND TO EXHAUST
116
ROUTE EXHAUST GAS TO ONE-WAY VALVE?
NO
YES
118
STEP 10: ROUTE EXHAUST GAS TO ONE-WAY VALVE
STEP 11: DRAW OPTICAL FIBER FROM GLASS PREFORM
130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