Oct. 27, 1970 L. K. FINDLEY 3,536,952

LIQUID COOLED AMPLIFIER

Filed Dec. 5, 1966 2 Sheets-Sheet 1

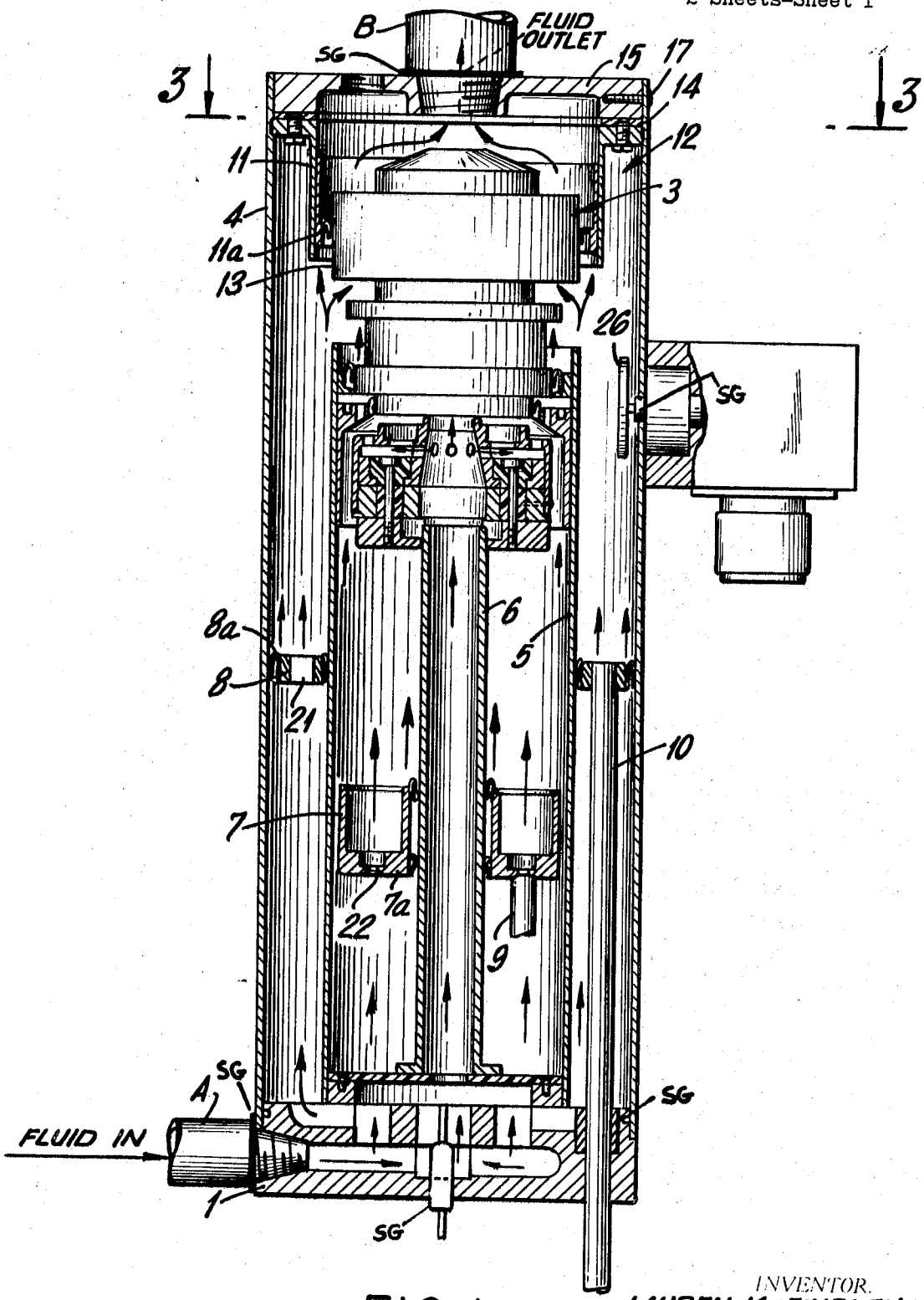


FIG. 1

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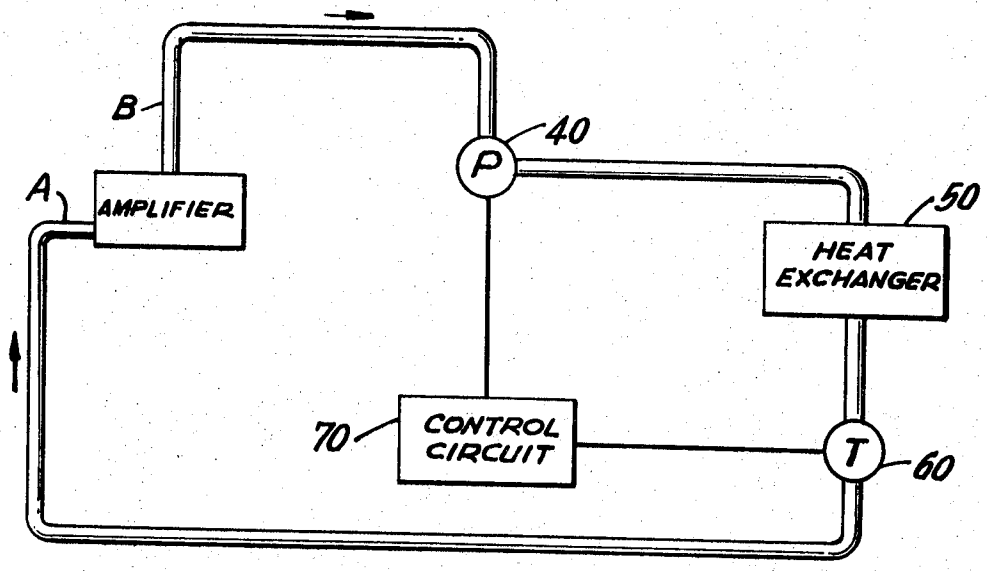


FIG. 2

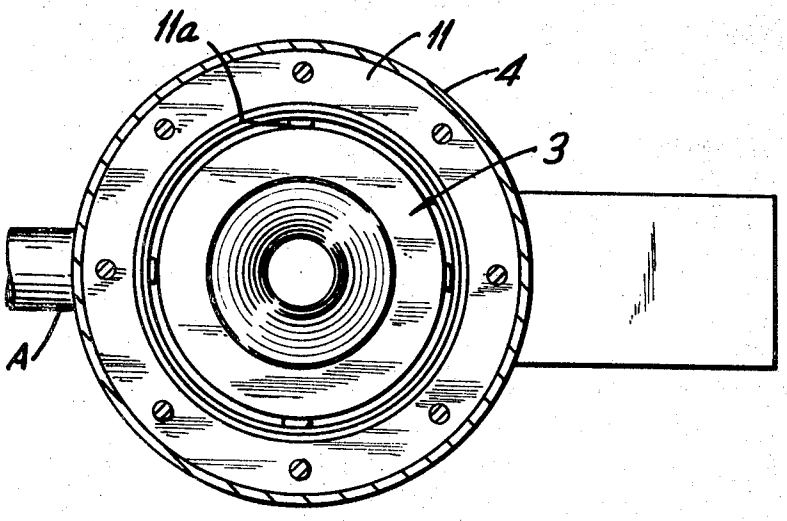


FIG. 3

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LIQUID COOLED AMPLIFIER

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Int. Cl. H01j 7/46, 7/26
U.S. Cl. 315—39 5 Claims

ABSTRACT OF THE DISCLOSURE

A microwave amplifier of the type having input and output tuning circuits and an active element is provided with ports and communicating channels for the circulation of a dielectric fluid. A circulating system transfers the fluid through the input and output circuits and around the active element to stabilize the temperature and provide the additional advantages outlined in the specification.

This invention relates generally to radio frequency or microwave amplifiers, modulators, oscillators, and the like, and in particular, to high power tubes and their adjunct circuitry.

Industry has long recognized temperature problems inherent in dissipating the heat from tubes amplifying, producing, or otherwise acting upon communication signals. This problem which is nonexistent at low power levels where the electrodes of the tubes can readily dissipate the heat, becomes of primary significance at large power levels. Numerous solutions have been proposed and many are in conventional use. These include radiating elements thermally contiguous the tube anode in conjunction with cooling fans and/or a circulating cooling fluid about the anode. Needless to say, unless suitable precautions are taken, the tube electrodes would become overheated causing the tube to either become inoperative or drastically shorten its life and efficiency.

Briefly, the present invention is predicated upon the concept of circulating a dielectric fluid not only about the tube anode but the remainder of its exterior surfaces and the adjunct microwave circuit as well. As a consequence, the following advantages are obtained:

(1) Because of the intimate contact between the fluid and the tube and circuit surfaces, temperature stability of tube and circuit is improved and thermal drift due to tube and circuit heating is essentially eliminated; frequency stability is thereby enhanced and the power level of operation is uprated.

(2) The adjunct circuitry is concentrated or made smaller since the dielectric (constant) of the fluid is greater than that of air rendering the microwave circuitry reduced in size.

(3) Critical voltage points on the tube and within the circuit cavities are now embraced by a high dielectric (strength) fluid rather than air. Consequently, the voltage breakdown problems prevalent at rarified atmosphere (for example, in high altitude planes) are obviated notwithstanding that the circuits are reduced in size.

(4) Amplifier generated heat may be remotely removed, for example, by a heat exchanger, thus reducing local physical noise inherent in the blowers conventionally used with power tubes having radiating fins.

(5) Corrosion problems, caused by sulphur or salt atmospheres, high humidity, dust, etc. within critical parts of the amplifier circuit are eliminated, and maintenance is drastically reduced.

(6) Since the dielectric constant of the cooling fluid may be responsive to temperature variations and in turn control the electrical dimension of the cavities, the circuit frequency characteristic may be made responsive to temperature and accordingly, vernier tuning may be effected by critical temperature control.

Accordingly, it is the object of this invention to provide a means for stabilizing the temperature of a microwave power tube within practical limits and to effect the advantages described immediately above.

The above mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will best be understood by reference to the foregoing description of an embodiment of the invention taken in conjunction with the accompanying drawings wherein:

FIGS. 1 and 3 illustrate side and top sectional views (the latter along line 3—3 in FIG. 1) respectively of one form of amplifier structure employing the present invention; and

FIG. 2 is a block diagram of a system according to the invention utilizing the amplifier of FIG. 1.

Referring now to FIGS. 1 and 3, there is shown an amplifier structure including a beam power tube **3** designed for forced air cooling by virtue of the radiating element **13**. Axially disposed with respect to tube **3** is a pair of concentric coaxial line resonators; tube **5** providing the inner conductor for the outer coaxial tube **4**, and the outer conductor for the inner coaxial tube **6**.

Electrically, the basic amplifier structure is similar to those conventionally known in the art and thus will be described only in sufficient detail to allow an understanding of how this type of structure may be modified in accordance with the invention.

Suffice to say, the input and output circuits of the amplifier are formed to include an input tuning annular brass member **7** having mounted thereon contact fingers **7***a* and a glass rod **9**, the assembly forming a shorting plunger of the conventional type; and an output tuning plunger including the annular brass member **8**, fingers **8***a* and glass rod **10**. Output coupling from the amplifier structure is afforded by means of disc **26** which, as is well known, displays the attributes of both a loop and a probe depending upon plunger position, etc.

The structure is hermetically sealed by virtue of the lower end cap **1** through which the dielectric cooling fluid is fed (via tube A), and upper end cap **12** through which the fluid leaves the structure (via tube **4**). The lower end cap is afforded a plurality of channels for dispersion of the fluid throughout the structure. For clarity of explanation, arrows have been applied to the drawings to indicate the directions which the fluid takes upon entering the structure. Needless to say only an exhaustive amount of views and sections would indicate the communication between the various vertical and horizontal communicating channels, and accordingly, it will be presumed that communication points exist where not shown in the particular view to distribute the liquid as indicated.

The upper end cap comprises a flanged member **11** having fingers **11***a* spaced upon the inner periphery for contacting and mechanically retaining the tube radiator **13**. Between flanged member **13** and end plate **15**, gasket **14** is disposed to hermetically seal this end of the amplifier. Screws **17** (only one of which is shown) are spaced about the periphery to retain end cap **12** in position with respect to outer coaxial element **4**.

Upon entering the lower end cap portion as described, the fluid is forced up and through the coaxial elements passing between the tuning elements and the associated coaxial tubes by virtue of the spacing afforded by the contact fingers. Since it is desirable that fluid turbulence be maintained at a minimum in order to insure good fluid contact with heated surfaces, it may prove necessary to add additional apertures (for example, **21** and **22**) to reduce eddy currents.

As may be seen from the figure, the fluid flows generally upwardly through the coaxial elements and the ports specifically provided for this purpose, passing about

the tube and in particular, in and about radiating element **13**, and ultimately passing out the fluid outlet in the end cap **12**.

At this juncture, it bears mentioning that care must be exercised to recognize both the RF leakage problem, as well as the fluid leakage problem. Thus, for example, with respect to the output element **26**, means must be provided to insure against leakage of the dielectric fluid to the output circuit. On the other hand, where ports such as **21** and **22** are introduced in the internal structure, care must be undertaken not only in the placement of the ports, but also in their size to reduce the RF leakage between adjacent stages. In general, the circuit configuration and the tube employed will dictate the input, output, and D.C. supply requirements which will in turn vary the sealing techniques required. While sealing techniques are well known, illustrative sealing gasket placement has been shown (SG). The gaskets themselves should be metal where possible and otherwise thin to reduce RF leakage.

FIG. 2 illustrates the overall system in block form. From this figure, it may be seen that the fluid passing upward, from the amplifier fluid outlet, proceeds to pump **40** from which it is circulated through the heat exchanger **50** which is remotely located with respect to the amplifier to reduce local noise and heat, through the temperature sensing device **60** and back to the amplifier at inlet A. Heat exchanger **50** may be of the conventional type with the fluid undergoing sufficient circulation through a cooling environment so that the temperature is reduced the desired amount. Provisions may be included for capturing air or gases in a reservoir, draining the systems and trapping residue or formed impurities (although clean dielectric fluids are available).

Since, as a general proposition, the heat loss from a fluid travelling through a heat exchanger depends upon the mass flow rate of the fluid, temperature sensitive element **60** may be employed to precisely control the speed of the pump **40** via the control circuit **70**. It is specifically envisioned that the control circuit **70** may fulfill the function of either maintaining the temperature at some predetermined constant, by regulating the fluid displacement effected by the pump **40**, or it may perform the more sophisticated function of tuning the frequency, as will be described.

To elaborate on the last point, it is well known that the dielectric constant of most fluids depends on the temperature. Accordingly, it is possible to vary the temperature within the practical limits to fine tune frequency. The change in frequency itself is inherent in the change in the dielectric constant since the frequency is dependent upon the relative electrical dimensions of the various components and these dimensions themselves depend upon the dielectric constant of the media embracing such components. Needless to say, this discussion would not be relevant where the dielectric constant remained stable and no dimensional changes are effected by changes in temperature. The discussion, however, pointedly illustrates a significant control feature which the invention introduces.

For example, temperature sensitive **60** could comprise a thermistor, hermetically sealed and inserted in the flow stream; the output of the thermistor controlling a D.C. amplifier in the control circuit which in turn would control a D.C. motor driving the pump. Auxiliary controls upon the exterior of the control circuit for superimposing a D.C. level voltage would allow vernier tuning of frequency.

Thus, it may be seen that by modifying conventional microwave amplifiers to permit the circulation of a dielectric fluid around the active element (tube) and through the adjunct circuit, the advantages specifically recited in the beginning of the specification are provided. The precise dielectric fluid employed may vary widely depending upon the desired result. A fluid with too great

a dielectric constant would cause the physical dimensions of the circuit to assume a size so small that it may become a practical impossibility to build a device. The dielectric constant which is too low, on the other hand, would produce very little physical reduction in size. A further consideration is a dielectric strength. That is, since the various components will be reduced in size, it is necessary that the voltage breakdown strength of the media employed be increased in direct proportion. A preferred coolant for this equipment is known as "DC 200" (dimethyl siloxane) which has a dielectric constant E of 2.78 and is manufactured by the Dow Corning Company. Other suitable coolants are liquids "FC 43" and "FC 75" (both inert fluoro-chemicals) made by Minnesota Manufacturing and Mining Company and "OS 45" (also a dimethyl siloxane) made by Monsanto Company.

It is to be noted that the inventive embodiment depicts the tube as the uppermost component with the anode on top. This is the preferred arrangement since the main heat source is the anode and any tendency of the fluid to assume a vapor state will occur here and not in the cavity where the electrical effect of the vapor could not be tolerated.

While the principles of the invention have been described in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention as set forth in the objects thereof and in the accompanying claims.

What is claimed is:

1. A microwave device comprising:

an active element;

at least one of an input tuning circuit and an output tuning circuit electrically and mechanically coupled to said active element;

an external hermetically sealed housing embracing said element and circuit;

means including communicating ports through said housing and passages in said circuit for permitting the circulation of a dielectric fluid around said active element and through said at least one tuning circuit; and

heat exchanger means coupled to said housing at said communicating ports for circulating said fluid between said exchanger means and said housing.

2. The improvement claimed in claim **1** further comprising means for sensing the fluid temperature; and means responsive to said temperature sensing means for regulating the temperature of said fluid.

3. The improvement claimed in claim **2** wherein said temperature regulating means comprises means for controlling the mass flow rate of the dielectric fluid.

4. The improvement claimed in claim **3** further comprising means for manually regulating the fluid temperature whereby the frequency of said circuit may be precisely controlled.

5. The improvement claimed in claim **4** wherein said element is a tube and said circuit includes at least one resonator.

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