Oct. 3, 1950 W. D. HERSHBERGER 2,524,290

METHOD OF AND MEANS FOR MEASURING DIPOLE MOMENTS OF GASES OR VAPORS

Filed July 26, 1946

FIG. 1

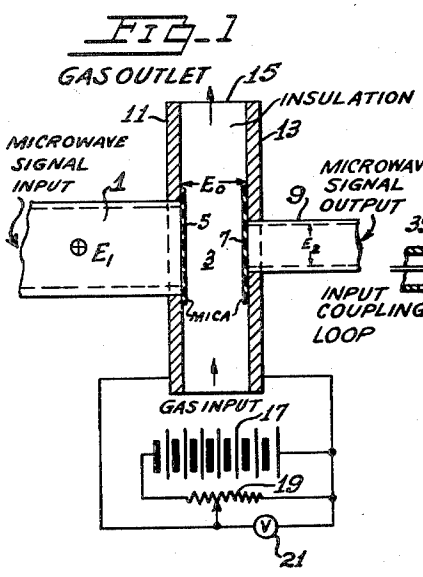


FIG. 2

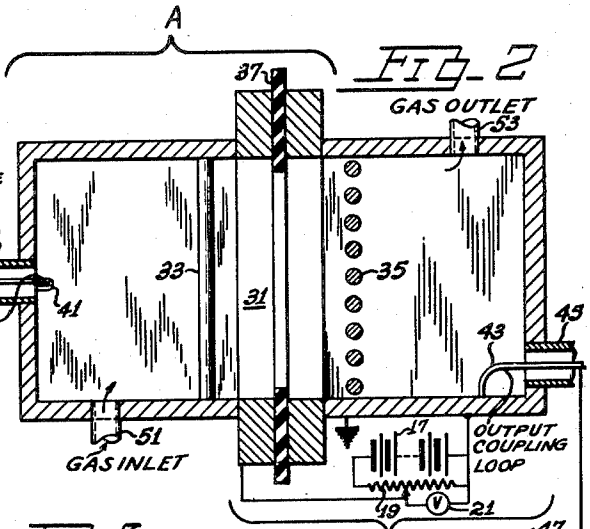
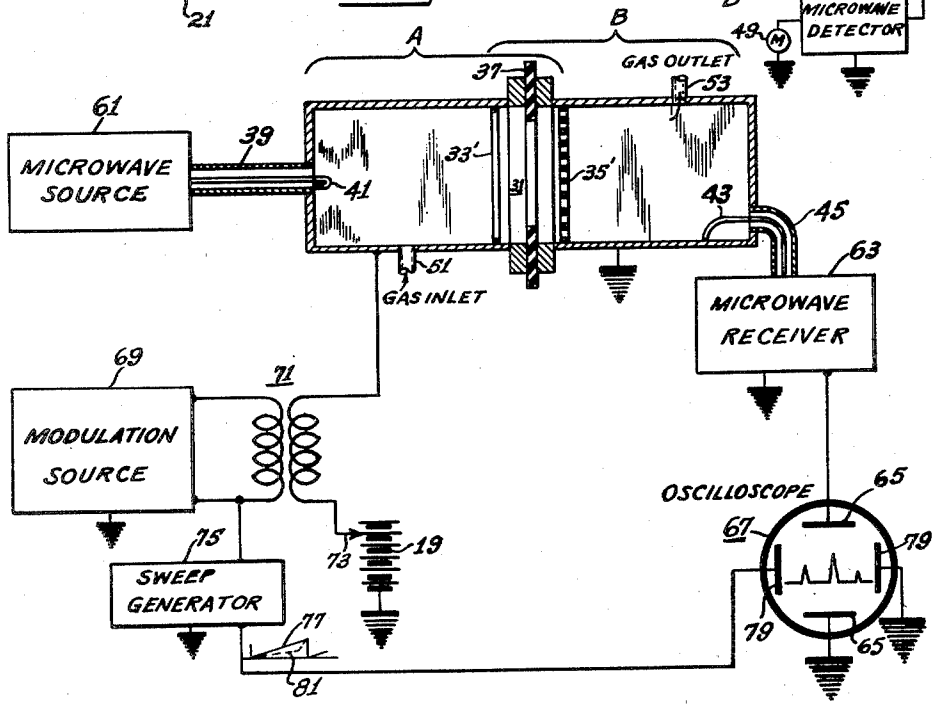


FIG. 3



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UNITED STATES PATENT OFFICE

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METHOD OF AND MEANS FOR MEASURING DIPOLE MOMENTS OF GASES OR VAPORS

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15 Claims. (Cl. 175—183)

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This invention relates generally to improved methods of and systems for gas and vapor analysis and more particularly to unique methods of and means for measuring the dipole moments of gases or vapors for determining the composition thereof.

The instant invention comprises improvements upon and modifications of the systems and methods described and claimed in applicant's copending application Serial No. 956,242, filed May 28, 1945, wherein analysis of gas composition is provided by measurements of the microwave energy loss, variations of dielectric constant and the frequency of the irradiating microwaves as a function of the gas pressure.

The instant invention also is an improvement upon the methods and systems described and claimed in applicant's second copending application Serial No. 596,244, filed May 28, 1945, which employ modulated microwaves for such gas analyses. In said latter application the modulated microwaves have a frequency providing appreciable microwave absorption in at least some components of the gaseous mixture. The gaseous mixture is irradiated by the modulated microwaves and is enclosed within a cavity resonator which is electrically resonant to the microwave carrier frequency and which is acoustically resonant to the modulation component of the modulated microwaves. Due to varying characteristics of different gases, the acoustic resonant frequency may be made a function of the gas composition, as well as of gas pressure, temperature and rate-of-flow in a continuous process.

Such gas analyses are extremely useful in monitoring chemical manufacturing processes as well as for indicating operating characteristics, or for controlling the operation of such processes. Output potentials derived from a microwave detector may be applied to control suitable devices such as pressure regulators, control valves, mixing jets, or controls for regulating the gas-flow characteristics in a continuous gas analysis system.

All such gas detection or analysis systems dependent upon microwave gas absorption, or variations in dielectric constant, in a microwave absorptive gas require considerable microwave-absorptive gas pressure in order to provide reasonable measurement sensitivity. Heretofore, gas production processes frequently have required the taking of samples of the gases for chemical or spectroscopic analyses. Such analyses require considerable time and also may require that the production process be interrupted until the

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analysis is completed, thus necessitating considerable delay and expense.

The instant methods and systems provide continuous analyses of any desired portions of such production processes thereby permitting either mechanical or automatic control of the production processes when the gas components vary between predetermined marginal limits. When complicated gaseous mixtures are involved, such as in the manufacture of butadiene in synthetic rubber production, there is always the possibility of production of gases other than those desired. In accordance with the instant invention, direct and simultaneous indications may be provided of the presence and relative amounts or proportions of all gases or vapors in the mixture having dipole moment characteristics.

The instant invention contemplates utilization of the rotation of the electric field of microwave propagation through gases or vapors having dipole moments as a combined function of the magnitude of the dipole moment, the frequency of the microwave propagation, and the magnitude of an applied electrostatic field through which the microwaves are propagated. A first embodiment of the invention comprises a pair of waveguides having perpendicularly disposed electrical axes, said waveguides being coupled together through a third wavepath disposed between the ends of said pair of waveguides. The microwaves propagated through the third wavepath are subjected to an adjustable electrostatic field which rotates the electric field of the propagated microwaves as a combined function of the dipole moment of gases or vapors introduced into said wavepath, the frequency of said microwave propagation, and the field strength of said adjustable electrostatic field.

In the absence of gases or vapors having dipole moments, there is substantially zero coupling between the first two of said perpendicularly disposed waveguides. Adjustment of the potential providing the adjustable electrostatic field in the third wavepath therefore may selectively provide 90° rotation of the electric field of the propagated microwaves which thence may be detected in the second of said pair of waveguides. The voltage range required for producing the required electrostatic field in the third wavepath is a function of the frequency of the microwaves propagated through the system. If desired, a continuous gas or vapor flow may be provided through the third wavepath for continuous gas or vapor analysis.

A second embodiment of the invention com-

prises a pair of telescoping rectangular cavity resonators, operating in modes such that the electric field of the first is perpendicular to the electric field of the second in the volume common to both, and separated by parallel disposed wire screens, or by slotted walls having perpendicularly disposed screen apertures. A microwave source may be coupled into one of said resonators by means of a coupling loop, or other known coupling device, and an output coupling element may be provided in the other of said intersecting resonators. The gas or vapor to be analyzed should be circulated through both of the telescoped resonators. If desired, the gas may be confined to the common portion of the two resonators by gas-tight, microwave permeable windows disposed adjacent and parallel to the screen elements. The two resonators should be electrically insulated from one another at a point intermediate the oppositely oriented, parallel disposed screens or slotted walls. An adjustable unidirectional potential applied to the two resonators provides an adjustable electrostatic field between the oppositely oriented screens. Adjustment of the electrostatic field magnitude thereby provides selective adjustment of microwave coupling between the cavity resonators as a function of the microwave frequency, the dipole moments of the gases circulated through said resonators, and the magnitude of the electrostatic field in the space intermediate the two screens.

A third embodiment of the invention utilizes a pair of intersecting cavity resonators of the type described wherein the magnitude of the electrostatic field established between the screens is varied by signals derived from a modulation signal source. A microwave receiver coupled to the second of said cavity resonators is connected to the vertical deflection electrodes of a cathode ray oscilloscope or other oscillographic indicator. A timing wave generator synchronized with or actuated by the modulation signal source is connected to the horizontal deflecting elements of the oscilloscope. The effective range of the system may be controlled by an adjustable unidirectional potential source connected between the insulated cavity resonators and by selection of a suitable microwave frequency for the microwave signals coupled into the first of said resonators. If desired, the timing frequency generator may provide a modified sawtooth waveform for expanding a desired portion of the oscilloscope scale. Direct indications are provided of the relative dipole moments and relative proportions of all gaseous or vapor components of the gaseous mixture which have dipole moments.

It should be understood that liquids as well as gases may be analyzed by any of the systems comprising the instant invention, since the normal vapor pressure of many liquids is ample for providing the desired control of coupling between the input and output wave propagation elements of the system.

Among the objects of the invention are to provide unique methods of and means for analyzing gaseous mixtures. A second object of the invention is to provide improved methods of and means for measuring the dipole moments of gases or vapors. Another object is to provide improved methods of and means for measuring dipole moments of continuously circulating gases or vapors. A further object is to provide improved methods of and means for controlling continuous gas processes as a function of the dipole moments of predetermined gaseous or vapor components of the gaseous mixture. An additional object is to provide improved methods of and means for determining the dipole moments of liquids providing suitable vapor pressure having such dipole moments. Another object is to provide improved methods of and means for analyzing the gaseous or vapor composition of mixed gases and/or vapors as a combined function of the dipole moments of said gases or vapors, the frequency of microwaves propagated through said gases or vapors, and the magnitude of an electrostatic field through which said microwaves are propagated and to which said gases or vapors are subjected.

A further object of the invention is to provide an improved method of and means for analyzing the composition of gases or vapors having dipole moments by utilizing a plurality of perpendicularly disposed waveguides or cavity resonators wherein the coupling between said waveguides or resonators is controllable as a combined function of the frequency of microwaves propagated therethrough, the dipole moments of gases or vapors enclosed within said system and the magnitude of an electrostatic field to which said gases or vapors and said microwave propagation are subjected. A still further object of the invention is to provide an improved method of and means for analyzing the composition of gases or vapors having dipole moments wherein said electrostatic field is varied in accordance with modulation signals, and wherein an oscillographic indicator provides visual indications of the relative dipole moments and relative quantities of gases or vapors having such dipole moments.

The invention will be described in greater detail by reference to the accompanying drawing of which Figure 1 is a cross-sectional, partially schematic diagram of a first embodiment thereof; Figure 2 is a cross-sectional, partially schematic diagram of a second embodiment thereof; and Figure 3 is a cross-sectional partially schematic diagram of a third embodiment thereof. Similar reference characters are applied to similar elements throughout the drawing.

Referring to Figure 1 of the drawing, a microwave signal source, not shown, is connected to the input of a first waveguide **1** having its electrical axis E_1 in a plane normal to the drawing. The first waveguide **1** is coupled into a propagation wavepath **3** through a microwave permeable insulating window **5**, such for example as a thin layer of mica. The electrical axis E_0 of the wavepath **3** is in a horizontal plane. The wavepath **3** is coupled through a second microwave permeable insulating window **7** into a second waveguide **9** having its electrical axis E_2 in a vertical plane. The wide faces comprising, for example, circular metallic plates **11**, **13** of the wavepath **3** are insulated from each other by an insulating spacer **15** such as polystyrene. Gases or vapors having dipole moments are confined within or circulated through the wavepath **3**. A source of unidirectional voltage, such for example as a battery **17**, having a voltage divider **19** and a voltmeter **21** shunted therewith is connected between the wavepath wide faces **11**, **13**, to apply thereto a unidirectional potential to establish an adjustable electrostatic field in the plane E_0. Each of the two waveguides operates in the TE_{10} mode.

The fundamental equation for describing the precession of a molecule about the lines of electric force between conductors **11** and **13** is

$$E_0 p \sin\theta - E_1 p \cos\theta = \frac{jh}{2\pi}\omega \sin\theta \qquad (1)$$

where p is the dipole moment, E_0 is the magnitude of the electric field applied to the gas (esu/cm.), E_1 is the microwave field strength (esu/cm.), θ is the angle between E_0 and p, h is Planck's constant, and j is an integer provided by quantum mechanics. E_1 has a frequency $v=\omega_0/2\pi$, and when E_0 is adjusted so that $\theta=90°$ then

$$E_0p=j\frac{h\omega_0}{2\pi}=jhv_0 \quad (2)$$

and the dipoles are always perpendicular to E_0 and all rotate in synchronism with said field, thus providing transmission of microwave energy from the first waveguide 1 to the second waveguide 9. Then

$$p=j\frac{hv_0}{E_0}$$

and E_0 may be swept through the value for resonance at a low frequency rate such as 60 cycles, and the resonance curve may be observed on an oscilloscope, thus providing a convenient measure of the dipole moment of the gas or vapor and a useful method of gas or vapor analysis.

The theory of rotating dipoles in an electrical field was developed by Mannebeck in Phys. Zeitschrift 28, 72 (1927) and a satisfactory summary thereof is provided in "Electric and Magnetic Susceptibilities" by VanVleck (Oxford 1932) pp. 147–155.

For symmetrical top molecules the expression provided heretofore, namely $E_0p=jhv$, where $v=\omega_0/2\pi$ is not correct, but instead three quantum numbers (j, m, λ) must be employed. The correct expression for the symmetrical top molecule is

$$E_0p=hv\frac{j(j+1)}{m\lambda} \quad (3)$$

If $j=m=\lambda=1$, it is seen that

$$E_0p=2hv \quad (4)$$

The latter equation provides the correct relationship between E_0, the electric field strength in esu per cm.; p, the dipole moment; h, the Planck's constant, and v, the operating frequency.

If E_0 is expressed in volts per cm, P_0 is expressed in Debye units (a Debye unit$=10^{-18}$ esu units of charge $\times$ cm.), and v is expressed in megacycles, then

$$E_0=\frac{3.93}{P_0}v_{mc} \text{ volts/cm.} \quad (5)$$

since Planck's constant is 6.55×10^{-27} ergs per second.

For methyl chloride, $p=1.85$, while for ammonia (NH_3) $p=1.5$, and for methyl bromide $p=1.3$ Debye units. Accordingly, if a microwave frequency of 1000 mc. or a wavelength of 30 cm. is employed, $E_0=2100$ volts per cm. for methyl chloride (CH_3Cl), but 3020 volts per cm. for methyl bromide (CH_3Br). Thus if an operating microwave wavelength of the order of 30 cm. is employed, transmission from the first to the second waveguide may be obtained at discrete and widely differing values of E_0, depending on the gas used for coupling.

If the system is operated at a wavelength of 3 cm. instead of 30 cm., the field strength required for transmission would be 21,000 and 30,200 volts per cm., respectively. Such extremely high voltages would give rise to corona discharges unless the system were operated at gas pressures considerably above 1 atmosphere. To avoid the high voltage gradients required for operation at 3 cm., and simultaneously to obtain a narrow voltage gradient range over which the transmission effect may be observed, operation at wavelengths of the order of 30 cm. is preferable whereby the gas pressure may be reduced to values as low as 10^{-3} mm. of mercury for satisfactory operation.

However, a pressure of 1 mm. of the gas under observation may be used to obtain enhanced effects. To prevent corona discharge and simultaneously to avoid pressure broadening of the spectral line, a non-polar gas such as argon or nitrogen is added until the total pressure is such that there is no voltage break down at 2000 to 3000 volts per centimeter. The total pressure should be of the order of 10 cm. of mercury or less.

However, since waveguides become cumbersome for transmission of microwaves having wavelengths of the order of 30 cm., a cavity resonator technique is indicated. Moreover, it should be emphasized that 30 cm. waveguides may be employed, but that in order to maintain reasonably uniform field conformation, wire grills, arranged perpendicularly to each other, should be placed across the openings between the waveguides.

Referring to Figure 2, a convenient form of cavity resonator system according to the invention comprises a pair of telescoped rectangular cavity resonators A and B having a common portion 31 disposed between two parallel disposed wire screens 33, 35, or slotted walls, having perpendicularly disposed screen apertures. The two resonators A and B are separated by an insulated gasket 37, whereby the slotted screens 33, 35 may be maintained at an adjustable unidirectional potential by means of the battery 17 and voltage divider 19. A microwave source, not shown, is coupled into the first cavity resonator A by means of an input coaxial line 39 terminated in an input coupling loop 41 disposed in a plane normal to the drawing. Similarly the second cavity resonator B is coupled by means of an output coupling loop 43 in a plane parallel with the drawing, and through an output coaxial line 45 to a microwave detector 47 including an indicator 49.

Due to the perpendicularly disposed wire screens 33 and 35, there will be substantially no microwave coupling between the cavity resonators A and B unless the dipole moments of gases or vapors circulated through the two cavity resonators, the applied microwave frequency, and the strength of the electrostatic field established between the screens 33 and 35 are so related that the electric field is rotated through an angle of 90° in the coupling space 31 between the wire screens. The gas to be tested may be confined within the two cavity resonators or it may be circulated continuously therethrough from a gas or vapor conduit system, the inlet portion 51 and outlet portion 53 only being shown. The system is operative in the same manner as that described heretofore by reference to the device in Figure 1, since the electric vectors of the cavity resonators A and B are in perpendicular relation due to the perpendicular orientation of the apertures of the wire screens 33 and 35. The coupling between the cavity resonators is entirely controlled by the synchronous rotation of the gaseous molecules in the region 31 common to both cavity resonators.

A continuous and direct indicating system for measuring the presence and quantities of gases having dipole moments in a gaseous mixture is shown in Figure 3 wherein a microwave source 61 is coupled through the input coaxial line 39 and terminated in an input coupling loop 41

arranged in a plane normal to the drawing. The input coupling loop 41 is coupled into the first cavity resonator A which intersects the second cavity resonator B and has a common coupling space 31, as described heretofore by reference to Figure 2. Instead of wire screens 33 and 35 comprising conductors arranged in perpendicular relation, slotted walls 33' and 35' having perpendicularly disposed slots, may be employed. The output coupling loop 43 and output coaxial line 45 are coupled from the second cavity resonator B to a microwave receiver 63, the demodulated output of which is coupled to the vertical deflecting elements 65 of a cathode ray oscilloscope 67. In order that the system may be swept through a predetermined dipole moment range for simultaneously indicating the presence of a number of different gases having different dipole moments, a modulation signal source 69 is coupled through a transformer 71 and a series connected unidirectional voltage source, such as a battery 19, to apply a continuously varying voltage to the two slotted screen electrodes 33' and 35'. The range of the modulated voltage may be adjusted by an adjustable tap 73 on the battery 19. A sweep voltage generator 75 actuated by, or synchronized with, the modulated signal source 69 applies a sawtooth sweep potential as shown in the solid line graph 77 to the horizontal deflecting elements 79 of the oscilloscope 67. If desired, the sweep generator 75 may provide a modified sawtooth waveform, as shown in the dash line curve 81, to spread a desired portion of the timing scale on the horizontal axis of the oscilloscope. Various methods and systems for providing such modified sawtooth timing signals are well known in the oscillographic art.

In operation, adjustment of the tap 73 on the high voltage source 19 (which should be of the order of 2000 to 3000 volts) determines the median value of the dipole moment range to be indicated, and the magnitudes of the modulation signals superimposed upon the unidirectional potential determine the upper and lower limits of the dipole moment scale. The presence of gases or vapors having dipole moments in the gaseous mixture circulated through or confined within the cavity resonators A and B thus provide vertical deflection of the oscilloscope cathode ray at one or more points on the horizontal scale. The magnitude of the vertical deflection is characteristic of the quantity of gas present in the mixture for gases or vapors of each dipole moment value. The horizontal scale may be calibrated in values of dipole moment or in terms of known gaseous or vapor components. As explained heretofore, the dipole moment scale also may be shifted by selection of a different applied microwave frequency. The modulation signal source 69 may have any desired low frequency providing a sufficiently high rate of horizontal scanning for satisfactory observation.

Thus the invention disclosed and claimed herein comprises several systems for measuring and indicating the presence of gases or vapors having dipole moments wherein microwave transmission through said gases or vapors is subjected to an adjustable or varying electrostatic field to provide rotation of the electric fields of the microwave propagation between a pair of waveguides or cavity resonators in which the electrical fields are normally perpendicular.

I claim as my invention:

1. The method of utilizing a pair of wave propagation devices having perpendicularly disposed electric axes for analyzing the composition of gases or vapors having dipole moments, comprising applying an electric field to said gases or vapors in an intermediate wavepath disposed between and coupling together said devices, varying the strength of said field to control said wave coupling between said devices as a combined function of said field strength and the dipole moments of said gases, and indicating the characteristics of said composition as a function of said dipole moments and of said field strength in said intermediate wavepath.

2. The method of utilizing a pair of wave propagation devices having perpendicularly disposed electric axes for analyzing the composition of gases or vapors having dipole moments, comprising applying an electric field to said gases or vapors in an intermediate wavepath disposed between and coupling together said devices, varying the strength of said field to control said wave coupling between said devices as a combined function of said field strength and the dipole moments of said gases, and indicating the characteristics of said composition as a combined function of said dipole moments, the frequency of said wave propagation, and of said field strength in said intermediate wavepath.

3. The method of utilizing a pair of wave propagation devices having perpendicularly disposed electric axes for measuring the dipole moments of gases or vapors, comprising applying an electric field to said gases or vapors in an intermediate wavepath disposed between and coupling together said devices, varying the strength of said field to control said wave coupling between said devices as a combined function of said field strength and the dipole moments of said gases, and indicating said dipole moments as a function of said field strength in said intermediate wavepath.

4. Apparatus for analyzing the composition of gases or vapors having dipole moments including a pair of wave propagation devices having perpendicularly disposed electric axes, an intermediate wave propagation path disposed between and coupling together said devices, means for applying an electric field to said intermediate wavepath, means for varying the strength of said field to control said wave coupling between said devices as a combined function of said field strength and said dipole moments, and means coupled to one of said devices for indicating the characteristics of said composition as a function of the magnitude of wave propagation between said devices and of said field strength in said intermediate wavepath.

5. Apparatus for measuring the dipole moments of gases or vapors including a pair of wave propagation devices having substantially perpendicularly disposed electric axes, an intermediate wave propagation path disposed between and coupling together said devices, means for applying an electric field to said intermediate wavepath, means for varying the strength of said field to control said wave coupling between said devices as a combined function of said field strength and said dipole moments, and means coupled to one of said devices for indicating said dipole moments as a function of said field strength in said intermediate wavepath.

6. Apparatus for analyzing the composition of gases or vapors having dipole moments including a pair of wave propagation devices having perpendicularly disposed electric axes, a source of microwave signals coupled into one of said

devices, a microwave signal output circuit coupled to the other of said devices, an intermediate wave propagation path disposed between and coupling together said devices, means for applying an electric field to said intermediate wavepath, means for varying the strength of said field to control said wave coupling between said devices as a combined function of said field strength and said dipole moments, and means coupled to said output circuit for indicating the characteristics of said composition as a function of the magnitude of said output signals and of said field strength in said intermediate wavepath.

7. Apparatus for analyzing the composition of gases or vapors having dipole moments including a pair of waveguides having perpendicularly disposed electric axes, an intermediate wavepath disposed between and coupling together said devices, means for introducing said gases or vapors into said intermediate wavepath, means for applying an electric field to said intermediate wavepath, means for varying the strength of said field to control said wave coupling between said pair of waveguides as a combined function of said field strength and said dipole moments, and means coupled into one of said waveguides for indicating the characteristics of said composition as a function of said wave coupling between said pair of waveguides and of field strength in said intermediate wavepath.

8. Apparatus for analyzing the composition of gases or vapors having dipole moments including a pair of microwave cavity resonators having perpendicularly disposed electric axes, a source of microwave signals coupled into one of said resonators, a microwave signal output circuit coupled to the other of said resonators, an intermediate wave propagation path disposed between and coupling together said resonators, means for applying an electric field to said intermediate wavepath, means for varying the strength of said field to control said wave coupling between said resonators as a combined function of said field strength and said dipole moments, and means coupled to said output circuit for indicating the characteristics of said composition as a function of the magnitudes of said output signals and of said field strength in said intermediate wavepath.

9. Apparatus for analyzing the composition of gases or vapors having dipole moments including an enclosed conductive gas or vapor chamber having a pair of conductive apertured elements disposed transversely therein, the apertures in said elements being perpendicularly disposed to provide a pair of intersecting microwave cavity resonators having perpendicularly disposed electric axes, a source of microwave signals coupled into one of said resonators, a microwave signal output circuit coupled to the other of said resonators, the space between said screen elements common to said resonators comprising an intermediate wave propagation path coupling together said resonators, a source of voltage, means for applying said voltage to said elements to provide an electric field in said space, means for varying the strength of said field to control said wave coupling between said resonators as a combined function of the strength of said field and said dipole moments, and means coupled to said output circuit for indicating the characteristics of said composition as a function of the magnitudes of said output signals and of said field strength in said intermediate wavepath.

10. Apparatus for analyzing the composition of gases or vapors having dipole moments including an enclosed conductive gas or vapor chamber having a pair of conductive apertured elements disposed transversely therein, the apertures in said elements being perpendicularly disposed to provide a pair of intersecting microwave cavity resonators having perpendicularly disposed electric axes, a source of microwave signals coupled into one of said resonators, a microwave signal output circuit coupled to the other of said resonators, the space between said screen elements common to said resonators comprising an intermediate wave propagation path coupling together said resonators, a source of modulation signals, means for applying said modulation signals to said elements to provide a varying electric field in said space to control said wave coupling between said resonators as a combined function of the strength of said field and said dipole moments, and means coupled to said output circuit for indicating the characteristics of said composition as a function of the magnitudes of said output signals and of said field strength in said intermediate wavepath.

11. Apparatus for analyzing the composition of gases or vapors having dipole moments including an enclosed conductive gas or vapor chamber having a pair of conductive apertured elements disposed transversely therein, the apertures in said elements being perpendicularly disposed to provide a pair of intersecting microwave cavity resonators having perpendicularly disposed electric axes, a source of microwave signals coupled into one of said resonators, a microwave signal output circuit coupled to the other of said resonators, the space between said screen elements common to said resonators comprising an intermediate wave propagation path coupling together said resonators, a source of modulation signals, means for applying said modulation signals to said elements to provide a varying electric field in said space to control said wave coupling between said resonators as a combined function of the strength of said field and said dipole moments, and an oscillograph coupled to said output circuit and to said modulation signal source for indicating the characteristics of said composition as a function of the magnitudes of said output signals and of said field strength in said intermediate wavepath.

12. Apparatus according to claim 10 including a source of voltage, means for applying said voltage to bias said apertured elements, and means for adjusting said bias voltage to control the effective range of said indications.

13. Apparatus for analyzing the composition of gases or vapors having dipole moments including an enclosed conductive gas or vapor chamber having a pair of conductive apertured elements disposed transversely therein, the apertures in said elements being perpendicularly disposed to provide a pair of intersecting microwave cavity resonators having perpendicularly disposed electric axes, a source of microwave signals coupled into one of said resonators, a microwave signal output circuit coupled to the other of said resonators, the space between said screen elements common to said resonators comprising an intermediate wave propagation path coupling together said resonators, a source of modulation signals, means for applying said modulation signals to said elements to provide a varying electric field in said space to control said wave coupling between said resonators as a combined function of the strength of said field

and said dipole moments, and a cathode ray oscilloscope having a first ray deflection element coupled to said output circuit and having a second ray deflection element coupled to said modulation signal source for indicating the characteristics of said composition as a function of the magnitudes of said output signals and of said field strength in said intermediate wavepath.

14. The method of utilizing gases or vapors having dipole moments for controlling microwave coupling between a pair of microwave propagation devices having perpendicularly disposed electric axes comprising applying an electric field to said gases or vapors in an intermediate wavepath disposed between and coupling together said devices, and varying the strength of said field to control said wave coupling between said devices as a combined function of said field strength and the dipole moments of said gases.

15. Apparatus for coupling together a pair of microwave propagation devices having perpendicularly disposed electric axes comprising an intermediate wave propagation path disposed between and coupling together said devices, a microwave energy absorptive gas or vapor having a dipole moment disposed within said intermediate wavepath, means for applying an electric field to said intermediate wavepath, and means for varying the strength of said field to control said wave coupling between said devices as a combined function of said field strength and said dipole moment.

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