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James

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[54] **COLLECTOR POLE PIECE FOR A MICROWAVE LINEAR BEAM TUBE**

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[73] Assignee: **Varian Associates,** Palo Alto, Calif.

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[52] **U.S. Cl.** **315/3.5,** 313/22, 313/25, 313/30, 315/5.35, 315/5.38

[51] **Int. Cl.** **H01j 25/34**

[58] **Field of Search** 315/3.5, 5.35, 5.38; 313/22, 25, 30

[56] **References Cited**

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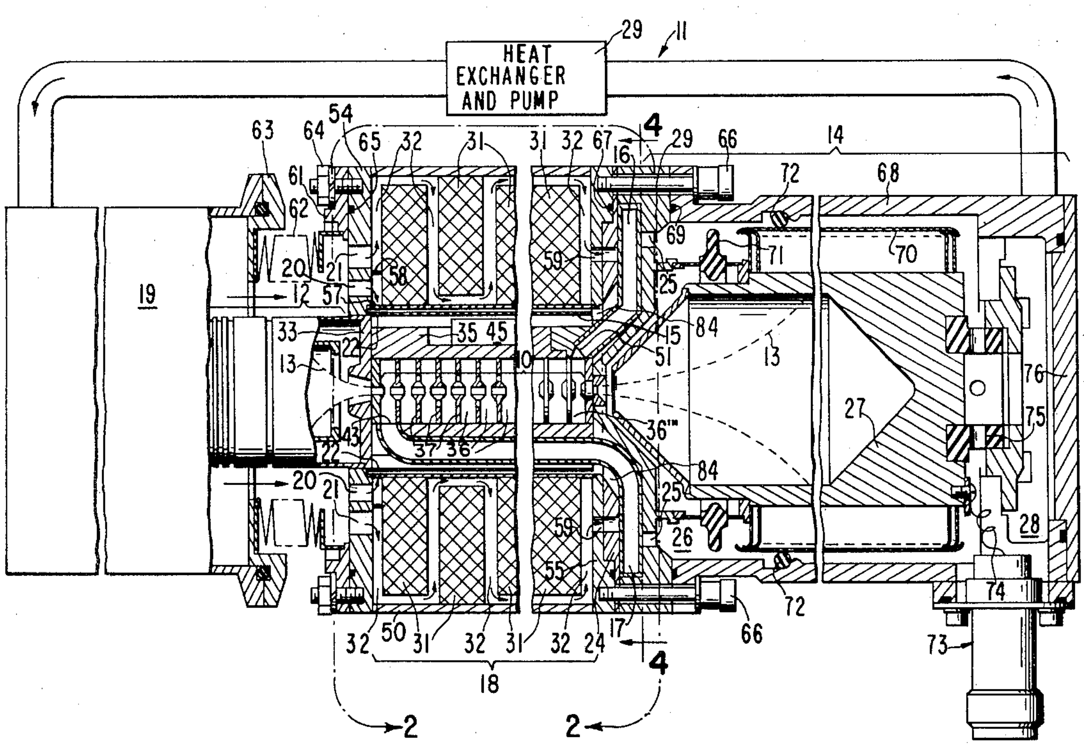
[57] **ABSTRACT**

The collector pole piece for a solenoid focused microwave linear beam tube contains a chamber therein. The output waveguide extends into and through the chamber in the collector pole piece to provide a wave communication passageway between the microwave interaction circuit of the tube and its surrounds. Fluid coolant passageways communicate with the pole piece chamber for directing a flow of coolant through the pole piece structure.

6 Claims, 4 Drawing Figures



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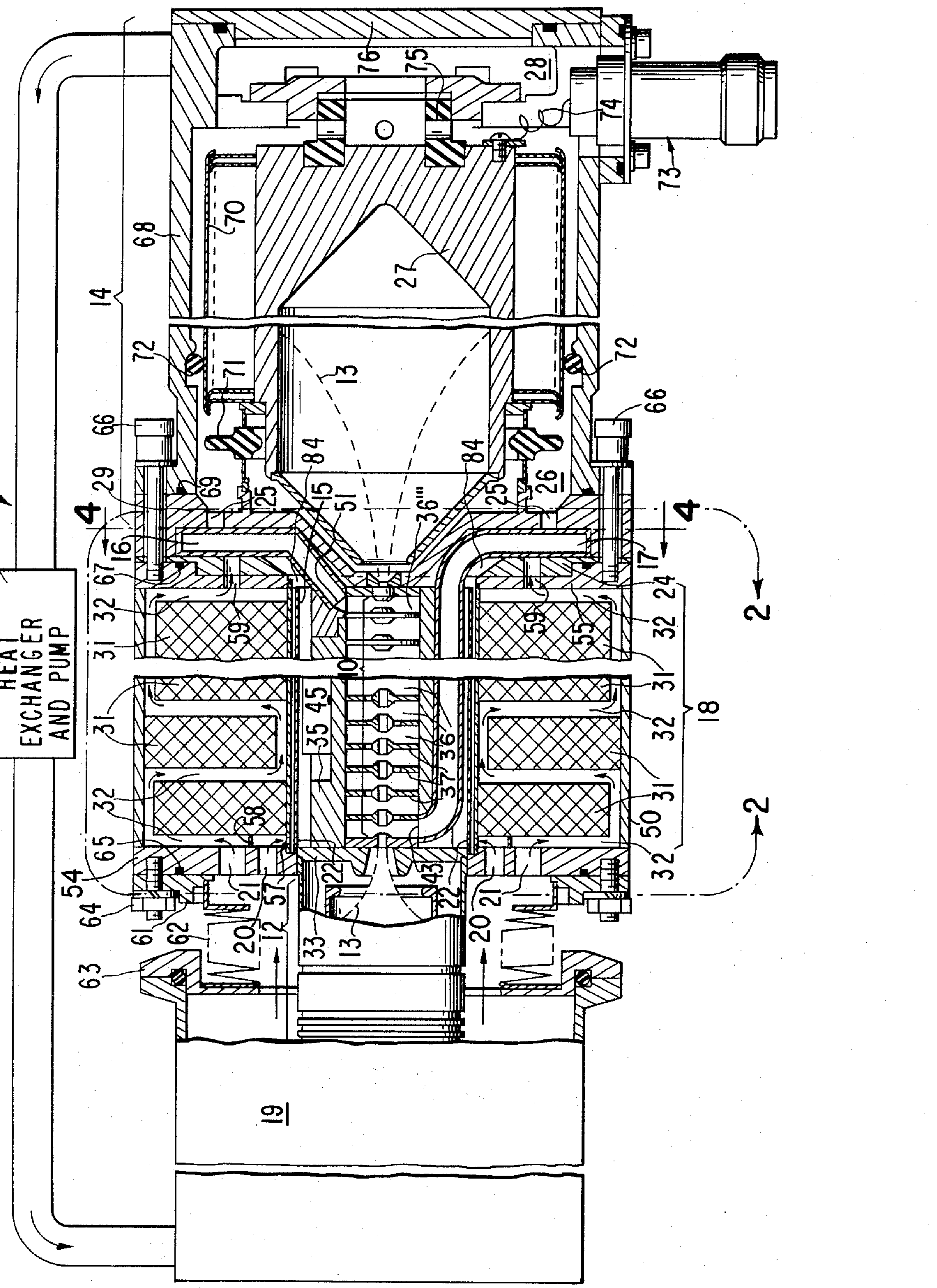
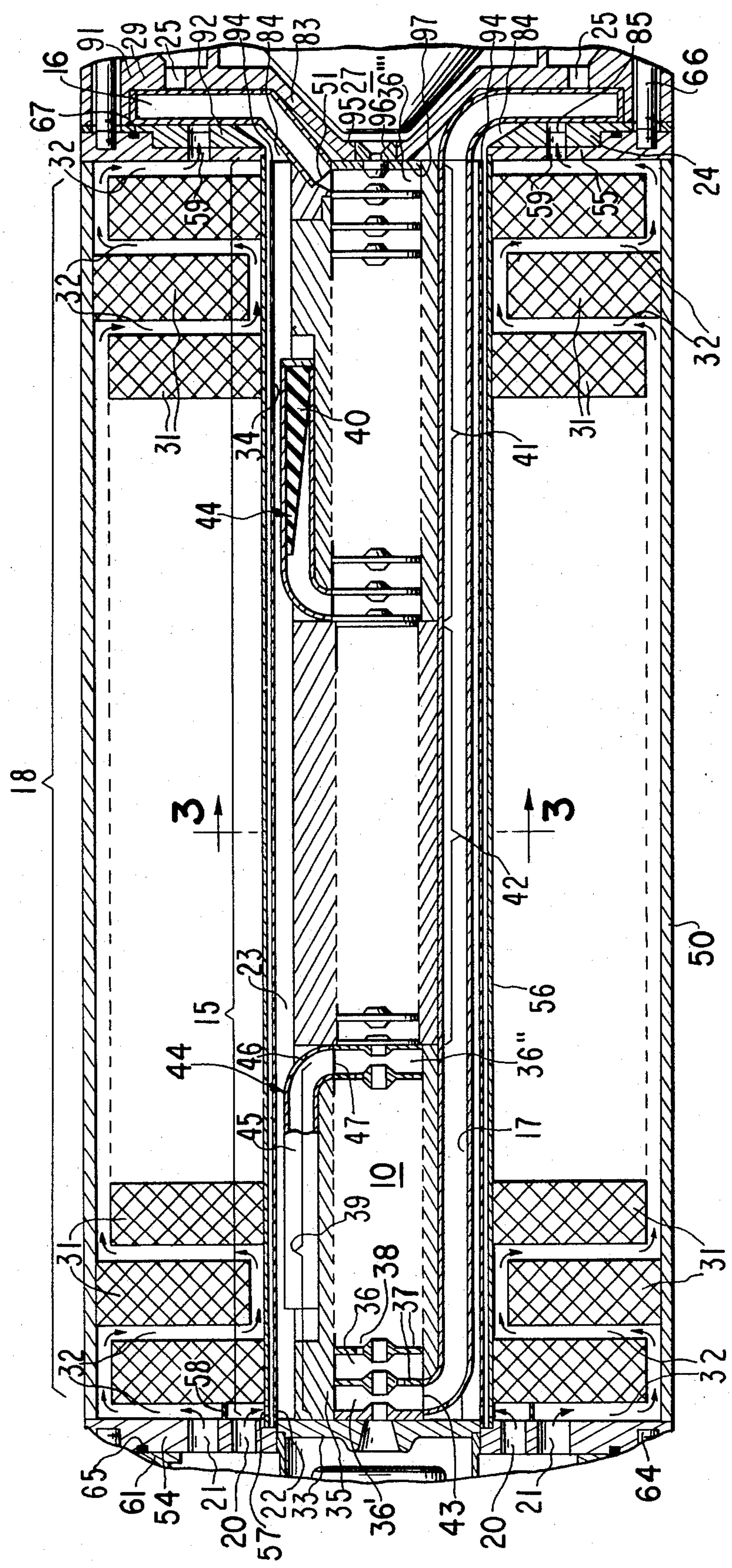


FIG.1

FIG.2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57
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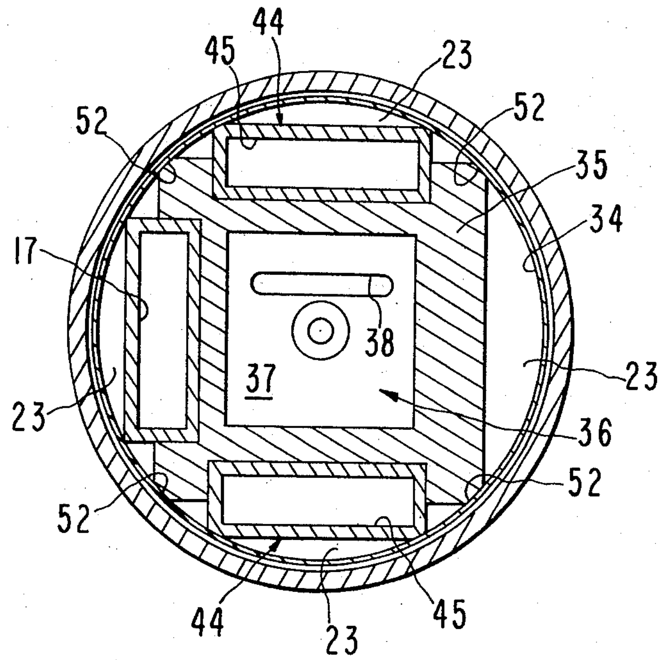
35
36'
43
20
21
64

FIG. 3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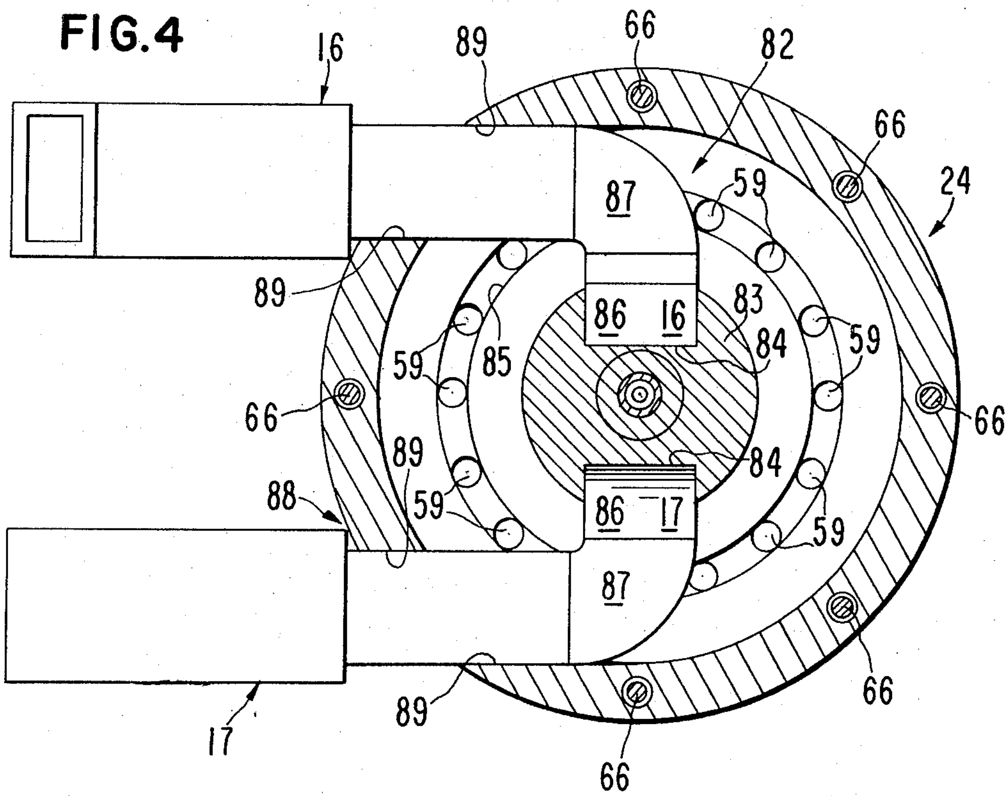
23

FIG. 4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COLLECTOR POLE PIECE FOR A MICROWAVE LINEAR BEAM TUBE

GOVERNMENT CONTRACT

The invention herein described was made in the course of or under a contract or subcontract thereunder, (or grant) with the Department of the U.S. Navy.

RELATED CASES

The block body construction of the tube of the present invention, as strengthened by a surrounding tubular member, forms the subject matter of and is claimed in copending U.S. application Ser. No. 421,174 filed Dec. 3, 1973 and assigned to the same assignee as the present invention.

BACKGROUND OF THE INVENTION

The present invention relates in general to microwave linear beam tubes and more particularly to an improved collector pole piece for such tubes.

DESCRIPTION OF THE PRIOR ART

Heretofore, collector pole piece structures for microwave linear beam tubes have been notched or apertured to permit passage of the output and sometimes the input waveguides therethrough such that the waveguide structures may traverse the region between the microwave circuit and the surrounds of the tube without unduly interrupting or disturbing the beam focus solenoid and/or the beam focus magnetic field produced by the solenoid. Collector pole pieces of this prior construction are disclosed in U.S. Pat. No. 3,336,491, issued Aug. 15, 1967 and assigned to the same assignee as the present invention.

While such prior art collector pole pieces have been satisfactory for the prior art microwave tubes, it is desirable to provide an improved collector pole piece structure adapted to be detachably secured to a solenoid collector pole piece and to provide fluid coolant passageways therein providing for a flow of coolant between the main body and the beam collector of the tube.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved collector pole piece structure for a solenoid focused microwave linear beam tube.

In one feature of the present invention, the collector pole piece structure includes a chamber therein with the output waveguide structure passing through said chamber of the pole piece.

In another feature of the present invention, the collector pole piece structure includes a chamber having an input and an output waveguide passing therethrough, such waveguide structures being disposed on opposite sides of the beam path and each having an H-plane 90° bend portion disposed within the chamber such that both waveguides pass out of the collector pole piece structure in substantial parallelism on the same side of the beam path, whereby the overall transverse dimensions of the tube are reduced.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view, longitudinally foreshortened and partly in block diagram form, of a microwave linear beam tube incorporating features of the present invention,

FIG. 2 is an enlarged view of a portion of the structure of FIG. 1 delineated by line **2—2**,

FIG. 3 is an enlarged section view of a portion of the structure of FIG. 1 taken along line **3—3** in the direction of the arrow, and

FIG. 4 is a sectional view of the structure of FIG. 1 taken along line **4—4** in the direction of the arrows.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **1**, there is shown an X-band linear beam microwave amplifier tube **11** incorporating features of the present invention. More specifically, the tube **11** includes an electron gun assembly **12** disposed at one end for forming and projecting a beam of electrons over an elongated beam path **13** to a beam collector structure **14** disposed at the terminal end of the beam path for collecting and dissipating the energy of the beam. A main body portion **15** of the tube is disposed intermediate the electron gun **12** and the beam collector **14.**

The main body portion **15** includes a microwave circuit **10** disposed along the beam path **13** in electromagnetic wave energy exchanging relation with the beam to produce output microwave energy which is coupled from the tube **11** via an output waveguide **16** for propagation to a suitable utilization device or load, not shown. In the instant case, the microwave tube **11** is an amplifier tube and amplifies input microwave energy in the X-band frequency range coupled to the input end of the microwave circuit **10** via input waveguide **17.** The input waveguide **17** passes axially the tube **11** to the input or gun end thereof for coupling microwave energy onto the microwave circuit **10.**

An electrically energized solenoid **18** is disposed coaxially surrounding the main body portion **15** for generating an axial magnetic field within the beam path **13** for focusing the electron beam **13** through the microwave interaction circuit.

A fluid coolant chamber or reservoir **19** is disposed surrounding the electron gun **12.** The coolant is electrically insulative and heat absorptive. A suitable coolant is a liquid fluorocarbon such as Coolanol **25** commercially available from Monsanto Chemical Company. Such liquid fluorocarbons are conventionally used as hydraulic oil in hydraulic systems. Coolant from the reservoir **19** passes through an inner and an outer circular array of apertures **20** and **21**, respectively, in the cathode pole piece **54** into the interior of the solenoid **18** wherein the flow of fluid coolant is divided into two streams one of which passes into the main body portion **15** of the tube via a circular array of circumferentially spaced apertures **22** in the main body **15** and thence along the length of the main body **15** via a plurality of passageways **23** to a collector pole piece structure **24,** as of cold rolled steel.

The collector pole piece structure **24** contains a hollow chamber and the hollow chamber is placed in fluid communication with the longitudinal fluid coolant passageways **23** in the main body portion **15.** A circular array of apertures **25** in the collector pole piece **24** provide fluid communication between the collector pole piece chamber and an annular fluid chamber **26** surrounding the beam collector electrode or bucket **27**. The fluid coolant is directed through a multitude of perforated cooling fins coupled to the exterior of the beam collector electrode **27** for cooling same. The fluid coolant is collected in a manifold structure **28** connected via tubulation to the input of a heat exchanger and pump **29** for removing the heat picked up by the coolant. The cooled coolant is then returned to the cathode reservoir **19** for recirculation through the tube.

In addition to the longitudinal fluid passageways **23** through the main body portion **15**, the solenoid **18** includes a plurality of coils **31** which are axially spaced apart and varied in inside and outside diameter such as to define an annular serpentine shaped fluid coolant passageway **32** in between and around the electrical coils **31** for cooling the solenoid in use. In a typical example, the fluid coolant flow rate through the entire tube is 3.3 gallons per minute, whereas the fluid coolant flow rate through the main body portion **15** is **1** gallon per minute leaving 2.3 gallons per minute flow through the solenoid **18**.

Referring now to FIGS. **2** and **3**, there is shown the main body portion **15** of the tube in greater detail. More particularly, the electron gun **12** includes an anode portion **33** which is sealed in a gas tight manner to the exterior envelope of the electron gun assembly **12**. Similarly, the main body portion **15** of the tube **11** is sealed in a gas tight manner to, and forms a part of, the anode **33**.

The main body portion **15** of the tube includes a cylindrical tubular strengthening member **34**, as of 0.020 inch wall thickness non-magnetic stainless steel, sealed, as by brazing, to the anode **33** and extending longitudinally of the tube **11** to the collector pole piece structure **24** to which it is sealed in a gas tight manner as by brazing. The main body **15** includes a block body portion **35**, as of copper, in which the microwave interaction circuit **10** is formed. More particularly, the block body portion **35** includes a series of rectangular cavity resonators **36** formed therein preferably in the manner as disclosed and claimed in U.S. Pat. No. 3,711,943, issued Jan. 23, 1973 and assigned to the same assignee as the present invention. The common walls **37** between adjacent resonators **36** are each centrally apertured to define a beam passageway through successive resonators **36**. Adjacent resonators are coupled together via inductive coupling holes **38** in the common wall **37** therebetween. The inductive coupling holes **38** alternate from one side of the beam path to the opposite side of the beam path to provide a serpentine shaped path of wave propagation for wave energy traveling on the interaction circuit **10**. This type of microwave interaction circuit has a backward wave fundamental space harmonic mode of operation and is operated on the first space harmonic having between π and 2π radians of phase shift per cavity of the circuit **10**.

The interaction circuit **10** is divided into a plurality of severed microwave circuit portions. More particularly, there is an input circuit portion **39**, an output circuit portion **41**, and an intermediate circuit portion **42**. The input circuit portion has wave energy to be amplified applied to the upstream cavity **36'** thereof via the input waveguide **17** communicating with the upstream cavity resonator **36'** via an input coupling iris **43**. The input waveguide **17** extends longitudinally of the block body portion **35**, is recessed therein and brazed thereto. The downstream end of the input circuit portion **39** is terminated in a lossy circuit sever **44** forming the subject matter of and being claimed in copending U.S. Pat. application Ser. No. 421,174 filed Dec. 3, 1973 and assigned to the same assignee as the present invention.

Briefly the circuit sever **44** includes a section of rectangular waveguide **45** recessed into a milled out portion of the block body portion **35** and brazed thereto. The circuit sever waveguide **45** is coupled to the last resonator **36''** via a 90° E-plane bend section **46** and coupling iris **47**. An E-plane tapered wave energy absorptive member **40** is disposed within the terminal end of the circuit sever **44** in heat exchanging relation with the walls of the circuit sever waveguide **45** and the fluid coolant within fluid coolant passageway **23**.

The input and output ends of the intermediate circuit portion **42** include circuit severs **44** of the type described with regard to the input section **39** of the microwave circuit. These severs **44** are located in recessed portions of the block body **35** on opposite sides from each other and on the sides of the rectangular cross section block portion **35** displaced 90° circumferentially from the input waveguide **17**, as shown in FIG. **3**.

Likewise, the output section **41** of the microwave circuit **10** includes a circuit sever **44** coupled to the upstream end thereof and the output waveguide **16** is coupled to the downstream resonator **36'''** via output iris **51**.

The block body portion **35** of the tube is supported from and strengthened by means of an interference fit between the four corners **52** of the block body **35** and the interior bore of the stainless steel strengthening tube **34**. As previously described, the block body **35** is of generally rectangular cross section to provide a substantially out-of-round surface spaced from the interior bore of the strengthening tube **34** for defining the four longitudinally directed coolant passageways **23** in the region between the out-of-round block body portion **35** and the inside wall of the strenthening tube **34**.

The collector end of the block body portion **35** is brazed to the inner end of an inwardly directed reentrant portion of the collector pole piece **24**.

The collector pole piece structure **24** is hollow and is joined in a fluid tight manner as by brazing to the collector end of the tubular strengthening member **34**. Rectangular apertures in the pole piece **24** are provided on opposite sides of the beam path **13** to permit the input and output waveguides **17** and **16**, respectively to pass from the main body portion **15** into the hollow pole piece structure **24**. The apertures which permit the input and output waveguides **17** and **16** to pass into the hollow pole piece **24** are slightly larger than the outside dimensions of the waveguides **16** and **17** to provide a fluid communication passageway interconnecting the longitudinal body fluid coolant passageways **23** with the hollow chamber of the collector pole piece **24**. In addition, at the output end of the block body portion **35**, the corners are removed to permit fluid communication between the side passageways **23**, 90° rotationally displaced from the input waveguide **17**, and the input and output waveguide passageways **23**.

The solenoid **18** includes an annular plate **54**, as of cold rolled steel, forming the electron gun pole piece of the solenoid **18**, and a similar annular plate **55**, as of cold rolled steel, forms the collector pole piece of the solenoid **18.** The two pole pieces are joined together by means of an inside tubular jacket **56**, as of non-magnetic stainless steel and an outside tubular magnetic yoke **50**, as of cold rolled steel. The jacket and yoke are sealed at their ends in a fluid tight manner as by brazing to each of the annular pole pieces **54** and **55**, respectively. The inside ring of perforations **20** in the cathode pole piece **54** provide fluid communication between the cathode reservoir **19** and the body coolant passageways **23** via the ring of apertures **22** in the strengthening cylinder **34** and a similar matching ring of apertures **57** in the inside jacket **56**. An annular septum **58** is provided in the solenoid between the inner ring of apertures **20** and the outer ring of apertures **21** in the cathode pole piece **54** for separating the flow of coolant to the solenoid **18** from that flow of coolant to the body **35** of the tube **11**. At the collector end of the solenoid a ring of apertures **59** is provided in the collector pole piece **55** of the solenoid **18** and in the collector pole piece **24** of the tube **11** to allow the coolant to flow from the solenoid **18** into the hollow collector pole piece **24** of the tube **11.**

The solenoid **18** is sealed in a fluid tight manner to the reservoir **19** via the intermediary of an annular mounting flange **61** and bellows **62**. The bellows **62** is sealed between a cover **63** of the reservoir **19** and the mounting flange **61**. The mounting flange **61** is secured to the cathode end of the solenoid **18** via a plurality of cap screws **64**. An "O" ring **65** is provided between the mounting flange **61** and the cathode pole piece **55** for providing a fluid tight seal therebetween.

Similarly, at the collector end of the solenoid **18**, the collector pole piece structure **24** of the tube **11** is joined in a fluid tight manner to the collector pole piece **55** of the solenoid **18** via a plurality of cap screws **66**. An "O" ring **67** is provided between the mating pole pieces **24** and **55** to provide a fluid tight seal therebetween. The cap screws **66** also serve to secure a cylindrical collector housing **68**, as of aluminum, to the tube pole piece **24**. An "O" ring **69** provides a fluid tight seal between the tube collector pole piece **24** and the housing **68**.

The beam collector electrode **27** is secured to the collector pole piece structure **24** via the intermediary of an annular electrical insulator assembly **71** to permit the collector electrode **27** (beam collector bucket) to be operated at a depressed collector potential relative to the potential applied to the block body portion **35** of the tube **11**. An "O" ring electrical insulator and seal **72** is disposed encircling the collector fin assembly in between the fins and the inside wall of the collector housing **68**. The "O" ring **72** serves to support the collector bucket **27** via the fins and to seal the annular space between the outside of the fins, which are closed off by a cylindrical baffle **70**, and the housing **68** such that the fluid coolant is forced to percolate through the perforated fins to the collector manifold **28** at the end of the tube **11.**

Electrical potential is applied to the collector bucket **27** via an electrical feedthrough assembly **73** interconnecting the collector bucket **27** and the center conductor of the feedthrough via a flexible wire **74**. The end of the collector bucket **27** is insulatively supported from an end wall **76** of the housing **68** via a cylindrical insulator **75** made of a high temperature resistant plastic, such as polyamide having a circular array of radially directed perforations therein permitting the coolant to flow radially into the center of the cylindrical insulator **75** and thence into the manifold **28.**

The tube **11** is readily removed and replaced within the solenoid **18** by loosening the collector cap screws **68** such that the tube is disconnected from the solenoid. The tube is then pulled out of the solenoid from the collector end. Since the cathode **12** and the main body portion **15** of the tube have generally the same outside transverse dimensions, the tube **11** is readily removed from the solenoid. The coolant tank **19** and solenoid are carried from a support structure via a mounting bracket assembly, not shown.

In a typical example, the tube **11** is utilized as an X-band power amplifier providing 10 KW of power output at X-band, with 50 db gain and 8 percent instantaneous electronic bandwidth (between 1 db points). The solenoid **18** provides an axial magnetic field within the beam of 2,500 gauss for focussing the beam **13.** The beam has a current of 2.5 amps and a beam voltage of 19 KV at a microperveance of 1.0. The tube together with its mounting bracket, waveguides, coolant, connectors, solenoid, and hoses weighs approximately 55 poinds, and is approximately 18 inches long.

Referring now to FIG. 4 the collector pole piece structure **24** is shown in greater detail. More particularly, the pole piece includes an annular chamber **82** which surrounds an axially reentrant centrally apertured cylindrical core portion **83**. The core portion **83** is notched at **84** on opposite sides of the beam path with rectangular notches to allow passage of the input and output waveguides **17** and **16**, respectively. The notches **84** have a radial depth greater than the outside height of the waveguides **16** and **17** such as to provide a fluid communication passageway communicating through the oversize notch between the fluid passageways **23** in the main body portion **15** and the chamber **82** of the collector pole piece structure **24.**

The annular array of perforations **59**, in the wall of the collector pole piece facing the solenoid **18**, is axially aligned with similar perforations **59** in the solenoid pole piece **55**. The inside wall of chamber **82** which faces the solenoid **18** is provided with an annular recess **85** at a radius corresponding to the radius of the circular array of perforations **59** so as to facilitate flow of coolant through those perforations **59** underlying the waveguides **16** and **17.**

The waveguides **16** and **17** each include an E-bend portion **86** extending radially outwardly of the beam path **13** on opposite sides thereof. The E-bend portions each connect to 90° H-bend elbows **87** for bending the waveguides **16** and **17** into parallel paths within the chamber **82**. The H-bend sections **87** connect to straight sections of rectangular waveguide of lesser dimensions than standard waveguide which pass through the outer wall portion **88** of the pole piece **24** via milled recesses therein at **89**. The waveguides **16** and **17** are brazed to the walls of the hollow collector pole piece structure **24** to provide thermally conductive fluid tight seals therebetween.

In a preferred embodiment (See FIGS. 2 and 4), the hollow collector pole piece structure **24** is fabricated by machining a first half **91** of the pole piece structure which faces the beam collector and a matching plate **92** which is brazed to the first half **91** to define the hollow collector pole piece structure **24**. The stainless steel tubular main body strengthening member **34** is brazed at

94 to the inner end of the reentrant central core portion 83 of the collector half 91 of the pole piece structure 24.

The core portion 83 of the pole piece structure 24 includes a central bore 95 into which is pressed an electrically and thermally conductive non-magnetic insert 96, as of copper. The insert 96 is centrally counterbored to define the beam passageway therethrough. The insert 96 is brazed within the interior bore 95 of the pole piece core 83. The reentrant end of the core 83 is brazed to the end wall of the block body portion 35 at 97.

What is claimed is:

1. In a microwave linear beam tube:

electron gun means for forming and projecting a beam of electrons over an elongated linear beam path;

beam collector means at the terminal end of said beam path for collecting and dissipating the energy of the electron beam;

microwave interaction circuit means disposed along said beam path intermediate said electron gun means and said beam collector means for electromagnetic wave interaction with the beam to produce output microwave energy;

electrical solenoid means disposed surrounding said microwave interaction circuit means for generating an axial magnetic field in the beam path for focusing the electron beam through said microwave interaction circuit means;

a collector pole piece structure disposed at the beam collector end of said solenoid for shaping the beam focus magnetic field in the region of said beam collector means, said collector pole piece structure being made of a ferromagnetic material and including a chamber therin; at least four passageways from said chamber through said pole piece structure:

an output waveguide structure for coupling the output microwave energy from said microwave circuit to a utilization device; a portion of said chamber containing a length of said waveguide structure, and said waveguide structure passing into and out of said chamber through two of said passageways; another portion of said chamber formed to contain a fluid coolant, and at least two of said passageways disposed for conduction of said fluid coolant into and out of said chamber.

2. The apparatus of claim 1 wherein said collector pole piece structure includes, a first ferromagnetic portion affixed to and carried from said solenoid means and a second ferromagnetic portion which includes said chamber and which is affixed to and carried from said microwave circuit means and said beam collector means, and means for detachably securing together said first and second portions of said collector pole piece structure.

3. The apparatus of claim 1 including an input waveguide structure for supplying microwave energy to said microwave circuit, said input waveguide structure passing through a portion of said chamber of said ferromagnetic collector pole piece structure.

4. The apparatus of claim 3 wherein said input and output waveguide structures include, oppositely outwardly directed portion on opposite sides of the beam path, and each of said input and output waveguides having a 90° H-plane bend portion within said collector pole piece structure for causing said input and output waveguide structures to pass through the wall of said collector pole piece structure in general parallelism to each other on the same side of the beam path.

5. The apparatus of claim 1 including body fluid coolant passageway means disposed in heat exchanging relation with said microwave circuit means for directing a flow of fluid coolant therethrough for cooling of said microwave circuit means, collector fluid coolant passageway means disposed in heat exchanging relation with said beam collector means for directing a flow of fluid coolant therethrough for cooling said beam collector means, and wherein said collector pole piece fluid coolant passageway means is disposed in fluid communication with said body fluid coolant passageway means and with said beam collector fluid passageway means for flow of fluid coolant between said body fluid coolant passageway means and said beam collector fluid coolant passageway means through said collector pole piece fluid coolant passageway means.

6. The apparatus of claim 5 including, solenoid fluid coolant passageway means disposed in heat exchange relation with said solenoid means for directing a flow of fluid coolant therethrough for cooling of said solenoid means, and wherein said collector pole piece fluid coolant passageway means is disposed in fluid communication with said solenoid fluid coolant passageway means.

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