United States Patent

[11] 3,604,430

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[73] Assignee **Industrial Nucleonics Corporation**
Continuation of application Ser. No. 543,916, Apr. 20, 1966, now abandoned.

[54] CIGARETTE DENSE END MEASURING AND CONTROLLING APPARATUS

16 Claims, 11 Drawing Figs.

[52] **U.S. Cl.** ..... **131/21 B,** 131/65
[51] **Int. Cl.** **A24c 5/32**
[50] **Field of Search** ..... 131/21, 21 B, 84, 21 D, 65, 66

[56] **References Cited**

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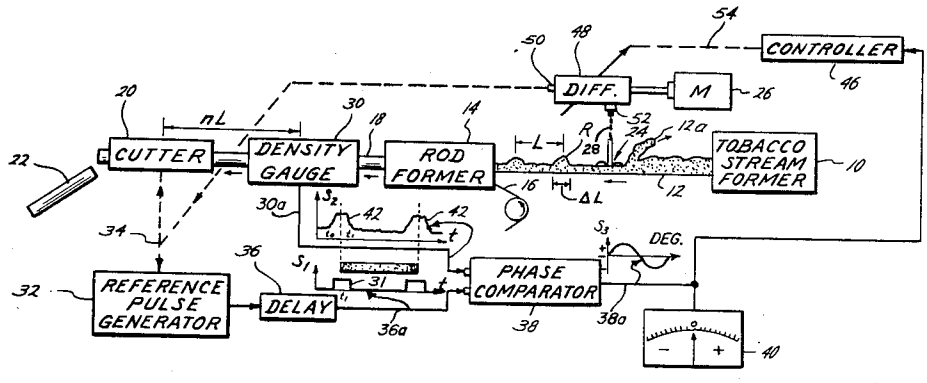
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ABSTRACT: A dense end controller is provided for a cigarette machine having means for making a continuous cigarette rod having dense tobacco regions spaced along the length thereof and a cutter. A density gauge provides a first signal proportional to the density of the tobacco rod. A phase comparator, such as a synchronous detector, continuously compares the phase of the periodic variations in the first signal relative to the phase of pulses in a second signal from the cutter to provide a control signal directly proportional to any deviation of said dense tobacco regions from the ends of cut cigarettes.



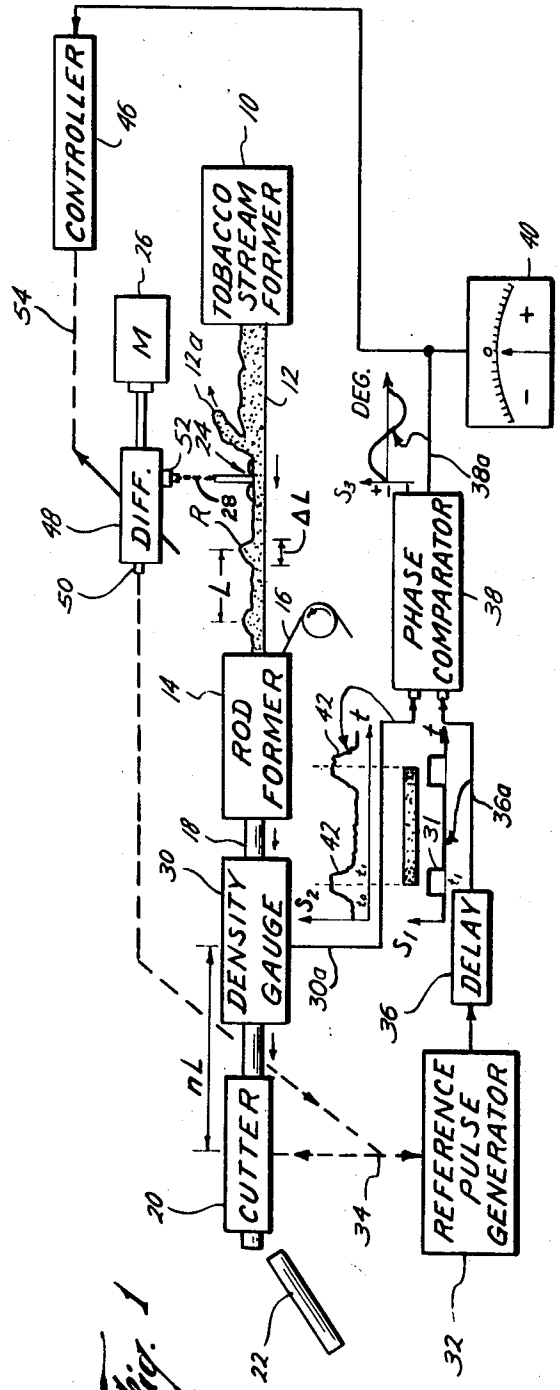


Fig. 1

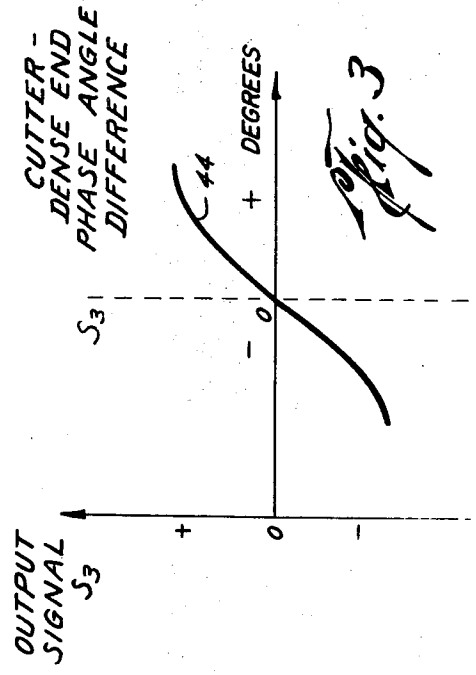


Fig. 3

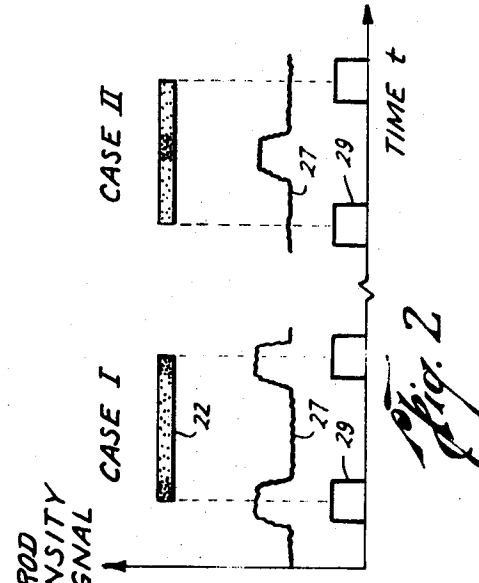


Fig. 2

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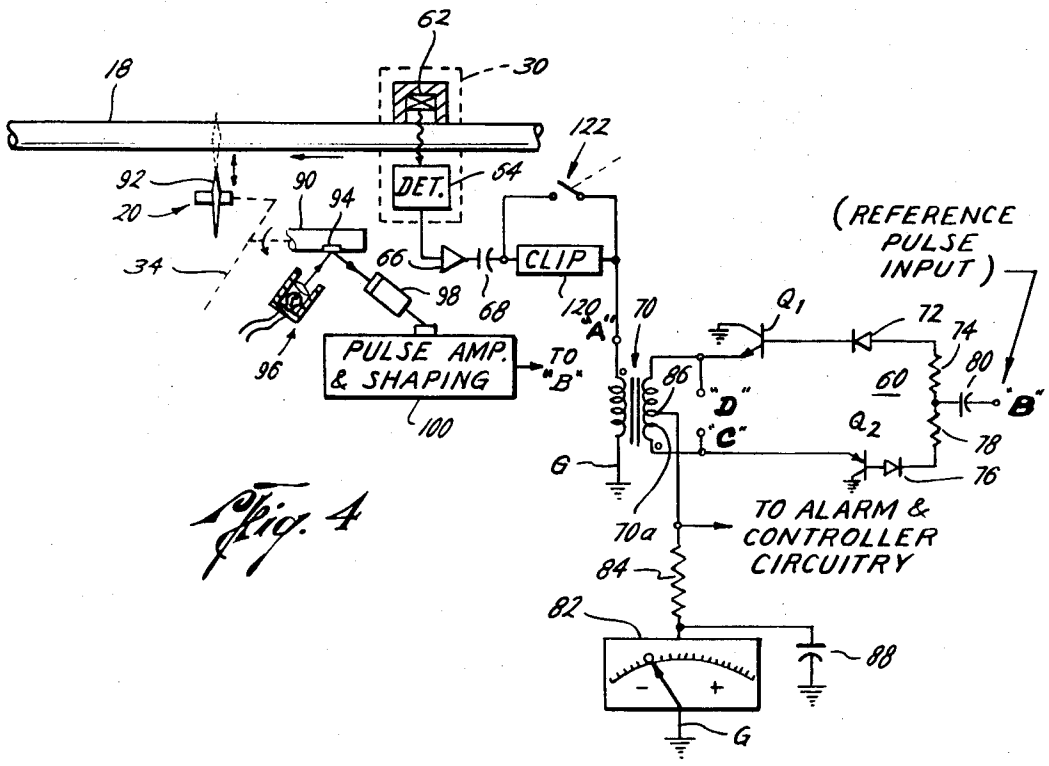


Fig. 4

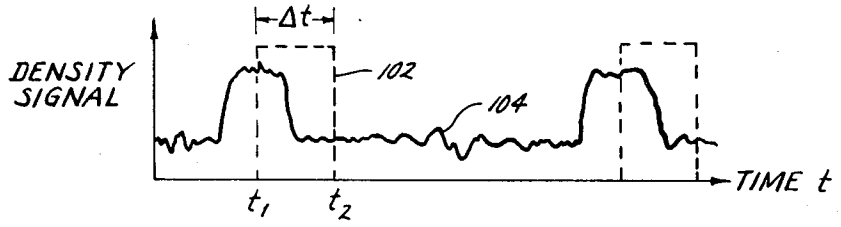


Fig. 5a

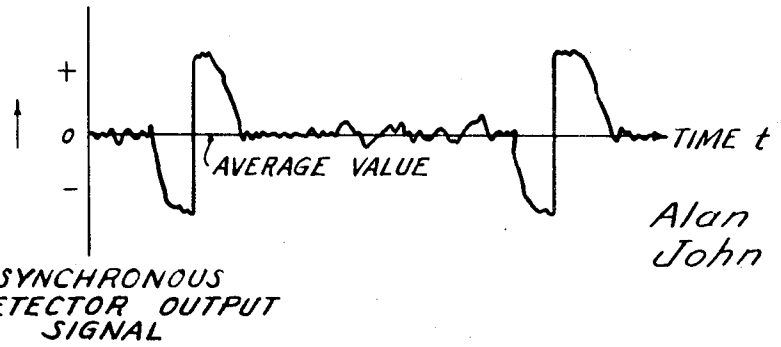


Fig. 5b

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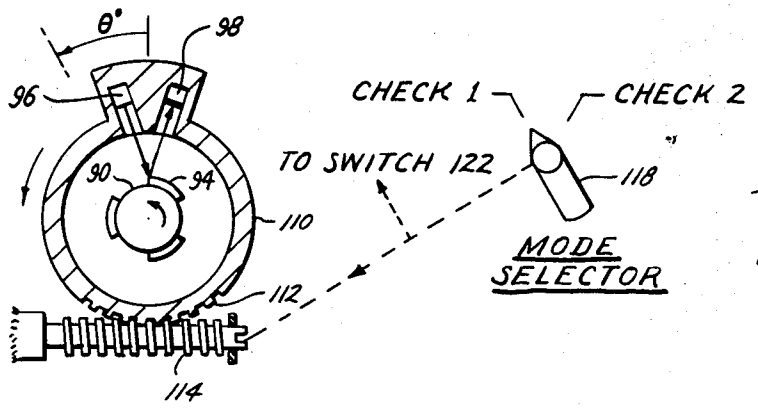


Fig. 6

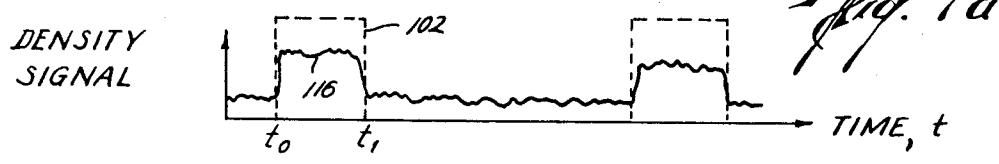


Fig. 7a

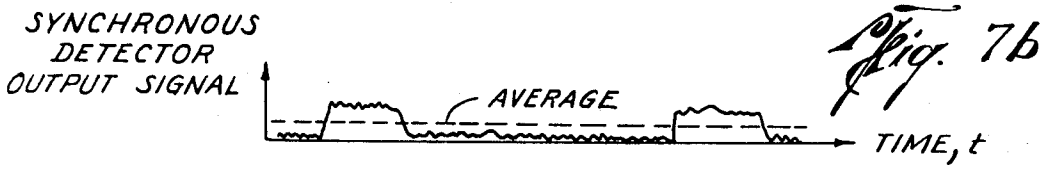


Fig. 7b

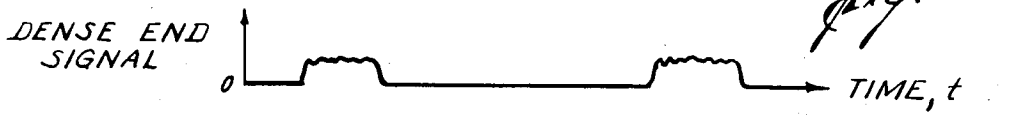


Fig. 7c

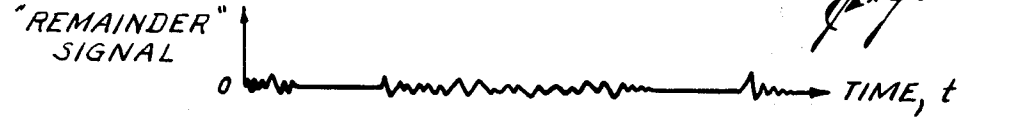


Fig. 7d

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CIGARETTE DENSE END MEASURING AND CONTROLLING APPARATUS

This is a continuation of my copending Pat. application Ser. No. 543,916, filed Apr. 20, 1966, now abandoned.

The present invention relates generally to cigarette makers and, more particularly, to improved apparatus for facilitating the manufacture of cigarettes having dense ends.

BACKGROUND

Many cigarettes are being manufactured by providing extra tobacco in the tobacco rod at the regions which will form the adjacent ends of cut cigarettes. The purpose of this "dense ending" is to give the cigarette ends added firmness, good appearance and to prevent small particles of tobacco from falling out of loosely packed ends.

Dense ending apparatuses are built into many modern cigarette machines and they may take on various forms. For example, suction techniques may be employed to drop increased amounts of tobacco onto the tobacco stream, compacting wheels may be used to compress the stream at various points or a rotating trimmer disc having peripheral indentations may be used to trim off more tobacco in some regions of the stream than in others. U.S. Pat. No. 3,032,041 issued to R. Lanore and British Pat. Nos. 813,576, 940,153, 941,852, and 948,736 are representative of the state of the art in this area.

One problem that arises frequently with these systems is that the extra tobacco in the cigarette rod may occur at the wrong location. The cutter is normally synchronized with the dense ending device so that the cutter cuts through the rod substantially in the center of the dense regions. While the system may be located several feet downstream from the dense ending device and the intervening rod forming mechanisms induce an unpredictable stretching of the tobacco stream and cigarette rod causing misregistration of the cutter with the dense regions. Instead of occurring in the two-butted adjustment cigarette ends where the rod is cut, the dense regions may appear in the center of the cigarette.

Another problem concerns the amount of increased density added to the dense regions. Machines are commonly designed to put typically a 10 percent, a 15 percent, or a 20 percent increase in density into the ends of the cigarettes. Machine faults or maladjustments may cause the magnitude of the dense regions of the tobacco rod to be less than desired.

PRIOR SYSTEMS

It has been necessary to sample the density of a large number of cigarettes manually to determine whether or not the dense regions were of the desired magnitude and occurring at the ends of adjacent cigarettes. When the production of faulty cigarettes was discovered, it was necessary to stop the machine and adjust the dense ending device. This method was not only time consuming but also wasteful, as a large number of objectionable cigarettes were produced as a result of the high production rate, e.g. 1,800 cigarettes per minute or more by one machine, before the fault was discovered. Moreover, it was virtually impossible to discriminate between a loss of cutter synchronization and a decrease in density of the dense regions.

BRIEF DESCRIPTION OF THE PRESENT INVENTION

We provide means for determining when a machine is producing cigarettes having acceptable dense ends. Generally, we provide a system for determining the phase relationship existing between the cutter and the dense end regions. A gauge is used to determine when one of the dense regions of the cigarette rod occurs at the location of the cutter. We also generate a reference pulse whenever the cutter cuts through the cigarette rod. By comparing the times of occurrence of the dense end regions relative to the occurrence of the reference pulse, we provide a signal proportional to the amount and direction of any deviation of said dense regions from the ends of the cut cigarettes. Automatic control apparatus responsive to the deviation signal is provided to maintain continuous production of cigarettes having the desired dense ends.

In a specific embodiment, the deviation in phase of the dense end signal components relative to the reference pulse is measured by a synchronous demodulator which provides an output signal directly proportional to any deviation in the synchronization of the cutter with the dense end regions. We also provide means for changing the reference phase of the demodulator to check for insufficiently dense ends.

BRIEF DESCRIPTION OF THE OBJECTS

Accordingly it is a primary object of the present invention to provide an improved dense end monitor for a cigarette machine.

It is another object of the present invention to provide a dense end monitor that provides a signal continuously indicative of the dense end condition of the cut cigarettes.

It is also an object of the present invention to provide a signal proportional to the amount and direction of any deviation in the synchronization of the cutter and the dense end regions.

It is still another object of the present invention to provide an improved dense end control system.

It is yet another object of the present invention to provide a dense end monitor not requiring skilled operating personnel.

DESCRIPTION OF THE FIGURES OF THE DRAWING

FIG. **1** is a block diagram, partly schematic, illustrating our dense end monitoring system for a cigarette dense ending machine together with three associated graphs of typical signal waveforms appearing in portions of the apparatus;

FIG. **2** is a graph of cigarette rod density vs. time for two cigarette samples;

FIG. **3** is a graph showing the output signal of the phase comparator employed in the monitoring system shown in FIG. **1**;

FIG. **4** is a partial sectional view, partly schematic, showing a preferred synchronous detector for use in the system shown in FIG. **1**;

FIGS. **5***a* and **5***b* are graphs showing the waveforms of the input signal and the output signal of the synchronous detector of FIG. **4** in one mode of operation;

FIG. **6** is a sectional view of apparatus for adjusting the time reference of the cutter pulse generator; and,

FIG. **7***a*–**7***d* are graphs of various waveforms occurring in the synchronous detector of FIG. **4** operating in an alternative mode.

CIGARETTE DENSE END PROCESS

With reference now to the drawings and particularly to FIG. **1**, a cigarette-making process includes a tobacco stream former **10** delivering a stream **12** of tobacco to a rod former **14**. Rod former **14** wraps a paper strip **16** around the tobacco stream **12** and glues the seam to form a cigarette rod **18**. The cigarette rod **12** is conveyed to a cutter **20** which periodically cuts a cigarette **22** of length L from the continuous rod **18**. In the past, this type of industrial process has been measured and controlled to provide cigarettes having a desired weight per unit length. For a more detailed description of the cigarette making machine, reference may be had to U.S. Pat. No. Re. 25,476 issued Nov. 12, 1963 to S. A. Radley et al. and assigned to the same assignee as the present invention.

Some machines are equipped with a dense ending device **24** which may comprise a rotating trimmer disc having raised portions spaced around the periphery thereof. Other devices may be employed to provide the same function; some of these are described in the patents cited, supra. The disc trims off some tobacco **12***a* which is returned upstream leaving an excess amount of tobacco in dense regions R spaced one cigarette length L apart from one another. The density of the tobacco in the dense regions R of the cigarette rod **18** may be up to 20

percent greater than the density in the remainder of the rod **18**. In a typical example, the length ΔL of the dense region may be 10 to 20 mm. while the entire cigarette may be some 70 mm. in length.

A main drive motor **26** provides motive power for simultaneously conveying the cigarette rod **18** toward the cutter **20** and actuating the cutter **20** to cut cigarettes of substantially equal length from the rod **18**. The dense end device **24** is also coupled to the main drive motor **26** as indicated by the dotted line **28**. The object is to time the cutter operation with the dense end device **24** so that the cutter **20** cuts the tobacco rod **18** substantially in the center of each dense region R. If, due to longitudinal dimensional changes of the rod **18** or slippage of the drive to either the cutter **20** or the dense end trimmer, the cutter and dense regions R are not in synchronism, the cigarettes **22** will either have an insufficient amount of tobacco at one end or the other or no dense ends at all.

This effect is graphically shown in FIG. **2** wherein a density profile **27** is plotted on the same time scale as pulses **29** occurring when the cutter **20** cuts through the tobacco rod. A superposed cigarette **22** is shown in section to illustrate an acceptable dense end condition (case I) and an objectionable dense end condition (case II). In both cases the ends of the cigarette **22** are in time coincidence with the cutter pulses **29**. In case I, however, the dense regions R arrive at the cutter **20** when a cigarette is being cut. Cigarettes are provided with dense end portions. Case II illustrates a situation where the dense regions R arrive at the cutter **20** several milliseconds late so that the cut cigarettes contain a centrally located dense portion.

It is desirable to cut the rod **18** continually in each dense region R. By cutting substantially in the center of this region, one end of the cigarette **22** contains approximately the same amount of extra tobacco as the other end. To accomplish this result, one must know when each dense region R occurs at the cutter **20**. By comparing the arrival time of each dense region with the time each cigarette is cut from the rod **18**, one may determine whether or not the cutter is properly synchronized and, if it is not synchronized, the amount and direction in which it is out of synchronization.

With reference now to FIG. **1**, we measure the relative degree of cutter synchronization by comparing the phase of cutter pulses **31** in a reference signal S_1 on line **36***a* relative to the increased density pulses in a signal S_2 provided on line **30***a* by a density gauge **30**. Pulses **31** are provided by a reference pulse generator **32** mechanically coupled to the cutter **20** as indicated by the dotted line **34**. In the specific embodiment shown, the pulses **31** generated by pulse generator **32** are delayed for a suitable length of time by a delay unit **36**, to be further described hereinafter, which provides the delayed pulses on its output line **36***a*. In its simplest form, generator **32** may be a switch contact which closes every time a cigarette **22** is cut from the rod **18**.

Density gauge **30** is preferably located upstream from the cutter **20** to measure the density of the rod **18** and may be of the capacitance type, for example. A preferred form of transducer is described hereinafter. The density gauge **30** is positioned as close as physically possible to the cutter **20**. By spacing the gauge **30** an integral number of cigarettes lengths, *nL*, away from the cutter **20**, one knows that a dense region R is occurring simultaneously at both the gauge **30** and the cutter **30**. If, due to the lack of space on the cigarette-making machine, for example, it is physically impossible to mount the gauge **30** in a location so as to provide this preferred spacing, either the gauge signal S_2 or the cutter signal S_1 may be delayed by a unit **36**. The amount of delay provided by unit **36** should take into account any inherent lags in the measurement of rod density by the gauge **30**.

A phase comparator **38** compares the phase of the density signal S_2 with that of the reference signal S_1. Phase comparator **38** provides an output signal which is directly proportional to a small deviation from cutter dense end synchronization, i.e. its magnitude passes through zero and its polarity always changes in the same direction as the cutter operation is brought from a lagging to a leading relationship with the dense end regions in the manner and for the reasons explained hereinafter. As one suitable output device, a meter **40** may be used to indicate the output signal S_3 provided by the phase comparator.

A related dense end monitoring system is the subject of a copending application Ser. No. 544,000 filed Apr. 20, 1966 by John E. DeWitt, now abandoned and refiled Oct. 3, 1969 as Ser. No. 864,292, and assigned to the same assignee as the present application.

In the embodiment shown, the density signal S_2 on line **30***a* at the output of density gauge **30** contains portions representative of the increased density in the dense regions R. These portions appear as density pulses **42** extending above the average density signal level. A typical pulse may start at a time t_o and be centered about a time t_1 as shown. If the cutter pulses **31** on line **36***a* at the output of the delay unit **36** arrive at time t_1, the cigarette rod **18** is being cut substantially in the center of the dense regions R and the output signal S_3 of the phase comparator **38** is zero as shown by the meter **40**. If the cutter pulses arrive either sooner or later than time t_1, the dense regions R either lead or lag relative to the cutter **20**. The cutter **20** is no longer synchronized with the dense end device **24**. Cigarettes **22** are produced either with an unequal amount of tobacco in each end or with no dense ends at all.

The variation of the output signal S_3 of the phase comparator **38** with the cutter-dense end timing or phase angle difference is illustrated in FIG. **3**. As shown by the characteristic curve **44**, for small deviations from proper cutter synchronization the signal S_3 is directly proportional to deviations from the desired phase angle difference, i.e. it indicates by its magnitude and polarity respectively both the amount and the direction of any deviation from synchronization. The signal characteristic **44** reverses polarity at 0° where the cutter **20** and dense end device **24** are correctly synchronized. Therefore, it is possible to determine not only when the cutter **20** is out of synchronization but also in which direction it is out. Meter **40** may be provided with a center zero dial so operating personnel can immediately observe any deviation in cutter-dense end synchronization.

This direction-sensitive capability of our phase comparator makes it especially useful in controlling the process to maintain the desired synchronization. For example, the meter scale may be calibrated in degrees. Operating personnel can read the amount and direction of cutter-dense end phase shift and make appropriate adjustments to the machine to correct the faulty dense end condition. This may be done manually by stopping the machine and rotating the dense end trimmer a given amount in one direction or the other. Alternatively, automatic control can be exerted by another suitable output device comprising a controller **46** operating directly from the comparator output signal S_3. A differential gearing unit **48** may serve to couple the main drive motor **26** simultaneously to the cutter **20** and the dense end device **24**. Differential **48** is provided with a pair of output shafts **50** and **52**, the relative speeds of which can be adjusted as indicated by the arrow. For example, a control shaft is often employed to vary the ratio of the speed of one shaft to the speed of the other. Controller **46** is coupled to this adjuster by the heavy dotted line **54**. Other mechanisms for effecting automatic control of cutter synchronization will be apparent to those skilled in the art.

PREFERRED DEMODULATOR EMBODIMENT

We have found it particularly useful to employ a synchronous detector circuit **60** as shown in FIG. **4** to demodulate the density signal provided by the gauge **30** because of the random nature of all of the density components in the signal except the dense region pulses. The phase of the density signal applied at terminal "A" is compared with the phase of the reference pulses applied at terminal "B" to obtain an output signal directly proportional to shifts in cutter-dense end synchronization.

In a preferred form, density gauge **30** comprises a radiation source **62** and a radiation detector **64** positioned on opposite sides of the cigarette rod **18** to provide a signal proportional to the density or weight per unit length of the cigarette rod **18**. Amplifier **66** amplifies the output signal of the radiation gauge. Capacitor **68** serves to couple the amplified density signal to the input terminal A of the synchronous detector **60** and effectively block any DC level the density signal may have.

The detector **60** comprises a center-tapped input transformer **70**, having the winding polarities arranged so that the input and output connections indicated by the dots will have their respective voltages in phase. Detector **60** further comprises an upper loop including transistor Q_1, diode **72** and resistor **74**, and a lower loop including transistor Q_2, diode **76** and resistor **78** connected to opposite ends of the transformer secondary winding **70***a*. The free ends of resistors **74** and **78** are connected together and a capacitor **80** connects their junction to the reference pulse input terminal "B." Output meter **82** is connected in series with a resistor **84** between the center tap **86** of the secondary winding **70***a* of transformer **70** and ground G. Capacitor **88** is connected across the meter **82** to average the current flowing between the transformer center tap **86** and ground G.

Reference pulses may be obtained by bouncing light off of rotating shaft **90** that forms part of the cutting mechanism of cutter **20**. The shaft **90** rotates continuously as the knife **92** cuts through cigarette rod **18**. Segments of reflecting paint or a tape strip **94** may be spaced around he periphery of the shaft **90**. A light source **96** directs light toward the axle **90**. A phototransistor **98** may be used to sense light reflected from the strip **94** as the shaft **90** turns. Phototransistor **98** thus generates a pulse train which can be amplified and shaped by a unit **100**. The output pulses from unit **100** are coupled to the reference pulse input terminal B of the synchronous detector **60**. The length of the strips **94** is made long enough to provide a reference pulse width substantially equal to the width of the dense region pulses **42** in the density signal to be detected.

OPERATION OF THE PREFERRED DEMODULATOR EMBODIMENT

The operation of the synchronous detector dense end monitor may be best explained by reference to the waveforms shown in FIGS. **5***a* and **5***b*.

The transistors Q_1 and Q_2 of the synchronous detector **60** act like a pair of ganged single-pole switches, connecting one loop and then the other into the output circuit in synchronism with the reference pulses applied at terminal "B." The effect is to invert that part of the density waveform that occurs during the time of the reference pulses **102** shown in dotted line in FIG. **5***a* for simplicity. The output signal, whose waveform is shown in FIG. **5***b* and which could be the current through meter **82**, is inverted from its sense shown in FIG. **5***a* except during the time Δt of the reference pulse **102**. When the cutter is properly synchronized with the dense regions, the reference pulse **102** from pulse amplifier **100** starts substantially in the center of the dense region at time t_1. Since the detector output signal as shown in FIG. **5***b* has a zero DC level because of capacitor **68** and transformer **70**, and since for all practical purposes the variations in density **104** of the rest of the cigarette rod **18** are random, and since the dense region pulse is relatively symmetrical about the time t_1, and inverted after time t_1 for a time period Δt, the average value of the output signal of the synchronous detector **60** is substantially zero.

The average value of the output will be different from zero whenever the leading edge of the reference pulse **102** does not appear at the time t_1. A shift in time one way will produce an output signal having one polarity and a shift in the other direction will cause the synchronous detector to provide a signal of the opposite polarity. The output signal characteristic of the synchronous detector **60** will be similar to that shown in FIG. **3**.

INITIAL SETUP

It is necessary to set the system up initially by angularly orienting the cutter shaft **90** to provide zero signal on the meter **82** when cigarettes are produced having equal dense ends. Thereafter, any deflection of the meter indication from zero indicates the direction and magnitude of cutter-dense end phase shift. To establish the desired initial mechanical-time reference, the apparatus shown in FIG. **6** may be used. The lamp **96** and phototransistor **98** are mounted in a housing **110** positioned adjacent to and rotatable with respect to the cutter shaft **90**. While the housing **110** is shown concentrically mounted, it need not surround the shaft **90**. The housing **110** is provided with a sector gear segment **112** that is engaged by a worm gear **114**. Housing **110** may be rotated relative to the cutter shaft **90** turning the worm gear **114**. The end of the worm gear **114** may be slotted to enable fine screwdriver adjustments to be made by operating personnel.

Light periodically reflects off of the tape segments **94** toward the phototransistor **98** as the cutter shaft **90** rotates. The length of the pulse generated by the phototransistor **98** will be proportional to the arcuate length of each strip **94**.

To set up our system, the cutter **20** and the dense end device **24** are adjusted with respect to one another so that the cutter **20** is cutting the rod **18** substantially in the center of the dense regions R. The worm gear **114** is turned to rotate the housing **110** until the output of the synchronous detector **60** goes to zero. If the cutter motion is stopped as the cutter is cutting through the rod **18**, the housing **110** will be positioned as shown in FIG. **6**. At this instant, when the cutter pulse reference is correctly adjusted, light is starting to reflect from the leading edge of the strip **94**. This instant is the time t_1 shown in FIG. **5***a*. Continued motion of the shaft **90** causes light to be reflected until time t_2. Several strips of reflecting tape may be placed on the shaft **90**. For example, if the cutter **20** cuts three cigarettes for every revolution of the shaft **90**, three strips **94** of equal length may be spaced 120° apart on the periphery of shaft **90**. Other mechanical or electronic devices may be employed with substantially equal utility to provide the required cutter pulse time reference.

ALTERNATIVE EMBODIMENTS

A different, useful result is obtained when the "window" provided by the reference pulse **102** is established in time coincidence with the dense region pulse as shown in FIG. **7***a*. When the reference pulse **102** starts at time t_0, an average value different from zero is computed by the signal inverting or differencing action of demodulator **60** and the averaging action of resistor **84** and capacitor **88**. This is shown graphically in FIG. **7***b*. It may be observed that the average value computed is primarily a function of the amplitude of the dense region pulses **116**, since the average of the random densities in the remainder of the signal is substantially zero. The reference pulse **102** is deliberately shifted in time to include the dense region pulse **116** by displacing the housing **110** (FIG. **6**) counterclockwise through a mechanical angle θ which corresponds to the difference between the times t_0 and t_1. If a 10 mm. dense end is placed on 70 mm. cigarettes the angle θ may be computed, for the apparatus shown in FIG. **6**, as follows:

$$\theta = 120° \times \frac{5 \text{ mm.}}{70 \text{ mm.}} \cong 8.5°$$

An operator's control knob **118** may be coupled to the worm gear **114** to rotate the housing **110** through the angle θ. Knob **118** may be provided with a dial for selecting either one of two modes of operation of the synchronous detector **60**, denoted Check **1** and Check **2**. Alternatively, a servomechanism may make the necessary displacement automatically on demand.

When placed in Check **1** position, the system responds primarily to the deviation of the cutter **20** and dense regions R for synchronization. When the proper extra density is being placed in each dense region R, the output signal of detector **60** is directly proportional to the deviation of the cutter and

dense regions from synchronization. Since the detector **60** is somewhat amplitude sensitive, a change in the magnitude of the density of the dense regions R may be reflected in the output signal. The detector **60** may be rendered insensitive to changes in dense region density by inserting a signal-limiting circuit such as a clipper **120** (FIG. 4) in the path of the density signal, for example. Alternatively, clipping may be provided in the output circuit of the detector **60**. The meter **82** always reads zero when the correct synchronization is provided irrespective of what changes occur in the magnitude of the density of the dense end regions R. It also displays in which direction the cutter and dense regions have fallen out of synchronization.

In the Check **2** position, our instrument responds not only to deviation but also to an undesired density of the dense regions R. The average value readout on meter **82** will be maximum if acceptable dense end cigarettes are being manufactured. If, for some reason or another, a deficient amount of tobacco is placed in the dense regions R, the indicated average value will decrease even though the machine may still be properly synchronized. If an "out of sync" condition prevails, the pulse **116** (FIG. 7*a*) is displaced relative to the pulse **102** causing the output signal to decrease in average value.

Referring to FIGS. 7*c* and 7*d*, when operated in Check **2** or peak reading mode, our detector **60** provides a signal for the dense end at the emitter of transistor Q_1 and a signal indicative of the density variation in the remainder of the cigarettes **22** appears at the emitter of transistor Q_2. These signals are alternately clamped to ground (zero potential) at different times when one or the other of the transistors Q_1, Q_2 is rendered conductive by the cutter reference pulse **102**. These signals may be separately processed and evaluated for purposes of overall cigarette inventory or control by means not shown. It may be necessary to disable the clipper **120** by means of a switch **122** operated by the operator's control knob **118** (FIG. **6**) when the instrument is used in the peak reading mode.

What is claimed is:

1. Apparatus including an output device for monitoring the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving along a path which includes the location of said cutter and having locally dense regions spaced along said tobacco rod, said apparatus comprising:

means for measuring the density of said tobacco rod as it passes a point along said path to produce a density signal having periodically varying portions indicative of the passage of each of said dense regions in said moving rod,

means for measuring the phase relationship between the operation of said cutter to cut said rod and the occurrence of said periodically varying portions in said density signal and for generating and coupling to said output device a signal directly proportional to the amount and direction of a deviation from the center of said dense regions of the ends of said cut cigarettes.

2. Apparatus including an output device for monitoring the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving relative to said cutter and having locally dense regions spaced along said tobacco rod, said apparatus comprising:

means responsive to the density of said tobacco rod for generating a first signal having a periodically changing portion indicative of each of said dense regions in said moving rod,

means for generating a second signal whenever said cutter cuts a cigarette from said rod, and

means for continuously comparing the phase of said periodically changing portions of said first signal relative to said second signal and for producing and coupling to said output device a third signal directly proportional to the amount and direction of any deviation from the ends of the cigarettes cut by said cutter of the center of said dense regions.

3. Apparatus for monitoring the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving relative to said cutter along a path which includes the location of said cutter, said rod having locally dense regions spaced along said tobacco rod, said apparatus comprising:

means responsive to the density of said rod as it passes a point along said path for generating a first signal having a waveform including periodic pulses indicative of the passage of said dense regions of said moving rod,

means synchronized with said cutter for producing a second signal corresponding to one portion of said first signal, and having a waveform that is inverted with respect to the waveform of said first signal, and

means responsive to said second signal and to another portion of said first signal to provide an output signal directly proportional to any deviation from the center of said dense regions of the ends of said cut cigarettes.

4. Apparatus for monitoring the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving relative to said cutter and having locally dense regions spaced along said tobacco rod, said apparatus comprising:

means for measuring said cigarette rod to provide a first signal having a waveform including periodic pulses indicative of the passage of said dense regions of said moving rod,

means synchronized with said cutter for periodically producing a second signal corresponding to one portion of said first signal and having a waveform that is inverted with respect to the waveform of said first signal for a predetermined period of time,

means for combining said second signal and said remaining portions of said first signal, and

means for averaging said combined signal portions to provide an output signal directly proportional to any deviation from the center of said dense regions of the ends of said cut cigarettes.

5. Apparatus for monitoring the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving relative to said cutter and having locally dense regions spaced along said tobacco rod by a dense-end forming device, said apparatus comprising:

means for generating a first signal having a waveform including periodic pulses indicative of the passage of said dense regions of said moving rod,

adjustable means coupled to said cutter for generating a reference signal having a pulse whose width is substantially equal to said periodic pulses,

means responsive to said reference pulse for periodically producing a second signal corresponding too one portion of said first signal, and having a waveform that is inverted with respect to the waveform of said first signal,

means for combining said second signal with the remaining portions of said first signal,

means for averaging said combined signal portions to obtain an output signal, and

means for adjusting said reference pulse generating means to initiate said reference pulse substantially in the center of each of said dense region pulses when said cutter and said dense end device are synchronized to provide an output signal directly proportional to any deviation of said dense regions from the ends of said cut cigarettes.

6. Apparatus as set forth in claim **5** further including:

means for adjusting said reference pulse generating means to change its time of operation relative to the operation of said cutter, thereby to initiate said reference pulse in time coincidence with the beginning of each of said dense region pulses to maximize said output signal when said dense regions are simultaneously of the desired magnitude and occurring in portions of said rod which are cut through by said cutter to separate adjacent cigarettes.

7. Apparatus as set forth in claim 5 further including: means responsive to said output signal for adjusting the relative position of said cutter and said dense end device to cut said cigarette rod substantially in the center of each of said dense regions.

8. Apparatus for controlling the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving relative to said cutter and having locally dense regions spaced along said tobacco rod by a dense end device, said apparatus comprising:

means for continuously measuring the density of said cigarette rod to provide a signal having periodic increased portions responsive to the passage of said dense regions of said moving rod,

means coupled to said cutter to provide a reference pulse whenever a cigarette is cut from said cigarette rod,

synchronous detector means for producing a signal which is directly proportional to the phase difference of said measured increased density portions from said reference pulses, and control means responsive to said measured phase difference signal for continuously maintaining said cutter and said dense end device in synchronization to cut said cigarette rod substantially in the center of each of said dense regions.

9. Apparatus for monitoring the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco movable relative to said cutter and having locally dense regions spaced along said tobacco rod by a dense end forming device, said apparatus comprising:

means for measuring the density of said cigarette rod to provide a first electrical signal having periodic pulses responsive to the passage of said dense regions of said moving rod, and

a phase detector for producing a signal indicative of a deviation from synchronization of the operation of said cutter and said dense end forming device wherein said cutter cuts said rod substantially in the center of each of said dense regions, said phase detector including

a pair of electrical circuit loops each having

a diode element for conducting current in one direction,

switch mans in series with said diode element and means for coupling said first signal to said phase detector,

a common load circuit shared by each of said loops and means for connecting said loops to said signal-coupling means to provide a current flow in each direction through said common load circuit and

adjustable means coupling said switch means to said cutter for providing for a current flow of one loop or the other of said phase detector for predetermined periods synchronized with the operation of said cutter.

10. Apparatus as set forth in claim 9 further including: controller means responsive to said average current value for continuously maintaining said cutter and said dense end device in synchronization to cut said cigarette rod substantially in the center of each of said dense regions.

11. Apparatus including an output device for monitoring the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving relative to said cutter and having locally dense regions spaced along said tobacco rod, said apparatus comprising:

means for measuring the density of said tobacco rod to produce a density signal having a waveform including a distinctive portion responsive to the occurrence of each of said dense regions in the vicinity of said cutter,

means for measuring the phase relationship between the operation of said cutter and the occurrence of said distinctive portions and for producing and coupling to said output device an output signal directly proportional to the amount and direction of any deviation from the ends of the cigarettes cut by said cutter of the center of said dense regions.

12. Apparatus including an output device for monitoring the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving relative to said cutter and having locally dense regions spaced along said tobacco rod, said apparatus comprising:

means for generating a first signal whenever one of said dense regions occurs at said cutter,

means for generating a second signal whenever said cutter cuts a cigarette from said rod, and

means for comparing the phase of said first signal relative to said second signal for producing and coupling to said output device an output signal directly proportional to the amount and direction of any deviation from the ends of the cigarettes cut by said cutter of the center of said denser regions.

13. Apparatus for controlling the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving relative to said cutter and having locally dense regions spaced along said tobacco rod, said apparatus comprising:

means for generating a first signal responsive to the passage of each of said dense regions in said moving rod,

means for generating a second signal each time said cutter cuts a cigarette from said rod,

means for comparing the phase of said first signal relative to said second signal for providing an output signal directly proportional to the amount and direction of any deviation of said cutter and said dense regions occurring thereat, and

control means responsive to said output signal for controlling the movement of said cutter relative to said tobacco rod.

14. Apparatus for controlling the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco moving along a path which includes the location of said cutter, said rod having locally dense regions spaced therealong, said apparatus comprising:

means responsive to the density of said rod as it passes a point along said path for generating a first signal having a waveform including periodic pulses indicative of the passage of said dense regions of said moving rod,

means synchronized with said cutter for producing a second signal corresponding to one portion of said first signal, and having a waveform that is inverted with respect to the waveform of said first signal,

means responsive to said second signal and to another portion of said first signal to provide an output signal directly proportional to any deviation from the center of said dense regions of the ends of said cut cigarettes, and

control means responsive to said output signal for controlling the movement of said cutter relative to said tobacco rod.

15. Apparatus for controlling the operation of a cigarette-making machine having a cutter providing a plurality of cigarettes cut from a continuous rod of tobacco having locally dense regions spaced along said tobacco rod and moving along a path which includes the location of said cutter, said apparatus comprising:

means responsive to the density of said rod as it passes a point along said path to provide a first signal having a waveform including periodic pulses indicative of the passage of said dense regions of said moving rod,

means synchronized with said cutter for periodically producing a second signal corresponding to one portion of said first signal and having a waveform that is inverted with respect to the waveform of said first signal for a predetermined period of time,

means for combining said second signal with the remaining portions of said first signal,

means for averaging said combined signal portions to provide an output signal directly proportional to any deviation from the center of said dense regions of the ends of said cut cigarettes, and

control means responsive to said output signal for controlling the movement of said cutter relative to said tobacco rod.

16. Apparatus as in claim 9 in which said adjustable means comprises:

means for indicating the average value of said current flowing through said load circuit, and

means for adjusting said coupling between said cutter and said switch means to provide an average current flow that is substantially zero when said cutter is synchronized with said dense regions of said rod and directly proportional to any deviation from the center of said dense regions of the ends of said cut cigarettes.