Jan. 4, 1966

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3,227,915

FLUID COOLING OF HOLLOW TUNER AND RADIO FREQUENCY PROBE IN KLYSTRON

Filed Oct. 17, 1960

4 Sheets-Sheet 1

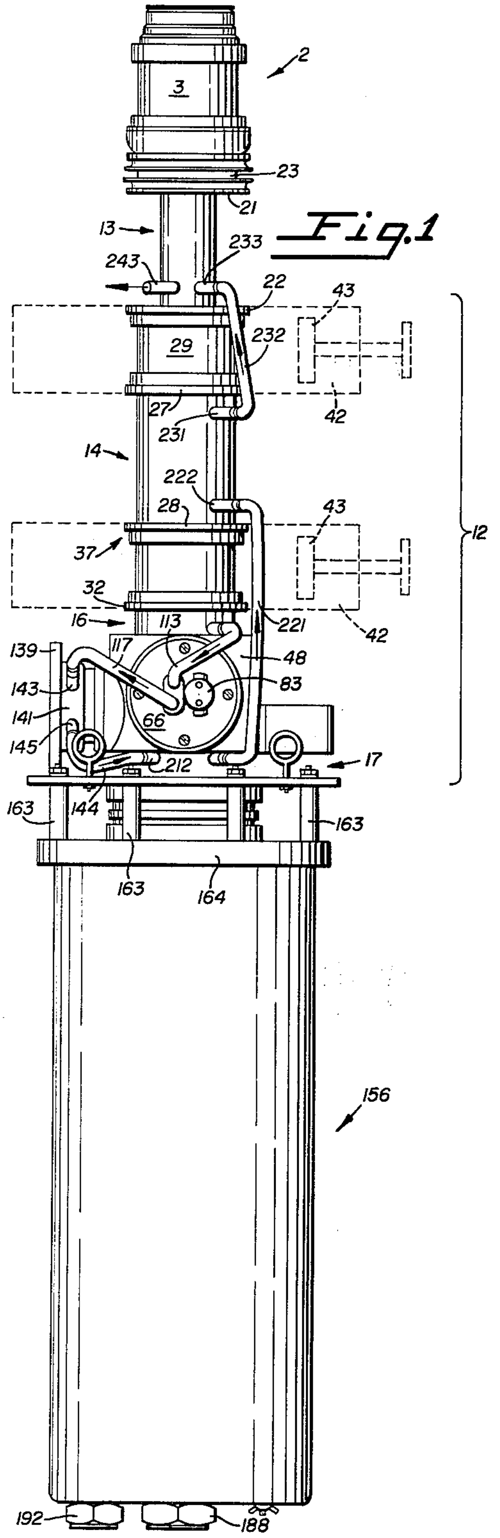

Fig.1

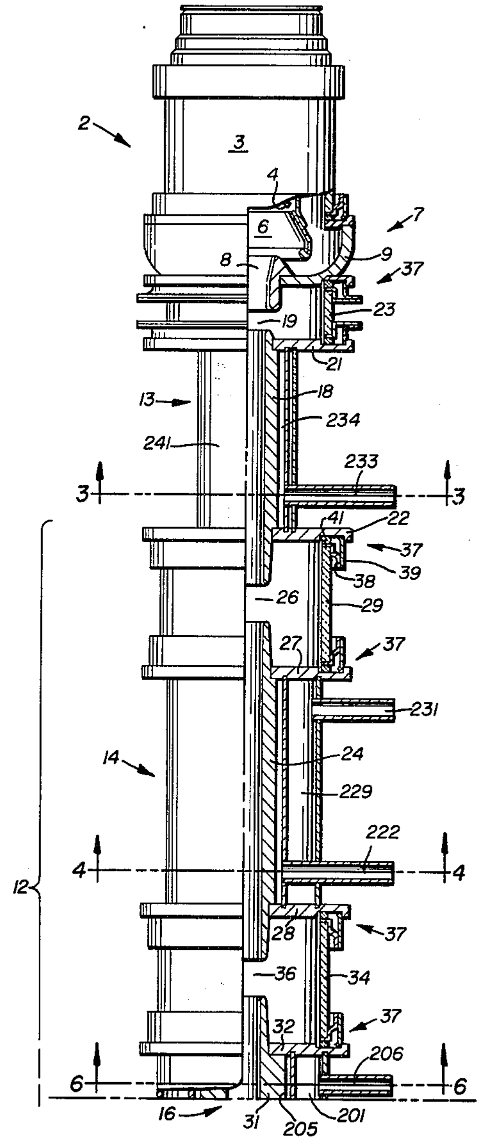

Fig.2

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Jan. 4, 1966 M. E. LEVIN 3,227,915

FLUID COOLING OF HOLLOW TUNER AND RADIO FREQUENCY PROBE IN KLYSTRON

Filed Oct. 17, 1960 4 Sheets-Sheet 2

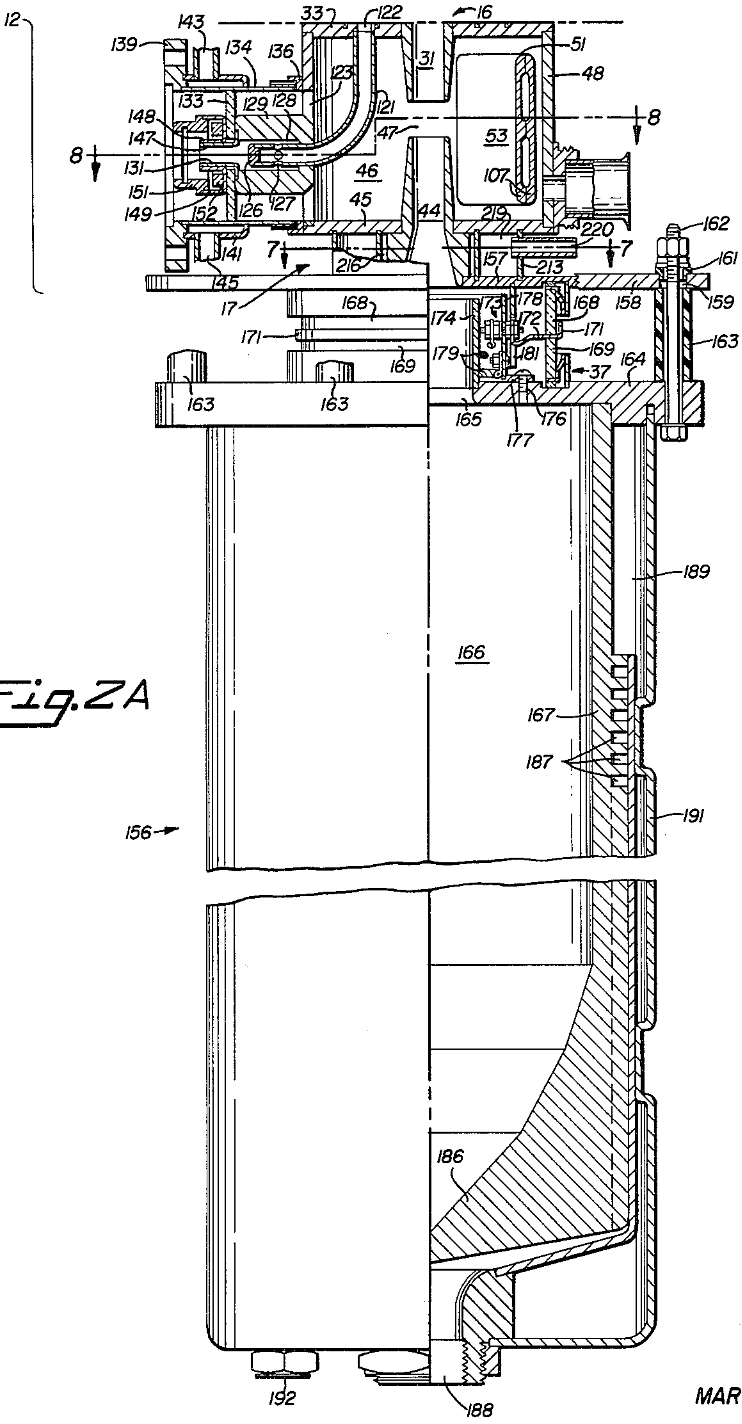

Fig. 2A

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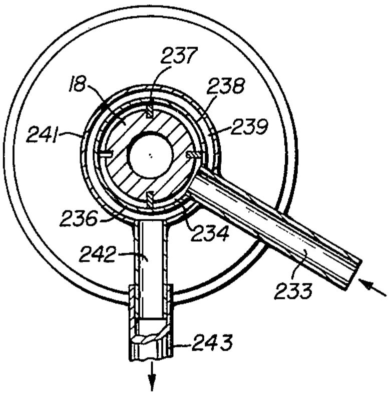
Fig. 3



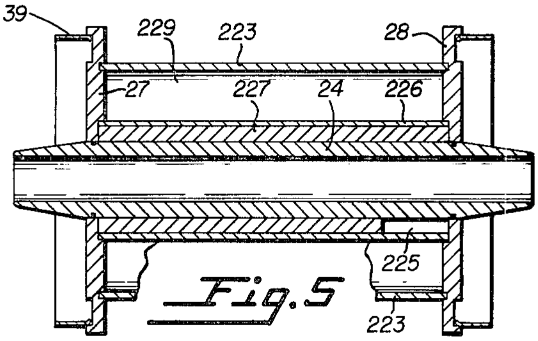


Fig. 5

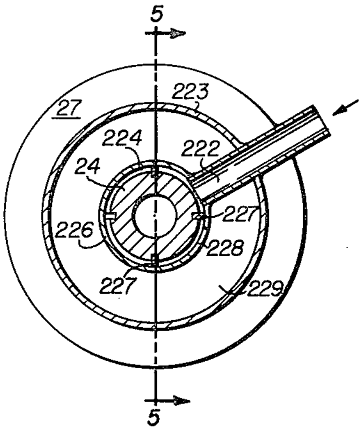
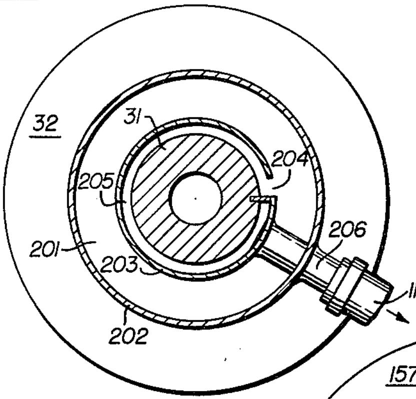


Fig. 4

Fig. 6



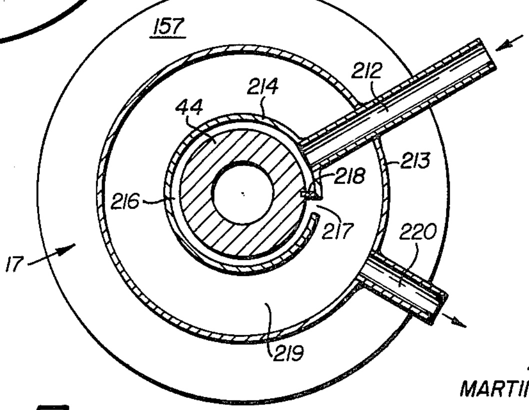


Fig. 7

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FLUID COOLING OF HOLLOW TUNER AND RADIO FREQUENCY PROBE IN KLYSTRON

Filed Oct. 17, 1960 4 Sheets-Sheet 4

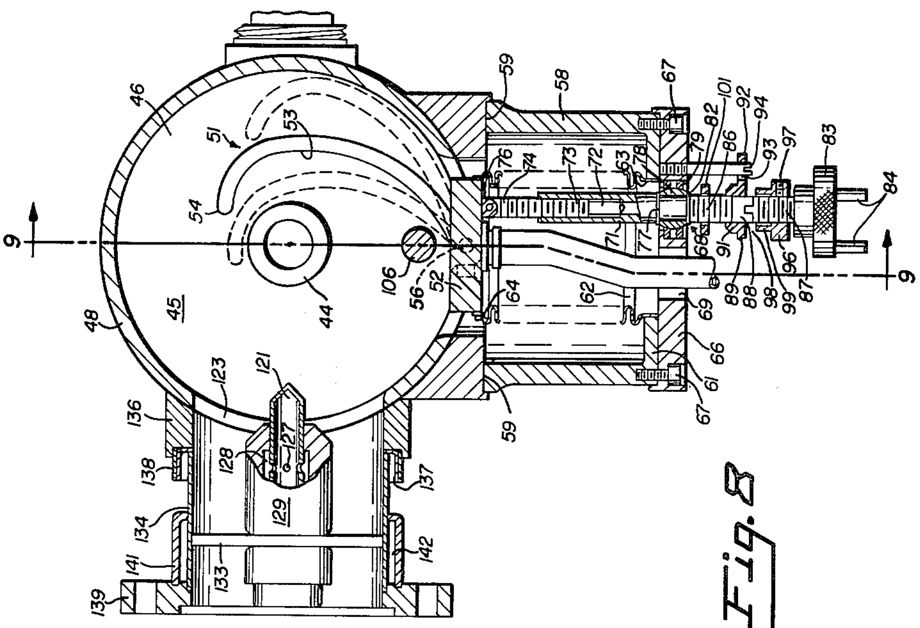

Fig. 8

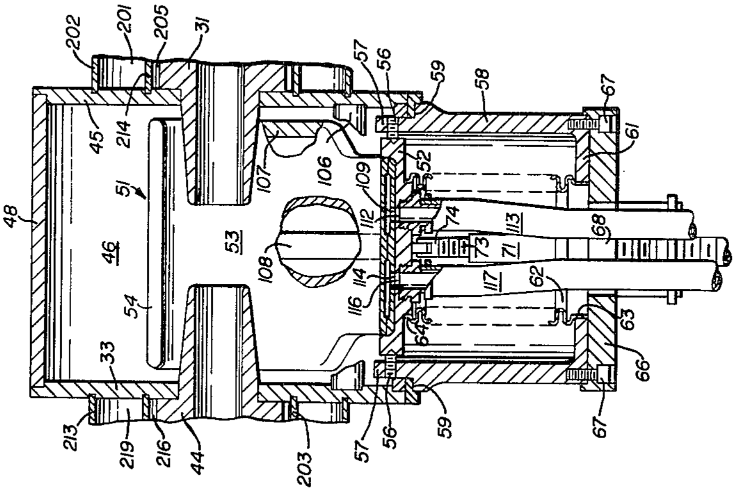

Fig. 9

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FLUID COOLING OF HOLLOW TUNER AND RADIO FREQUENCY PROBE IN KLYSTRON

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Filed Oct. 17, 1960, Ser. No. 63,001
10 Claims. (Cl. 315—5.46)

My invention relates to electronic discharge devices, and particularly to a discharge tube of the klystron type.

One of the important objects of the present invention is the provision of a multi-cavity klystron tube in which the output cavity is an integral cavity.

Another object of the present invention is the provision of a multi-cavity klystron for the production of from 50 to 75 kilowatts of continuous wave power at from 755 to 985 megacycles with at least a 15 bd gain.

A still further object of the invention is the provision of a klystron tube in which novel means are utilized to tune an integral cavity to the desired frequency.

Still another object of the invention is the provision of a tuning means which is accurately movable to tune the output cavity to a selected frequency and which incorporates appropriate cooling means.

Still another object of the invention is the provision of tuning means enclosed within an evacuated output cavity and having a configuration cooperating with the configuration of the cavity to provide tuning over a wide range of frequencies.

In high power klystron tubes of the type described, cooling of the elements of the tube which are subjected to extremely high temperature is a problem. It is therefore a further object of the invention to provide novel drift tube, collector and output loop assemblies arranged to provide optimum cooling efficiency.

Another problem presented by integral cavity klystron tubes is the problem of extracting electromagnetic energy from the output cavity. It is accordingly another object of the present invention to provide a novel cooled output window in the output cavity of a klystron.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of the invention. It is to be understood that I do not limit my invention to the embodiment disclosed, as I may adopt variant embodiments within the scope of the appended claims.

Briefly described, the klystron tube of my invention comprises an electron gun assembly connected at one end to a radio frequency interaction assembly including drift tube sections separated by dielectric radio-frequency window sections aligned with the drift tube sections. The radio-frequency assembly has attached to its other end a collector electrode to collect the beam of electrons projected by the electron gun through the radio-frequency assembly. The drift tube sections are axially spaced to provide interaction gaps at spaced intervals along the axis of the tube. The radio-frequency structure is provided with an integral output cavity surrounding the output gap of the drift tube. The electron gun, radio-frequency structure, and collector electrode are integrally and hermetically united together to form a vacuum-tight envelope which is subsequently evacuated. Surrounding each of the drift tubes intermediate the gaps is a novel and efficient coolant jacket assembly designed to provide an optimum amount of turbulence in the coolant fluid surrounding each of the drift tubes. For optimum efficiency, the coolant input is preferably arranged to place the coolant in contact with the hottest parts of the assembly first, or as close thereto as is practicable. Either water or some other coolant, such as a glycol solution, may be used. The integral output cavity is designed for resonance at the desired output frequency, the range extending from about 750 to 1,000 megacycles. Means are provided within the integral cavity movable to tune the cavity to the desired frequency from outside the cavity. Also associated with the output cavity is an output loop adapted to provide means for extracting electromagnetic energy from the output cavity. Means are provided in both the tuning means and the output loop in the output cavity for the passage of a fluid coolant. To couple the output cavity to a load, a novel output window is provided in one wall of the output cavity. Collector means are provided integrally united with the output cavity to receive the electrons after they pass from the output cavity. Because of the large power that is required to be dissipated by the collector electrode, suitable means are provided for cooling the collector electrode.

Referring to the drawings:

FIGURE 1 is an elevational view showing the entire klystron tube of my invention in operating position.

FIGURE 2 is an elevational view partly in vertical section of a part of the tube and showing the internal structure thereof.

FIGURE 2A is a continuation of FIGURE 2 in the same scale and disclosing the remaining part of the tube in elevation with parts shown in vertical section to disclose the internal construction.

FIGURE 3 is a horizontal sectional view taken in the plane indicated by the line 3—3 of FIGURE 2.

FIGURE 4 is a horizontal sectional view taken in the plane indicated by the line 4—4 of FIGURE 2.

FIGURE 5 is a vertical sectional view taken in the plane indicated by the line 5—5 of FIGURE 4.

FIGURE 6 is a horizontal sectional view taken in the plane indicated by the line 6—6 of FIGURE 2.

FIGURE 7 is a horizontal sectional view taken in the plane indicated by the line 7—7 of FIGURE 2A.

FIGURE 8 is a fragmentary horizontal sectional view taken in the plane indicated by the line 8—8 of FIGURE 2A.

FIGURE 9 is a fragmentary vertical half sectional view taken in the plane indicated by the line 9—9 of FIGURE 8.

FIGURE 1 is drawn to a scale approximately 1/6 actual size. FIGURES 2 and 2A are drawn to a scale approximately 1/3 actual size. FIGURE 3 through 9, inclusive, are drawn to a scale approximately 1/2 actual size.

In terms of greater detail, the klystron tube forming the subject matter of this invention comprises an electron gun designated generally by the numeral **2** and includes, operatively associated within a clyindrical dielectric housing or envelope portion **3**, electrode elements comprising a cathode **4**, a beam focusing electrode **6**, and an accelerating or modulating anode **7**, the latter including a centrally positioned coaxially arranged drift tube section **8**, and a housing or envelope portion **9** integrally and hermetically united to one end of dielectric cylinder **3**. Each of the electrodes is appropriately provided with an external terminal which may be connected to a source of power.

Operatively associated and integrally united with the output or downstream end of the electron gun is a radio-frequency structure designated generally by the numeral **12**. The radio-frequency structure includes a plurality of axially aligned and spaced drift tube assemblies designated generally by the numerals **13**, **14**, **16**, and **17**. Drift tube assembly **13** comprises a drift tube esction **18**, axially aligned with drift tube section **8** and spaced therefrom to provide a gap **19**, and provided adjacent its ends with integral annular mounting plates or flanges **21** and **22**. Serving to integrally and hermetically unite the electron gun structure with the radio-frequency (RF) structure is a cylindrical dielectric insulator **23**. The insulator is coaxially arranged around the adjacent end portions of drift tube sections **8** and **18** and about gap **19**, and is integrally and hermetically brazed at one end to modulating anode **7**, and at its opposite end is united in like manner to the peripheral edge portion of mounting flange **21**. Insulator **23** thus functions to electrically insulate the gun and RF structures while hermetically uniting them into a composite envelope.

Drift tube assembly **14** may be designated as the intermediate or long drift tube assembly and comprises a drift tube section **24** axially aligned and spaced from drift tube section **18** to provide an interaction gap **26**. Brazed adjacent opposite ends of drift tube **24** are parallel mounting plates or flanges **27** and **28**. To integrally and hermetically unite drift tube assembly **14** to drift tube assembly **13**, a cylindrical dielectric RF window **29** is interposed between flanges **22** and **27**. Opposite ends of the window are united to the associated annular flanges and brazed adjacent the outer peripheries thereof. As with insulator **23**, the window **29** functions to mechanically support the drift tube assemblies in axially spaced relationship, and functions also to electrically insulate these two drift tube assemblies against the passage of RF energy from one to the other. A third function performed by window **29** is to provide a portion of the envelope wall. It will be seen from FIGURE 1 that window **29** encloses a chamber between plates **22** and **27** which comprises a portion of a resonant cavity.

Drift tube assembly **16** is axially spaced from drift tube assembly **14** and comprises a drift tube section **31**, having oppositely disposed integrally united transversely extending annular plates **32** and **33** brazed adjacent opposite ends of the adjacent drift tube sections. As shown best in FIGURE 2, a cylindrical dielectric window **34** is integrally and hermetically interposed between flanges **28** and **32**. The lengths of the window and associated parts are proportioned to provide an interaction gap **36** between the adjacent ends of drift tube sections **24** and **31**.

It has been indicated that insulator **23** and each of RF dielectric windows **29** and **34** are integrally and hermetically united respectively to the associated modulating anode **7** and metallic plates **21**, **22**, **27**, **28**, and **32**. For clarity of description, the means utilized to form a hermetic and temperature-compensating union will be described only once, the construction being typical wherever required. As shown associated with radio-frequency window **29** and plate **22**, the sealing means as indicated generally by the numeral **37** comprises a thin metallic flange **38** brazed along one peripheral portion to the metalized end of dielectric cylinder **29**. The other end of flange **38** is autogenously welded, as by a heliarc process, to the adjacent and juxtaposed end of cylindrical flange **39**, the other end of which is in turn integrally brazed to a peripheral portion of plate **22**. A backing ring **41** of dielectric material similar to the material of window **29** is brazed on flange **38** opposite to and axially aligned with window **29** to relieve stresses in the union and form an abutting member against the plate **22** which permits relative motion between the parts.

From the foregoing it will be apparent that each of the sub-assemblies of the klystron tube is integrally and hermetically united to each of the other sub-assemblies in a rigid union capable of withstanding and compensating for expansion and contraction of the parts due to thermally imposed stresses. It will also be apparent that the relationship of the parts, being formed in a cylindrical configuration, renders the structure easy to fabricate, thus lessening the cost of the unit.

It is also apparent that mounting flanges **21–22**, **27–28**, and **32–33** on opposite ends of drift tube sections **18**, **24**, and **31** provide a near ideal means for detachably mounting external tuning boxes **42**, shown in dash lines in FIGURE 1. With this detachable type of tuning box in position, radio-frequency windows **29** and **34** define a portion of the resonant cavity within the evacuated envelope and permit the passage of electromagnetic energy into the external portion of the resonant cavity formed by the tuning boxes. Such tuning boxes are designed for the particular frequency range in which the tube is designed to operate and may be provided with conventional tuning means **43** capable of being adjusted from outside the tuning box. It will of course be obvious that in the event external tuning boxes are not applicable for a particular environment, gaps **26** and **36** may be surrounded by a resonant cavity completely enclosed by plates or mounting flanges **22–27** and **28–32**, and a metallic wall integrally united with the outer peripheral edges of these plates to provide integral cavities. Where integral cavities are provided, appropriate tuning means as hereafter described are preferably included within the evacuated chamber forming the resonant cavity; however, it is to be understood that the tuning means described herein is also applicable in external cavity resonators.

As shown best in FIGURES 2A and 7, drift tube assembly **17** comprises a drift tube section **44** axially aligned with drift tube section **31**. Annular plate **45** integrally brazed on drift tube section **44** adjacent one end lies axially spaced and parallel to plate **33** on drift tube assembly **16** and therewith defines a portion of an integral resonant cavity **46**. Drift tubes **31** and **44** are spaced from each other within the cavity to provide an output or working gap **47** therein. To complete resonant cavity **46**, conductive walls **33** and **45** are provided with a cylindrical interconnecting conductive wall **48** which encloses and defines the resonant output cavity and provides a conductive path connecting the adjacent ends of drift tube sections **31** and **44** for the passage of radio-frequency current. Means are provided associated with the integral cavity thus formed for tuning the cavity to the desired resonant frequency and for coupling energy out of the cavity.

The tuning means for the integral output cavity comprises a tuning paddle **51** (FIGURE 8) movably interposed between working gap **47** and wall **48** of the cavity. One edge of the tuning paddle remote from the working gap is integrally united to a pivotal base plate **52**. The tuning paddle extends away from the base plate in a shallow curved portion **53**, and terminates adjacent its free end **54** in a curved surface having a relatively shorter radius than the shallow curved portion **53**. As shown best in FIGURES 8 and 9, tuning paddle **51** has one edge which is parallel to the annular plate **45** and another edge which is parallel to the annular plate **33** of the cavity **46**. As can be seen from FIGURES 8 and 9, movement of the tuning means or paddle **51** toward and away from the drift tubes **44** will not change the spacing between the edges of the tuning paddle and the respective annular plates **33** and **45**. The distance between the parallel walls **33** and **45** of the cavity **46** and the edges of the tuning plate is less than the distance between the drift tubes and the face of the tuning paddle or plate throughout the major portion of the movement of the paddle or plate. It is only when the tuning paddle **51** is close to the drift tubes that the distance between the paddle **51** and the drift tubes **44** becomes equal to or less than the distance between the parallel walls of the cavity and the edges of the tuning paddle **51**. The capacitance between the edges of the paddle and the corresponding walls of the cavity is not affected by movement of the tuning plate or paddle **51**. However, as the tuning plate or paddle **51** approaches the center of the cavity where the high electric field is located, the capacitance formed by the edges of the tuning paddle and the corresponding walls of the cavity interacts more strongly with the electric field thereby changing the resonant frequency of the cavity. When the tuning plate or paddle **51** approaches close to the drift tube additional tuning is achieved due to the added capacitance across the gap. The base or pivot plate is pivotally mounted by conical type bearing pins **56** adjustably mounted on integral and inwardly extending lugs **57** formed on the inner end of a tuning housing 58. The housing is preferably cylindrical and extends transversely to the axis of the drift tubes. At its end adjacent lugs 57, the cylindrical housing is provided with shoulder 59 adapted to be integrally and hermetically brazed to wall 48 of resonant cavity 46, the lugs 57 extending into the cavity.

The end of the housing remote from resonant cavity 46 is provided with a radially inwardly extending integral annular flange 61 having a large central aperture therein. The aperture in flange 61 is hermetically closed by bellows 62 having its outer end 63 integrally and hermetically united to the inner periphery of annular flange 61, and its inner end 64 integrally and hermetically united to the side of pivotal base plate 52 remote from paddle 51. It will thus be seen that the tuning paddle 51 is permitted to pivot back and forth toward and away from gap 47, and the convolutions of the bellows flex to accommodate such movement. It is thus possible to control the movement of the tuning paddle by means outside the integral cavity. Such control means include a plate 66 detachably secured to the outer end of the tuning housing by cap screws 67 to provide a rigid but detachable support for the control mechanism. Plate 66 is provided with a circular bearing aperture 68, and an adjacent and elongated access aperture 69. When plate 66 is disposed over the end of cylindrical housing 58, apertures 68 and 69 lie disposed within the peripheral limits defined by the open end of bellows 62. The apertures thus provide passages for inserting mechanism through plate 66, which mechanism may be attached to pivot plate 52. Such mechanism includes an elongated stem 71 extending through aperture 68, and provided at its inner end with a threaded bore 72 in which is adjustably engaged a threaded stem extension 73 having a bifurcated lug 74 at its inner end pivotally connected detachably to an integral lug 76 on pivot plate 52. The lugs 74 and 76 cooperate to permit pivotal movement of the stem in one plane, but prevent rotation of stem extension 73. It is thus made possible to rotate stem 71 which is provided on its outer end with means for digitally manipulating the stem to control transverse movement of the tuning paddle.

As seen best in FIGURE 8, the stem is provided intermediate its ends with an integral shoulder 77 which determines the position of a bearing 78. The bearing 78 surrounds the stem within aperture 68 and cooperates with bushing 79 therein to provide a permanently flexible joint between the stem and plate. The bushing may be secured in the aperture by a suitable set screw (not shown). To lock bearing 78 on the shaft, a detachable snap ring 82 is provided on the side of the bearing opposite shoulder 77. As shown in FIGURE 8, by providing a peripheral surface on bearing 78 cooperating with a complementary surface in bushing 79, an effective universal joint is provided at this point. The stem is thus permitted to rotate about its own axis, which, as can be seen, extends transverse to the axis of drift tubes 31–44, and is also permitted to move in transverse planes about bearing 78 as a pivot point or fulcrum, but is prevented from moving longitudinally. Since clockwise rotation of the stem about its own axis will cause stem extension 73 to become further engaged in bore 72 and pivot plate 52 on pivot pins 56 to swing the tuning paddle outward into the high frequency position, the lug 76 will also swing in an arc about pivot points 56. This necessitates that the stem be capable of moving in a transverse plane when tuning paddle 51 is adjusted.

Rotation of the stem is effected by turning knurled head 83 on the outer end of the stem, which head is provided with lugs 84 for detachable engagement of a suitable wrench. It is desirable to prevent the tuning paddle from touching drift tubes 31 and 44 because to do so would probably melt the paddle as the result of electron bombardment or intense RF current flow, and it is also desirable to keep the tuning paddle from bearing against wall 48 of the resonant cavity because to do so could result in placing a destructive stress on the pivot pins 56. Means are therefore provided on the stem to limit inward and outward movement of the paddle upon rotation of head 83 to prevent the transmission of mechanical stress onto the pivot pins 56 at either extreme of the paddle movement.

Outside the housing the stem is provided with a threaded section 86 adjacent bearing 78, and another threaded section 87 adjacent turning head 83. Intermediate these two threaded sections of the stem is a section 88 devoid of threads. Threadedly engaging the section 86 of the stem is a guide plate 89 having a central hub 91 from which extends integral guide flanges 92 having slots 93 adjacent their outer ends. The flanges 92 extend on opposite sides of the stem, and the slots are snugly and slidably engaged by the outer end of a control screw 94, the inner end of which is threadedly engaged in plate 66. It will thus be seen that as the stem is rotated in either a clockwise or counterclockwise direction to manipulate the tuning paddle, guide plate 89 is prevented from rotation by screws 94 working in slots 93, but is permitted to move in either direction along the threaded section 86 relative to the stem. The slots, of course, accommodate transverse movement of the outer end of the stem.

To control outward movement of the tuning paddle toward the wall 48, a stop nut 96 adjustably threaded on threaded section 87 of the stem is provided. A set screw 97 in the stop nut adapted to be jammed against the stem provides means for locking the lock nut in a desired position. The position in which lock nut 96 will be locked is determined by the extent that it is desired the tuning paddle 51 to move. Thus, as shown best in FIGURE 8, space 98 between flange 99 on the stop nut and hub 91 of guide plate 89 may be adjusted to permit a prescribed number of clockwise revolutions of the stem to bring the guide plate into jamming relation with the stop nut. Further rotation of the stem in this direction is therefore prevented. Conversely, to limit inward movement of the tuning paddle, a stop washer 101 is adjustably interposed on threaded section 86 between hub 91 of guide plate 89 and snap ring 82. Adjusting the position of washer 101 with respect to hub 91 thus determines the number of counterclockwise revolutions required to bring the guide plate into jamming relationship with washer 101. When these two elements have been brought into this jamming relationship, further rotation of the stem is prevented, and further movement of the tuning paddle toward the drift tubes is terminated. It will, of course, be understood that if desired the parts may be proportioned so that washer 101 abuts the snap ring and thus determines the inner limit of movement of the tuning paddle.

Because radio-frequency current will tend to flow around the cavity between the drift tube tips 31 and 44, there will be a tendency for the current to follow the conductive path provided by lugs 57, pivot pins 56, and pivot plate 52. Inasmuch as there is a discontinuous electrical path through the three elements, passage of current therethrough will tend to form an arc and/or heating at such discontinuity. To minimize the passage of current through these elements, means are provided electrically connecting the plates 33 and 45 in the area closely adjacent pivot plate 52. Such means comprise at least one axially extending conductor rod 106 integrally extending between plates 33 and 45. The conductor rod 106 thus forms a low resistance path between the two plates and prevents radio-frequency current from following the more resistive path through the pivot points.

Because it is subject to heating from electron bombardment, the tuning paddle is preferably hollow to provide for the passage of a fluid coolant therethrough. The tuning paddle is thus preferably fabricated from two shaped plates of copper provided with complementary peripheral flanges 107 adapted to be abutted and brazed to each other to complete the paddle. A centrally disposed pad 108 in the nature of a peninsula having a connection with peripheral flange **107** only at one end of the paddle, the pivot end, forms with the peripheral flange a tortuous path through the paddle for the turbulent passage of a coolant. An inlet aperture **109** adjacent the base of the tuning paddle communicates with aperture **112** in pivot plate **52** to admit coolant into the tuning paddle. The inlet aperture in the plate is connected by suitable means such as flexible conduit **113** to a source of coolant. An outlet aperture **114** adjacent the base end of the tuning paddle and on the opposite side of pad **108** from the entrance aperture is provided to permit the egress of water from the tuning paddle. The outlet aperture **114** is in registry with an outlet aperture **116** formed in pivot plate **52**. Flexible conduit means **117** connected with outlet aperture **116** carries the coolant away from the tuning mechanism. It will thus be seen that regardless of what position the tuning paddle may be in, coolant fluid may be pumped therethrough to carry away heat.

To couple radio-frequency energy out of integral output cavity **46**, means are provided on one wall of the cavity permitting the extension of a coupling loop **121** into the cavity. The coupling loop comprises a copper tube formed into an L shape and having one end within the resonant cavity integrally and hermetically brazed to plate **33** in registry with aperture **122** therein, as shown best in FIGURE 2A. The other end of the coupling loop extends out of the cavity through aperture **123** formed in wall **48**. The outer end of the tubular coupling loop is provided with a plug **126**, and apertures **127** extend through the wall thereof at a point spaced from the plugged end of the tube. Apertures **127** communicate the interior of the hollow coupling loop with the interior **128** of hollow coolant jacket **129**. At its inner end the coolant jacket **129** is integrally and hermetically brazed about tube **121** to prevent the passage of coolant into the output cavity except through the hollow loop **121**. At its outer end the coolant jacket **129** is provided with a sealing flange **131** extending through the central aperture of an annular dielectric radio-frequency window **133**. The outer periphery of the dielectric window **133** is integrally and hermetically brazed on the interior surface of copper cylinder **134**. As shown best in FIGURE 2A, the dielectric window is interposed between the inner and outer ends of cylinder **134**. The inner end of cylinder **134** is integrally and hermetically welded to wall **48** of the output cavity by means of a junction ring **136** and sealing flanges **137** and **138**. The union at this point is similar to hermetic seal **37** previously described, with the exception that the backing ring **41** is omitted. It will thus be seen that cylinder **134** is coaxially arranged with aperture **123** and the outer end of coupling loop **121**. It will also be apparent that cylinder **134** functions as the outer conductor of an integral coaxial transmission line section adapted to be connected to a complementary transmission line by an annular connecting flange **139** integrally brazed at its inner periphery on the outer end of cylinder **134**. An annular shell **141** surrounds cylinder **134** in the vicinity of radio-frequency window **133** in radially spaced relationship to provide a coolant passage **142** about cylinder **134**. The outer end of shell **141** is integrally connected in a water-tight manner to flange **139**, while the inner end of shell **141** is brazed about the cylindrical periphery of cylinder **134**. Inlet and outlet tubes **143** and **145**, respectively, are provided to admit and carry coolant away from the jacket.

Means are provided outside the dielectric window electrically connecting the outer end of coupling loop **121** to provide a connecting means for the inner conductor of an associated transmission line. Such means comprise an annular metallic sealing ring having a generally U-shaped cross section and a diameter substantially equal to the diameter of coolant jacket **129**, with the bottom of the U-shaped ring integrally and hermetically brazed to an annular metalized surface on the dielectric window **133** immediately adjacent the inner periphery thereof. The inner flange **147** of the sealing ring lies coaxially arranged and contiguous about the sealing flange **131**. By heliarc welding their outermost edges **148** as shown, the union at this point is made integral and hermetic. The outer flange **149** is brazed about the outer peripheral portion of a window bushing **151** coaxially arranged with respect to the aperture in the window. As shown in FIGURE 2A, the bushing **151** is preferably spaced a short distance from the outer surface of ceramic ring **152** interposed between bushing **151** and the bottom of the U-shaped sealing ring. Ceramic ring **152** forms a backing ring for the sealing ring to prevent rupture of the hermetic union between the sealing ring and dielectric window **133**. Spacing bushing **151** from backing ring **152** permits a measure of contraction and expansion of the parts due to fluctuations in temperature. From the foregoing it will be apparent that means having a uniform impedance have been provided for coupling energy out of the integral cavity which are at once rigid but which compensate for thermal expansion and contraction and which also provide for the passage of cooling liquid over elements which experience the greatest fluctuations in temperature. It will, of course, be obvious to those skilled in the art that in the event it is desired to couple a waveguide to the integral cavity, the coupling loop **121** would be omitted and window **133** would be replaced by a window designed to cooperate with an appropriate cavity-to-wave-guide transition section interposed between the cavity and the particular waveguide.

Rigidly mounted on the terminal end of the radio-frequency structure is a collector electrode assembly designated generally by numeral **156**. The tube shown is designed to have a maximum beam power of 210 kw. and a RF output of 50–75 kw., resulting in the collector being required to dissipate at least the energy remaining in the spent beam, which can be as high as 160 kw. Inasmuch as a beam may inadvertently be projected at a time when there is no RF in the circuit, it is desirable that the collector be capable of dissipating the entire 210 kw. of D.C. power in the beam. To dissipate the heat generated by this much power requires a collector of substantial size. Because the collector is substantial, a difficult problem is posed of mechanically attaching the collector electrode to the terminal end of the radio-frequency structure while maintaining the collector electrically insulated therefrom. Such connecting means preferably comprises a plate **157** integrally brazed on the terminal end of drift tube **44**, and an apertured annular ring **158** having threads on its inner periphery engaging the outer periphery of plate **157**. Apertures **159** adjacent the outer periphery of annular plate **158** receive dielectric bushings **161** which permit the passage of bolts **162** which bind the collector electrode to plate **158**. Dielectric spacers **163** surrounding bolt **162** and interposed between plate **158** and base plate **164** of the collector cooperate to electrically insulate and mechanically bind plates **158** and **164**.

Collector plate **164** is preferably of heavy copper-nickel and annular in cross-section to provide a central aperture **165** through which the electron beam may enter into the interior **166** of collector body **167**. Because the collector is axially spaced from the terminal end of the radio-frequency structure, means must be provided to hermetically communicate the interior of the collector to the interior of the radio-frequency structure. Such means are preferably provided by axially aligned dielectric cylinders **168** and **169** connected respectively to plate **157** and collector base plate **164**. One end of each of these cylinders **168** and **169**, which are preferably ceramic, is integrally and hermetically united to the associated plate by means of a seal **37** similar to those previously described. The adjacent metalized edges of the two axially aligned cylinders are integrally and hermetically brazed to an intervening terminal and sealing ring **171**, extending into the envelope to provide an inner terminal **172** to which is connected an appropriate gettering structure designated generally by numeral **173**. The gettering structure is shielded from the electrons passing between the radio-frequency structure and the collector by means of cylindrical flange **174** brazed at one end adjacent the inner periphery of collector plate **164**. The gettering structure is detachably connected to collector plate **164** by screws **176** utilized to anchor flange **177** of the getter structure to the plate. The cylindrical upstanding flange **178** coaxially arranged with cylinder **174** supports the getter material **179**. Another cylindrical shield **181** is brazed at one end to plate **157** and surrounds the upper end portion of flange **178**, the free end of which is spaced from plate **157**. It will thus be seen that shield **181** prevents the gettering material from being splattered on the interior surface of dielectric cylinders **168** and **169**, which would provide a conductive path between plates **157** and **164**.

The body of the collector comprises a tubular cross-section open at its end adjacent collector plate **164** and integrally brazed thereto. The other end of the collector remote from plate **164** is provided with a closed end formed by a cap **186**. Suitable spiral coolant passages **187** surround body **167** of the collector in a manner to provide non-laminar turbulent flow and communicate an inlet port **188** with an outlet passage **189** provided between the body of the collector and a coolant jacket **191**. An outlet port **192** communicates with the space **189** to permit the escape of coolant fluid. The end of jacket **191** adjacent plate **164** is integrally brazed thereto in a fluid-tight connection.

The collector, however, is not the only element of a klystron tube which requires cooling. Other elements of the structure closely related to the electron beam are apt to be bombarded by electrons and become hot and therefore require cooling. Such other elements include the drift tube assemblies and the radio-frequency windows associated therewith. To effect such cooling I have provided an interconnected cooling system adapted to provide optimum turbulence in the coolant fluid in contact with the elements required to be cooled. It should therefore be noted that all coolant passages have been designed to provide a passage having a cross-sectional area equivalent to a passage approximately one inch wide and one-eighth inch deep. These proportions have been found to provide "turbulent" flow in contradistinction to "parallel," "laminar" or "viscous" flow of ethelene glycol in the temperature range between +5° C. to +65° C. Because it is important that the coolant fluid enter the system at or adjacent the point of highest temperature, the system which I have provided preferably admits the coolant to the system through radio-frequency window **133** into coolant jacket **129**. It will, of course, be apparent that in a particular application coolant may be admitted at two points in the system and exit at a common outlet. From coolant jacket **129** the coolant flows through apertures **127** and hollow coupling loop **121** into an appropriate jacket assembly surrounding drift tube section **31**, and shown best in FIGURE 6. As there shown, the coolant enters the jacket assembly through aperture **122** in plate **33** and flows into chamber **201** comprised by outer cylindrical shell **202** and inner cylindrical shell **203**. As shown in the drawing, shell **203** is radially spaced in coaxial relationship to the exterior surface of drift tube **31**. A slot **204** in cylindrical shell **203** permits coolant to flow from the chamber **201** into chamber **205** provided between inner shell **203** and the drift tube. From this relationship of the shells **202** and **203**, it will be seen that inner shell **203** is spaced from the drift tube an amount to ensure the requisite cross-section for turbulent flow.

From its point of entry, the coolant flows in a turbulent manner around the drift tube and exits through tube **206** having its inner end integrally brazed to shell **203** and communicating with passage **205**. Its outer end extends outwardly through chamber **201** in a fluid-tight manner, to be appropriately connected at its outer end by conduit means shown best in FIG. 1. As shown, such conduit

means comprises conduit **113**, shown in FIGURES 1 and 9, communicating with the inlet port of the tuning paddle **51**. Coolant from the jacket thus enters the tuning paddle, circulating turbulently through the hollow paddle, and exiting through conduit **117**, the other end of which is connected to inlet tube **143** of jacket **141** surrounding the radio-frequency window.

From this coolant jacket, conduit **144** connects the outlet connection **145** to the inlet **212** of a coolant jacket assembly surrounding drift tube **44**, shown best in FIGURE 7. The inlet tube **212** extends in a fluid-tight manner through outer coolant jacket shell **213** and inner jacket shell **214**. Inlet coolant is thus deposited immediately adjacent the periphery of the hot drift tube and passes therearound turbulently through passage **216**, to exit through slot **217** in cylindrical jacket shell **214**. A baffle **218** integrally interposed between shell **214** and the drift tube channels the coolant in the proper direction for optimum heat transfer. From opening **217** the coolant spills into the chamber **219** contained between shells **213** and **214** and exits through an outlet tube **220**. Appropriate conduit means **221** connects the outlet tube **220** with the inlet tube **222** associated with the coolant jacket assembly on drift tube assembly **14**.

As best shown in FIGURES 2 and 4, this drift tube assembly differs somewhat from the previous jacket assemblies in that drift tube **24** is longer, thus exposing a greater area to the coolant, and providing greater opportunity for the use of appropriate baffles to channel the coolant in a manner to create turbulence in the flow of the coolant fluid over the drift tube surface. It should be understood that the baffles do not create turbulence by virtue of forming a tortuous passage, but rather by providing a passage of the proper cross-section. Thus, inlet tube **222** (FIGURE 4) extends in a fluid-tight manner through outer cylindrical jacket **223** and empties into chamber **224** confined between inner cylindrical jacket **226** and the exterior surface of drift tube **24**. To channel the flow of liquid around the drift tube with optimum turbulence, a plurality of baffles **227** are interposed between wall **226** and the drift tube. The baffles are circumferentially spaced at appropriate intervals about the drift tube to provide a passage between adjacent baffles having the requisite cross-section for optimum turbulence and extend longitudinally thereof. Each baffle, with the exception of one, is somewhat shorter than the drift tube to provide a gap **225** between one of its ends and an associated wall **28** or **27**, the gap formed by adjacent baffles being positioned at opposite ends of the drift tube. It will thus be seen that coolant entering chamber **224** immediately adjacent the inlet end of tube **222** will travel turbulently longitudinally along the drift tube between two adjacent baffles, one of which, as shown in FIGURE 5, extends the full length of the drift tube, and will spill across into the next adjacent chamber at the end of the drift tube where a gap appears due to the baffle end being spaced from the associated wall. The coolant thus progresses around the drift tube assembly in a zigzag fashion until it reaches exit port **228** which permits the coolant to spill into outer chamber **229** and from there through an outlet tube **231**.

Outlet tube **231** is connected by appropriate conduit means **232** with inlet tube **233** associated with the coolant jacket on drift tube assembly **13**. The inlet tube **233** is associated with the end of drift tube **18** remote from the electron gun, and empties into chamber **234** confined between cylindrical jacket wall **236** and drift tube **18**. Again, baffles **237** circumferentially spaced around the drift tube and interposed therebetween and wall **236**, channel the coolant longitudinally along the drift tube in one section, and permit it to spill over into another adjacent section and travel longitudinally along the drift tube in an opposite direction to provide a turbulent zigzag movement to the coolant which is very efficient in absorbing heat. The coolant exits from chamber **234** through port **238** into chamber **239** confined between the inner jacket wall

236 and outer jacket wall 241. The chamber 239 communicates through outlet tube 242 with an appropriate conduit 243 terminating in a waste line if the coolant fluid happens to be water, but terminating in apparatus for cooling the liquid if the coolant happens to be some other fluid such as glycol.

It will thus be seen that optimum cooling efficiency is obtained by admitting the coolest coolant at or near the hottest point of the apparatus and causing it to circulate turbulently through the unit, progressively encountering those elements which are coolest. It will also be apparent that the integral coolant jacket assemblies, being connected as they are between the drift tube or mounting flanges 21, 22, 27, 28, 32, 33, and 44, lend rigidity to the structure and provide a conductive path for heat to flow away from windows 29 and 34. It will also be apparent that novel means have been provided for tuning a resonant cavity, and for coupling energy out of that cavity and into an associated waveguide or coaxial transmission system.

I claim:

1. In a discharge device including means for projecting a beam of charged particles, means for intercepting the beam, and radio-frequency interaction means including at least one hollow cavity adapted to confine an electromagnetic field interposed between the beam projecting and intercepting means for interaction with the beam; the combination comprising a hollow tuner extending into the cavity, a hollow output conductor extending into the cavity and coupled to the electromagnetic field, and cooling fluid conduits associated with the tuner and opposite ends of the output conductor to effect cooling of the tuner and output conductor.

2. A klystron comprising an electron gun for providing a beam of charged particles, a collector for collecting the beam, cavity resonator interaction means between said gun and said collector and including a drift tube assembly adapted to provide a field free drift space for the beam of charged particles, said drift tube assembly comprising a hollow metallic cylinder, metallic wall plates brazed adjacent opposite ends of the cylinder, a first tubular sleeve disposed around said cylinder and integrally united at opposite ends to an associated wall plate to define therewith and with said cylinder a first chamber, a second tubular sleeve disposed around said first tubular sleeve and integrally united at opposite ends to an associated wall plate to define therewith and with said first tubular sleeve a second chamber communicating with said first chamber, inlet means connecting one of said chambers with a source of fluid coolant, and coolant outlet means connecting the other of said chambers.

3. The combination according to claim 2, in which said inlet means connects with said first chamber to place the coldest coolant in contact with the metallic cylinder.

4. The combination according to claim 2, in which said first and second tubular sleeves are concentrically arranged about said hollow metallic cylinder.

5. A klystron comprising an electron gun for providing a beam of charged particles, a collector for collecting the beam, cavity resonator interaction means between said gun and said collector and including a drift tube assembly adapted to provide a field free drift space for the beam of charged particles, said drift tube assembly comprising a hollow metallic cylinder, metallic wall plates brazed adjacent opposite ends of the cylinder, a first tubular sleeve disposed concentrically around said cylinder and united at opposite ends to an associated wall plate to define therewith and with said cylinder a first chamber, a second tubular sleeve disposed concentrically around said first tubular sleeve and united at opposite ends to an associated wall plate to define therewith and with said first tubular sleeve a second chamber communicating at one end with said first chamber, inlet means connecting one of said chambers with a source of fluid coolant, means interposed in said one of said chambers providing a tortuous path for said coolant between its inlet into the chamber and said communication between chambers, and coolant outlet means connecting the other of said chambers.

6. The combination according to claim 5, in which said means providing a tortuous path comprises at least one baffle interposed between said cylinder and first tubular sleeve arranged to cause said coolant to flow around said cylinder in a turbulent manner.

7. A klystron comprising an electron gun, a collector, and interaction means positioned between said gun and said collector, said interaction means comprising spaced drift tube sections forming gaps therebetween and a cavity resonator around each gap, a hollow coupling loop in the one cavity resonator closest to said collector, wall means around the drift tube section adjacent said one cavity resonator and forming a first cooling chamber, fluid conduit means connected to one end of said hollow loop, and the other end of said loop opening into said first chamber.

8. A klystron as claimed in claim 7 further comprising a tuner in said one cavity resonator and having a cooling passage therein, and conduit means connecting one end of said passage to said first chamber.

9. A klystron as claimed in claim 8 further comprising a disk shaped dielectric window insulating said loop from said one cavity resonator, wall means forming a second cooling chamber around the outside rim of said window, and conduit means connecting the other end of said tuner passage to said second cooling chamber.

10. A klystron as claimed in claim 9 further comprising wall means around another of said drift tube sections and forming a third cooling chamber, and conduit means connecting said second and third cooling chambers.

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