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Jawor

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[54] **APPARATUS FOR MEASURING DENSITY AND MOISTURE**

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[51] **Int. Cl.** **G01r 27/04**

[58] **Field of Search** ..... 324/58.5 A, 58 A

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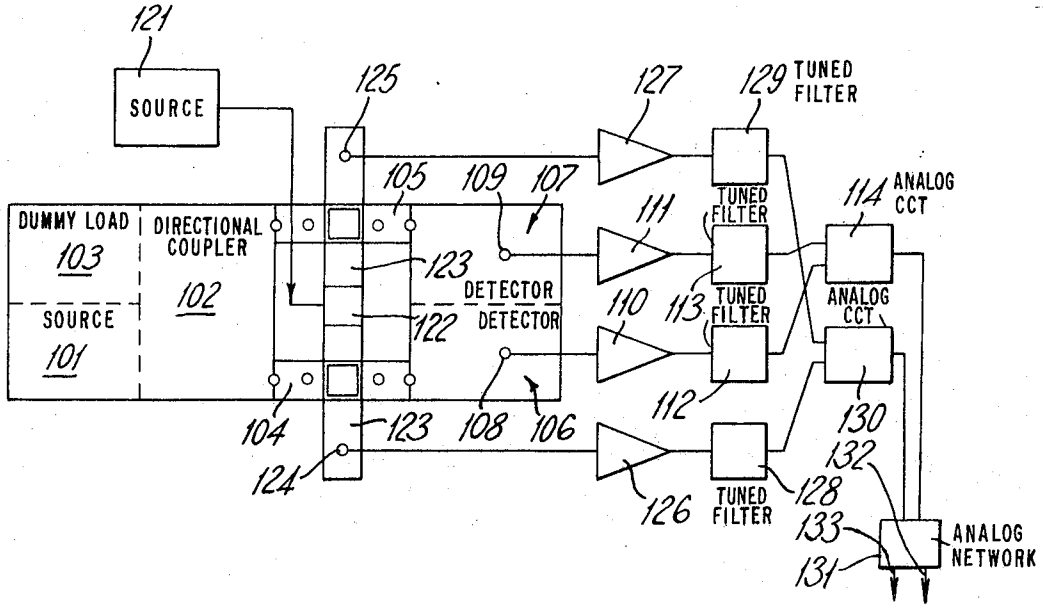
[57] **ABSTRACT**

A device for monitoring density of a rod of tobacco in a cigarette-making machine comprises a source of microwave radiation and a waveguide through which said radiation is propagated in the evanescent mode to a detector. The rod is passed across the path of the radiation, through apertures in the walls of the waveguide. The radiation may be split into two beams, one beam being directed through said waveguide and the other beam directed through a second, similar waveguide to a second detector providing a reference signal.

6 Claims, 2 Drawing Figures



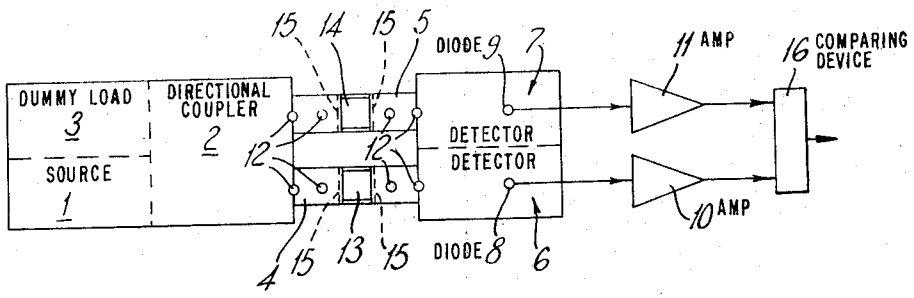

DUMMY LOAD
3
SOURCE
1
DIRECTIONAL COUPLER
2
DETECTOR
DETECTOR
DIODE
9
7
DIODE
8
6
11 AMP
10 AMP
16 COMPARING DEVICE
12
13
14
15
4
5

FIG. 1.

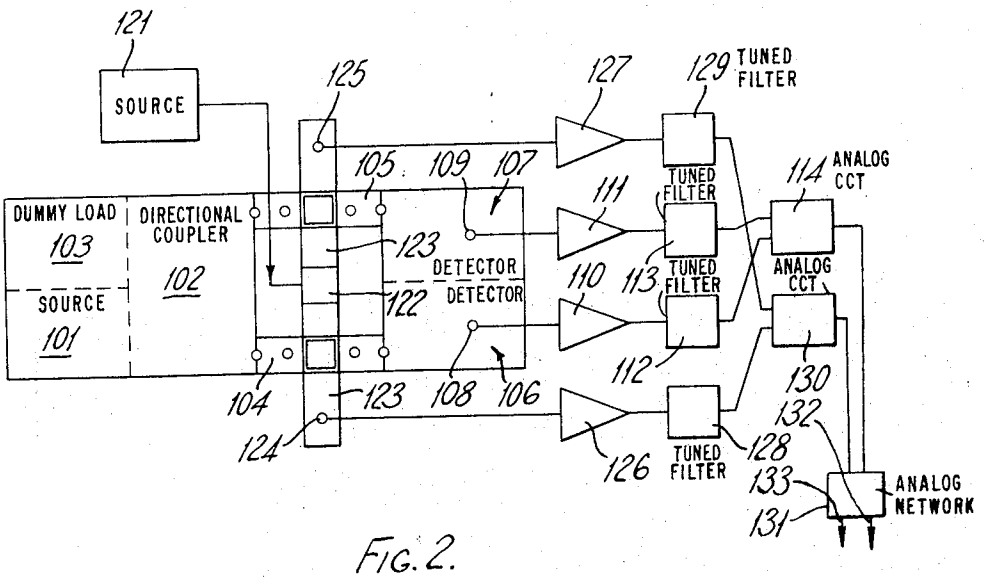

121
SOURCE
DUMMY LOAD
103
SOURCE
101
DIRECTIONAL COUPLER
102
DETECTOR
DETECTOR
125
127
129 TUNED FILTER
105
109
107
111
TUNED FILTER
114 ANALOG CCT
123
122
110
113
TUNED FILTER
ANALOG CCT
104
123
108
106
112
130
132
124
126
TUNED FILTER
128
133
131
ANALOG NETWORK

FIG. 2.

APPARATUS FOR MEASURING DENSITY AND MOISTURE

This invention relates to devices for monitoring the density of a rod of material to be tested, e.g. a rod of tobacco in a continuous-rod cigarette-making machine. As will later become apparent, a device embodying the invention may also be used to monitor density of fluids.

In a continuous-rod cigarette-making machine, which forms tobacco into a continuous rod, wraps the rod in paper and cuts the wrapped rod into lengths constituting individual cigarettes, it is necessary to obtain the least possible variation of the mass per unit length of the tobacco rod from its desired value. Hence various means have been devised for monitoring the mass per unit length of the tobacco rod (for convenience termed the density) and for controlling feed and/or trimming devices in accordance with the density detected. Notably, a device has been employed in which Beta-radiation is passed through the rod and the emergent radiation employed to generate a control signal for the tobacco feed and/or trimming devices, as the attenuation of the Beta-radiation passing through the tobacco varies with the tobacco density. While such Beta-ray devices have proved satisfactory in many ways, there are inconveniences due to the presence of radioactive material as a source of Beta-radiation and some expense is involved in handling such material with proper safety precautions. Moreover, the radiation emission level is not truly constant as Beta-radiation is essentially a random emission of particles with a continuous and non-uniform energy spectrum.

It is an object of the present invention to provide an improved device for monitoring tobacco rod density, not requiring the use of radioactive material.

According to the invention, there is provided a device for monitoring the density of a rod of tobacco or the like in a continuous rod cigarette-making machine, comprising a source of microwave radiation, a detector for said radiation, and a waveguide providing a path for said radiation from said source to travel to said detector, in which said waveguide includes a portion of such narrow cross-section that said radiation is propagated therethrough in the evanescent mode, said portion of waveguide having apertured walls to permit said rod to be fed across the path of said radiation.

By use of microwave radiation, no radioactive material is required and, of course, the source may be deenergised whenever the monitoring device is not required to operate.

The detector provides an output signal which will be affected by any change suffered by the microwave radiation in its passage through the waveguide and, in particular, will be affected by any attenuation of the radiation caused by the presence of the rod of tobacco or the like. Such attenuation may arise from absorption of the radiation by the tobacco and/or detuning of the waveguide i.e. alteration of its "Q" factor by the presence of the tobacco.

It is desirable to provide automatic compensation for any fluctuation in the output of the source. Preferably the source includes a microwave generator (e.g. a Gunn device in a cavity resonator) delivering its output to a directional coupler arranged to split the microwave radiation into two beams of equal intensity. With this arrangement, the two beams are directed to separate detector devices via separate but similar waveguides,

said waveguides having apertured walls to permit the tobacco rod to traverse one of the waveguides so that at least part of the microwave beam travelling through that one waveguide must pass through the rod, and thus the detector device receiving the beam through said one waveguide produces a measuring signal which varies with changes of rod density. The detector device associated with the other waveguide produces a reference signal, and comparison of the measuring signal and the reference signal (e.g. by subtracting one from the other) yields a control signal which is unaffected by any change in the output of the source.

In that portion of the waveguide which is of narrow cross-section, so that the radiation is propagated therethrough in the evanescent mode, the characteristic impedance is for practical purposes purely inductive, so that by providing appropriate capacitance (e.g. one or more tuning screws) complete transmission of the microwave energy may be obtained over a narrow frequency band. The reduced cross-section of this portion makes it an especially convenient location for the apertures in the walls of the waveguide through which the tobacco rod may be fed.

The performance of a device embodying the invention is liable to be adversely affected by variations in moisture content of the tobacco, as a change of moisture content may affect the device in the same way as a change of tobacco density. In circumstances where the moisture content is liable to vary, the monitoring device may be duplicated, the two parts of the device generating at different frequencies (e.g. 10 GHs and 30 GHz) and from the two signals produced secondary signals may be derived (e.g. by an analogue network) to indicate the tobacco density and moisture content separately. In such a duplicated device, the arrangement is such that the lower-frequency radiation (e.g. 10 GHz) is propagated in the evanescent mode in the narrow portion of the waveguide, but the higher-frequency radiation (e.g. 30 GHz) is propagated in the normal mode throughout.

In order that the invention may be well understood, preferred embodiments thereof will now be described with reference to the accompanying diagrammatic drawings, in which:

FIG. 1 illustrates one form of monitoring device embodying the invention, and

FIG. 2 illustrates a more complex device.

Referring first to FIG. 1, a source 1 of microwave radiation has its output connected directly to a 3*db* directional coupler 2 also connected to a dummy load 3 and to two waveguides 4, 5. The microwave radiation delivered by the source 1 is accordingly divided equally between the two waveguides 4, 5 and a microwave beam passes through each of said waveguides to a pair of detector units 6, 7; the detector unit 6 is coupled to the waveguide 4 and contains a diode 8 delivering its outputs to an amplifier 10, while unit 7 is coupled to the waveguide 5 and contains a diode 9 similarly connected to an amplifier 11. Corresponding parts of the device are mutually similar, i.e. waveguides 4 and 5 are of similar dimension to one another, diode 8 is similar to diode 9, and amplifier 10 is similar to amplifier 11.

Each of the waveguides 4, 5 is of such dimensions as to operate in the evanescent mode, e.g. the source 1 conveniently operates at a frequency of 10 GHz, and for this frequency each of the waveguides 4, 5 may have an inner cross-section 8.5 mm. by 4.0 mm. and a

length of 34 mm. Each of said waveguides is provided with four tuning screws **12.** Halfway along each of the waveguides **4, 5** the side walls of the waveguide have mutually similar apertures **13, 14** respectively of a size to permit passage of a tobacco rod (travelling normal to the plane of the drawing) of which the density is to be monitored. Adjacent to these apertures each waveguide has screens **15** closing the waveguide against entry of foreign bodies, said screens being of low-loss glass to minimise attenuations of the microwave beams. If desired, wavetraps (not shown) of conventional form may be fitted to the apertures **13, 14** to minimize escape of microwave radiation. It may also be of advantage to provide a polarisation filter (not shown) between the source **1** and coupler **2** to reduce the possibility of reflected radiation returning to the source; such a filter may also be provided between each of the wave-guides **4, 5** and its associated detector unit **6, 7,** as in part the presence of the tobacco rod may rotate the polarisation plane of the microwave radiation, hence a polarisation filter in the position mentioned serves to increase the effect of the rod's presence on the radiation level at the detector unit.

It should be noted that the source **1** includes means for modulating the microwave output, as this allows the amplifiers **10, 11** to be a.c. amplifiers. With a microwave frequency of 10GHz, the modulation may conveniently be a 10KHz square wave, e.g. provided by a simple multivibrator. If desired, diodes or other detectors may be provided at the outputs of the amplifiers **10, 11** so that the output signals are d.c. voltages; this is especially convenient as a comparing device **16,** e.g. an analogue network can be coupled directly to these outputs to derive therefrom a single signal representative of the rod density.

Now turning to FIG. **2,** this illustrates a more complex monitoring device, also embodying the invention, which provides for the fact that material such as tobacco normally contains moisture which affects the results obtained with a device such as that of FIG. **1** so that the device of FIG. **1** cannot be used to determine the density of the material unless the proportion of moisture present is separately determined.

The device shown in FIG. **2** includes many parts corresponding to those found in FIG. **1,** namely a source **101,** coupler **102,** dummy load **103,** two waveguides **104, 105,** two detector units **106, 107,** two diodes **108, 109,** and two amplifiers **110, 111** (corresponding respectively to the parts **1, 2, 3, 4, 5, 6, 7, 8, 9, 10** and **11** of FIG. **1**). Additionally, a second microwave source **121** is provided, delivering its output to a hybrid ("magic-T") junction **122** from which said output divides equally in the two possible directions of propagation along a waveguide **123** extending at right-angles to the waveguides **104, 105.** The waveguides **104, 105** are apertured in the same manner as the waveguides **4, 5,** of FIG. **1** so that a tobacco rod extending normal to the plane of the drawing may pass across the path of microwave radiation travelling along the wave-guide **104** and so that the two waveguides **104, 105** are mutually similar although no rod is passed through the apertures of waveguide **105.** Also, however, the waveguides **104, 105** are apertured to permit passage of microwave radiation travelling along the waveguide **123** which intersects both of the wave-guides **104, 105.** The hybrid junction **122** is symmetrically placed between the waveguides **104, 105** and the waveguide **123** extends for equal distances on either side of the junction **122,** the portions of the waveguide **123** are functionally separate waveguides providing mutually similar paths for microwave radiation from the junction **122** to each of two detector units containing diodes **124, 125** symmetrically mounted adjacent to the ends of the waveguide **123** and serving as detectors, coupled respectively to amplifiers **126, 127.**

Each of the sources **101, 121** is arranged to produce a modulated microwave output, the carrier frequencies and modulation frequencies being however different. Conveniently for example the source **101** may produce a 10GHz carrier modulated at 10KHz, while the source **121** produces a 30GHz carrier modulated at 1MHz. The diodes **108, 109, 124** and **125** all serve as demodulators so that the amplifiers **110, 111, 126, 127** are all a.c. amplifiers operating at the modulation frequencies, i.e., amplifiers **110, 111** operate at 10KHz and amplifiers **126, 127** at 1MHz. The outputs of the four amplifiers **110, 111, 126, 127** are fed into tuned filters **112, 113, 128, 129** respectively each of which filters is sharply tuned to the appropriate modulation frequency to minimize any "cross-talk" and includes a rectifier at its output so that the four tuned filters deliver d.c. outputs. These d.c. outputs are fed to a pair of analogue comparing circuits **114, 130,** the circuit **114** receiving the outputs from filters **112, 113** and the circuit **130** receiving the output from filters **128, 129.** Each of the analogue circuits is arranged to produce a single output representing the ratio between the two d.c. signals it receives. The two signals supplied to the circuit **114** comprise an information signal (i.e., one derived from microwave radiation which has passed through waveguide **104** and hence through the tobacco rod) and a reference signal (i.e. one derived from microwave radiation which has passed through waveguide **105** and thus has not passed through the rod, but otherwise has been treated in exactly the same manner as the radiation from which the information signal is derived). The circuit **114** produces an output representing the ratio;

$$\text{Information signal/Reference signal} = R$$

and it can readily be shown that

$$R = 1 - (aV + bW)$$

where V and W are respectively the volumes of solid (tobacco) and of water in the path of the radiation from which the information signal is derived, and a, b are constants. A similar equation, with different constants, is applicable to the output from the circuit **130,** hence these two equations enable the values of V and W to be found from the values of the outputs from circuits **114, 130.** Conveniently computing means in the form of an analogue network **131** for solving said equations may be connected to receive the outputs of the circuits **114, 130,** allowing the values of V and W to be continuously calculated and delivered (as varying voltages or otherwise) at separate outputs **132, 133** as a rod is moved across the path of the microwave radiation travelling along waveguide **104.**

The waveguide dimensions are such that the 10GHz radiation from source **101** is propagated through the waveguides **104, 105** in the evanescent mode while the 30GHz radiation from source **121** is propagated through the waveguide **123** in the normal mode.

What I claim as my invention and desire to secure by letters Patent is:

1. A device for monitoring the density of a rod of tobacco or the like in a continuous rod cigarette-making machine, comprising a source of microwave radiation, a first detector for said radiation, a waveguide providing a path for said radiation from said source to travel to said detector, in which said waveguide includes a portion of such narrow cross-section that said radiation is propagated therethrough in the evanescent mode, said portion of waveguide having apertured walls to permit said rod to be fed across the path of said radiation, a second detector, means in the form of a directional coupler for splitting the radiation from said source into two beams and directing one of said beams into said waveguide, a second similar waveguide arranged to receive the other of said beams and provide a path for said other beam to travel to said second detector, means for comparing output signals delivered by said first detector with output signals delivered by said second detector, a second source of microwave radiation, a further detector, and a further waveguide arranged to receive radiation from said second source and providing a path for said radiation to travel to said further detector, said second source being arranged to operate at a frequency different from that of the first-mentioned source and said further waveguide being arranged to intersect the narrow portion of said waveguide so that said rod can be fed simultaneously across the paths of radiation in both said narrow portion and said further waveguide.

2. A device as claimed in claim 1, in which said second source is arranged to operate at such a frequency that microwave radiation therefrom is propagated through said further waveguide in the normal mode.

3. A device as claimed in claim 1, including an additional detector, an additional waveguide similar to said further waveguide and providing a path for radiation from said second source to said additional detector, and further means for comparing output signals delivered by said further detector with output signals delivered by said additional detector.

4. A device as claimed in claim 3, including computing means connected to receive outputs from both the comparing means and from the further comparing means.

5. A device as claimed in claim 4 in which said computing means is an analogue network.

6. A device as claimed in claim 3 in which said further waveguide and said additional waveguide are integral with one another and extend in opposite directions from the second source.

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