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COUNTING APPARATUS

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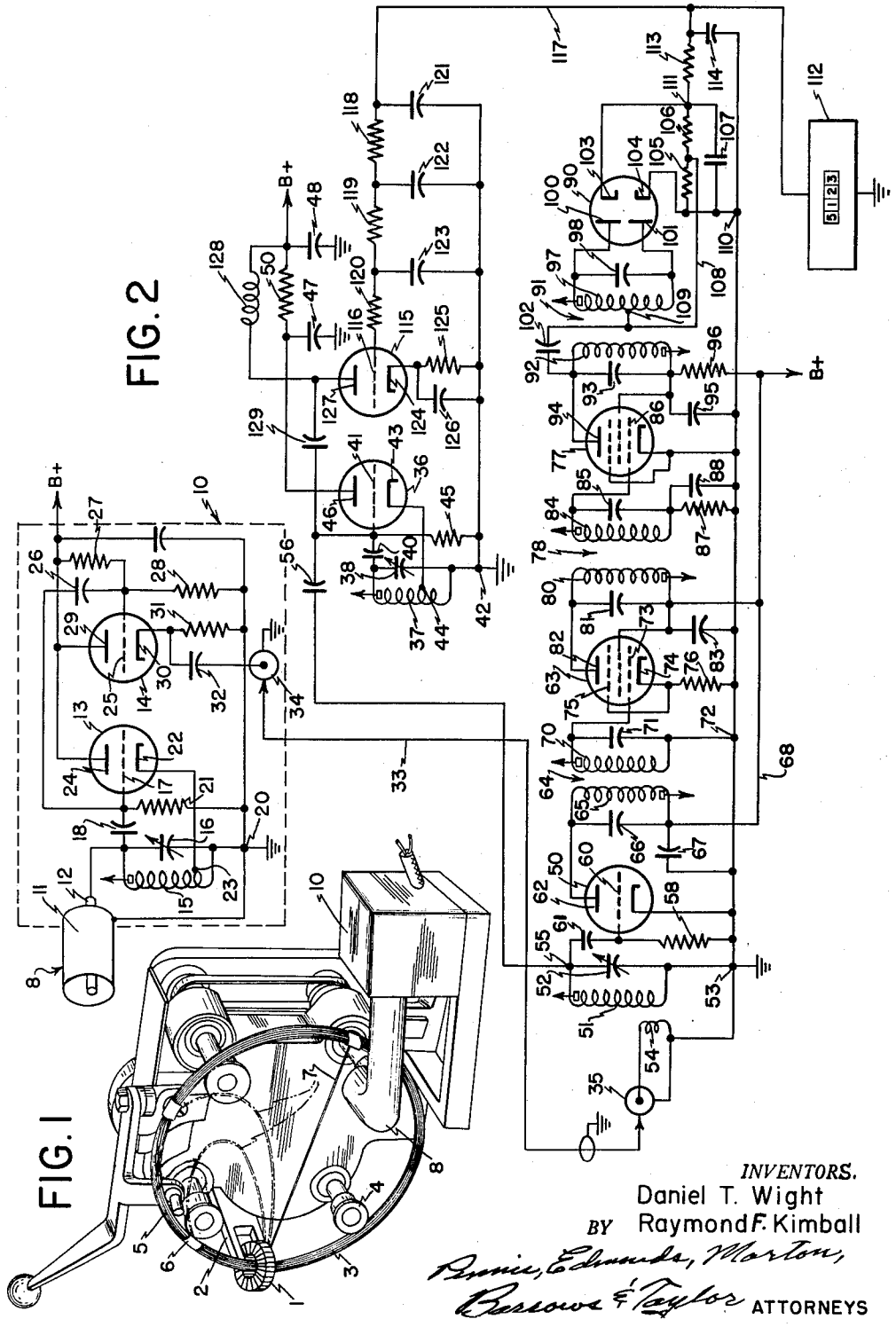


FIG. 2

FIG. 1

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COUNTING APPARATUS

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This invention relates to apparatus for counting the number of turns of wire as the wire is wound on a coil form.

It is common knowledge among persons familiar with apparatus for winding coils on curved or closed forms or cores that the problem of counting the number of turns of wire wound on the core is peculiarly complicated by the fact that there is no member of the winding apparatus whose motion is directly and precisely related to the number of turns actually wound. The only recurring motion which is directly related to the number of turns of wire wound on the core is the motion of the wire itself and this has been used for counting purposes for some years. Conventional winding machines have a circular wire-carrying winding shuttle which is continually rotated through the hole in an annular core. The wire is unwound from the shuttle and wound on the core. As each turn of wire is wound on the core a length of the wire sweeps across the plane of the shuttle. This is the recurring motion which is directly related to the number of turns and it is the motion on which turn counting depends.

The practice has been to place the actuating lever of a mechanical counter or the movable element of a small electric switch, connected in circuit with an electromechanical counter, so that it intercepts the wire sweeping across the plane of the shuttle. Actual contact between the wire and the lever or switch element is relied on to cause the counter to advance one count.

Arrangements of this kind have proved reasonably satisfactory provided that the winding speeds are low enough to be followed by mechanical means and further provided that the wire and its insulation can withstand the stress and abrasion set up each time the wire contacts the lever or switch element. However, the recent demand for large numbers of miniature and sub-miniature coils having a precise number of turns of very small gauge, thinly insulated wire has demonstrated the basic limitations of counters which use essentially mechanical wire sensing devices.

It has been apparent to those engaged in production of such coils that the basic problem lies in the pickup or sensing device, i.e. the counter lever or the switch element, and the necessity for actual physical contact between some part of the pickup and the wire. A strictly mechanical counter must be constructed with great precision if it is not to require an actuating force which is so great that it would frequently break the wire or damage the insulation. In any case, a mechanically actuated counter is not fast enough to follow the high speed winding machines currently in use.

A number of electromechanically actuated counters have been devised, but to our knowledge they all include some type of spring contact connected in circuit with the counter actuating mechanism. The wire being wound is drawn between the spring contact and its contact plate to open the counter actuating circuit and thereby cause the counter to advance one count. Such contacts have

proved to be only moderately satisfactory for numerous reasons. One of these is that the contact pressure between the spring element and the contact plate must be small to avoid breaking the wire or damaging its insulation. As a result, the contact is not reliable and frequently will not reestablish contact after every passage of the wire. The inevitable result is that turns are "lost." Another difficulty related to the necessarily light pressure between the spring element and the contact plate is that the element is frequently given to "bouncing" and "chattering." The result of this condition is, of course, that the number of counts accumulated is greater than the number of turns of wire on the core. Oscilloscope displays of the wave form caused by contact "bounce" under normal winding conditions show as many as forty individual contacts established between the spring element and the contact plate for each passage of the wire between the spring element and the contact plate. This condition is greatly aggravated where bifilar types of wires are being wound on a core or form. The irregularity of the surface of twisted pairs or bifilar types only causes the spring element to bounce and chatter all the more.

It is clear enough that the root of these troubles is the necessity for physical contact between the wire and the essentially mechanical pickup that is used to actuate the counter or the counter driving circuit.

Moreover, it is not possible to use conventional electromechanical counters where the wire being wound is uninsulated, for the circuit which should be opened as the wire passes between the contact points of the switch remains closed through the wire itself. Consequently, conventional counters cannot be used to count turns wound on potentiometers or other apparatus using coils of uninsulated wire.

We have invented an electronic counting apparatus which uses a probe to establish an electric field in the path of the wire. The passage of the wire is detected by the disturbance its passage creates in the electric field rather than by any sort of actual physical contact. The use of such a probe is not, however, the entire solution to the problem, for fully operative apparatus according to our invention requires special circuitry which can utilize the field disturbance as an input signal to develop a single well defined pulse to actuate a counter.

In its broadest terms, our invention encompasses apparatus for detecting and indicating the passage through a limited region of a body capable of altering an electric field, either electrostatic or electromagnetic. To accomplish this we provide means for establishing an electric field in the region through which the body, such as a wire, is to pass. We also provide a resonating circuit of which the field establishing means is a frequency determining element. The characteristics of the resonating circuit are arranged so that when there is no body to be detected in the region in which the field exists, the current in the resonating circuit has some predetermined frequency. We provide means which are operatively connected to the resonating circuit to detect when the frequency of the current therein departs from the predetermined frequency. A suitable form of counting device is arranged to be actuated in response to each departure of the frequency of the resonating circuit from the predetermined frequency, the change in frequency being due to the disturbance in the field created by the passage or presence of the body to be counted.

The principal objects achieved by our invention are the elimination of the need for actual physical contact between the wire being wound and the pickup device of the counting apparatus and the elimination of limits on the ability of the counting apparatus to detect and register

accurately each and every turn of wire wound by the winding apparatus without practical limitation on the rate at which the winding operation is conducted. When our new counting apparatus is used the speeds at which contemporary winding apparatus may be operated are not limited by the characteristics of the counting apparatus nor must the apparatus operate within any narrow range of speed dictated by the limitations of the counting apparatus.

Furthermore, elimination of the need for physical contact between the counter pickup and the wire eliminates a major cause of defective coils. The counter is no longer the cause of the wire being broken during winding and completed coils do not have to be rejected because the insulation has been scraped off or pierced by the counter pickup. Our new apparatus also functions equally well with non-conductive and conductive objects and, for the first time, it is possible to count turns of uninsulated wire being wound.

These and other features of our invention are explained in detail in the following description of a particular embodiment of our invention. In the course of that description reference is made to the accompanying drawing, in which:

Fig. 1 is a perspective view of coil winding apparatus having a pickup probe for the counting apparatus of our invention; and

Fig. 2 is a schematic circuit diagram of counting apparatus according to our invention.

In Fig. 1 there are shown the main operative components of a winding aparatus for winding coils of wire on a toroidal core or form. A complete description of the construction and operation of apparatus of this kind is to be found in the United States Letters Patent No. 2,793,818, issued to W. W. Clarke et al. on May 28, 1957. To understand the relation between our new counting apparatus and this coil winding apparatus it is sufficient to note that a toroidal core or form is supported by suitable means 2 so that it may be rotated or oscillated about its axis. A circular shuttle 3 is rotatably mounted on and driven by four small wheels 4 having grooved peripheries. The shuttle is provided with a break so that it may be sprung open to be interlinked with the toroidal core 1.

The shuttle carries a supply of wire 5 in a groove in its outer periphery. The wire is threaded through a slot in a slider 6 which is free to move along the shuttle. A length of the wire 7 extends from the slider 6 to the core 1 on which the coil is to be wound.

As the shuttle rotates the length of wire 7 is made to encircle the core by being carried through the hole in the annular core and then around the outside of the core. During the half revolution of the shuttle occurring between the passage of the slider 6 through the hole in the toroid and arrival of the slider at a point diametrically opposite the core 1 the wire being wound on the core becomes taut and causes the slider to retrogress on the shuttle thereby allowing a small additional length of wire to be pulled off the shuttle. During the next half revolution of the shuttle the distance between the slider and the core is decreasing and, therefore, the wire becomes slack. It is evident that one turn of wire is put on the core as the shuttle turns through approximately one revolution. The cycle is repeated until the desired number of turns has been wound on the core.

It is seen that the length of wire 7 between the slider and the core at any given time is generally in the plane of the shuttle and that the wire is swept through substantially the whole plane of the shuttle each time one complete turn of wire is wound on the core. The turn counting apparatus of our invention is adapted to sense the passage of the wire through any small area of the plane of the shuttle and to register one count each time the wire is sensed in this area.

In the particular embodiment of our invention shown in Figs. 1 and 2 a probe 8 made of a short length of coaxial cable is fixed at one end to the wall of a housing 10 mounted adjacent the coil winding apparatus. The open and unsupported end of the cable is placed adjacent the plane of the shuttle so that the wire passes close to the probe but does not touch it. In view of the fact that the wire passing from the shuttle to the core is taut during that part of the revolution of the shuttle when the slider is moving away from the core we prefer to place the probe so that the open end is presented to the lower half of the shuttle circle. This placement of the probe insures that the wire will not be accidentally snagged as it might be if the probe were placed adjacent the upper half of the shuttle circle where the wire is slack. However, there is nothing inherent in the apparatus which compels its placement as shown.

The probe is essentially a capacitive device. That is, an electrostatic field may be established in a limited region adjacent the end of the cable and as will be understood by persons skilled in the art this field may be disturbed by introducing into the field an object which has dielectric properties different from air. The result is that the effective capacity of the probe is changed by the presence of the body or wire. It is this phenomenon which is utilized to detect the wire each time it is swept through the plane of the shuttle and past the end of the probe.

The circuitry of our new apparatus is shown schematically in Fig. 2. In this particular embodiment compactness and flexibility of construction is realized by mounting only a part of the circuit components in the housing 10 immediately adjacent the winding apparatus. The remaining components are mounted on a separate chassis at any convenient location. In Fig. 2 the housing 10 is indicated by the broken outline and the probe 8 is shown schematically to consist of an outer shell 11 and the inner conductor 12.

Within the housing 10 there is a triode vacuum tube 13 arranged as an electron coupled oscillator. The tuned circuit of the oscillator consists of an inductance 15, a variable capacitance 16 and the probe 8—effectively a multi-valued capacitance—connected in parallel. As shown, the parallel inductive-capacitive circuit is coupled to the grid 17 of the triode through capacitance 18 and is connected to ground at 20. A suitable bias resistance 21 is connected between the grid and ground and the cathode 22 of the triode is connected to a intermediate turn of the inductance 15 at 23. A suitable voltage is applied to the plate 24 through the lead labeled B+.

The circuitry described so far forms a first resonating circuit which is arranged to have a normal frequency of, for example, 110.7 megacycles. As is well known to those skilled in the art this frequency is determined by the values of the inductance 15, the capacitance 16 and the capacity of the short length of the coaxial cable which constitutes the probe 8. As previously explained, however, the frequency of this first resonating circuit may be changed because the effective capacity of the probe 8 is changed by the presence of a body, such as a wire, in the region adjacent the open end of the probe.

The triode 14, located within the housing 10, is connected as a conventional cathode follower. The oscillating current from the first resonating circuit is coupled to the grid 25 of the triode 14 through a capacitor 26. Series resistances 27 and 28 connected between the B+ lead and ground serve as a voltage divider to provide the proper bias voltage for the grid 25 which is connected to the junction between the resistances. Plate 29 is connected to the B+ lead and cathode 30 is connected through resistance 31 to ground. This cathode follower circuit serves two purposes, namely, isolating the first resonating circuit from the remainder of the circuitry and providing a low impedance output which permits the remainder of the circuitry to be located at some convenient distance from the winding apparatus.

The cathode follower output voltage having a frequency of 110.7 megacycles is coupled forward in the circuit through the capacitor 32. As shown, the con-

nection between the circuit apparatus within the housing 10 and the remainder of the circuit apparatus is made through a shielded cable 33 having plug and jack connectors 34 and 35 at opposite ends.

The triode 36 is the active component of a second resonating circuit the frequency of which is determined by the values of the inductance 37 and the variable capacitance 38 connected in parallel.

This inductive-capacitive circuit is coupled to the grid 41 of the triode through capacitor 40 and is connected to ground at 42. The cathode 43 of the triode is connected to an intermediate turn of the inductance 37 at 44. Grid bias is established under normal operating conditions by the grid resistor 45 connected between the grid 41 and ground although special provisions to be discussed below are made for controlling the bias. The plate 46 is supplied with suitable voltage from the lead B+. Capacitors 47 and 48 and resistance 50 form a filter section which presents a low impedance to ground to the high frequency currents in the oscillator circuit.

In this preferred embodiment the values of the circuit components of the second resonating circuit are selected so that the frequency of the current in the circuit is 100 megacycles.

The output signals of the first and second resonating circuits are coupled into the input circuit of a heterodyne mixer circuit, the active component of which is the triode 50. The mixer input consists in part of the coil 51 in parallel with the capacitor 52, one junction between these elements being connected to ground at 53. The signal brought in from the cathode follower circuit on the shielded lead 33 is inductively coupled into the coil 51 from the small coil 54 and the signal from the second resonating circuit is connected to the mixer input at the junction 55 through capacitor 56. The values of the coil 51 and the capacitor 52 must be selected so that the parallel combination will pass 110.7 megacycle currents and the value of the capacitor must also present a relatively high impedance to 100 megacycle currents since voltages of both frequencies must be impressed on the grid 60 through coupling capacitor 61. By proper selection of the resistance 58 connected between grid 60 and ground 53 and of the voltage applied to the plate 62 the triode is made to operate on the non-linear portion of its characteristic curve. The triode then operates as a heterodyne mixing circuit to produce a signal having a beat frequency or intermediate frequency which is equal to the difference of the frequencies at which the first and second resonating circuits operate. In this particular embodiment the frequency of the beat signal will be 10.7 megacycles.

The specific frequencies given in this description are solely for illustrative purposes; in general, it is only necessary that the frequency of the first resonating circuit be greater or less than the frequency of the second resonating circuit by some predetermined difference frequency when there is no object in the field of the probe 8.

A pentode vacuum-tube amplifier 63 is used to raise the level of the intermediate frequency signal produced by the mixer stage. The two stages are coupled by a transformer 64 having a primary winding 65 tuned to the intermediate frequency by parallel capacitor 66. The primary of the transformer is connected between the plate 62 and ground through the capacitor 67 and suitable D.C. voltage is applied to the plate through the primary winding 65 from the power supply lead 68.

The secondary winding 70 of transformer 64 is also tuned to the intermediate frequency by capacitor 71 and is connected between ground at 72 and the control grid 73 of the pentode amplifier 63. The cathode 74 and the third grid 75 are connected to ground through cathode resistor 76.

Following the amplifier stage is a pentode vacuum tube 77 which is connected as an amplitude limiting stage and which is coupled to the amplifier 63 by a transformer 78. The primary winding 80 of this transformer is tuned to the intermediate frequency by capacitor 81 and is connected between the plate 82 of the amplifier and ground through capacitor 83. The secondary winding 84 of transformer 78 is also tuned to the intermediate frequency by capacitor 85 and is connected between the control grid 86 of the pentode 77 and ground through the resistor 87 and the shunt capacitor 88.

The limiter stage and the duo-diode 90 form a type of detector circuit which is known as a limiter-discriminator circuit. In this circuit the pentode 77 and the duo-diode 90 are coupled by a transformer 91. The primary winding 92 of the transformer is tuned to the intermediate frequency by capacitor 93 and is connected between the plate 94 and ground through the capacitor 95. Plate voltage for the pentode 77 is applied from the B+ lead 68 through the resistor 96.

The secondary winding 97 of the transformer 91 is shunted by a capacitor 98 and the opposite ends of the secondary winding are connected to the plates 100 and 101, respectively, of the duo-diode 90. The midpoint of the secondary 97 is coupled through capacitor 102 to the plate 94 of the pentode 77.

A circuit comprising the resistances 105 and 106 in series and the capacitor 107 in shunt with the two resistances is connected between the cathodes 103 and 104 of the duo-diode 90. The junction between the resistances 105, 106 is connected through the lead 108 to the midpoint 109 of the secondary winding of transformer 91 and cathode 104 is connected to ground at 110.

In operation the limiter stage limits the amplitude of the high level intermediate frequency signal developed by the pentode amplifier 63. The purpose of this is to remove any amplitude modulation from the signal and to reduce it to a relatively constant value. The discriminator stage is a phase detector which is responsive to the difference in phase of the two currents induced in the two halves of the secondary winding 97 whenever the frequency of the current departs from the resonant frequency, in this case 10.7 megacycles. The cathode voltages of the two sections of the tube 90 are developed across resistances 105 and 106 and the circuit is arranged so that the available output voltage between the point 111 and ground is equal to the difference between the voltages developed across the resistances 105 and 106. In this particular embodiment the circuit components are selected so that at the intermediate frequency the output voltage is zero. Any departure from the intermediate frequency causes a negative or positive voltage to be developed at the point 111 depending on whether the frequency of the signal is higher or lower than the intermediate frequency.

Having described the circuitry and the functions of the major components thereof it is now apparent that when no object is within the field of the probe 8 the output frequencies of the first resonating circuit and of the second resonating circuit are combined in the mixer circuit to produce an intermediate frequency signal having the predetermined difference frequency. So long as the output signal of the mixer has this predetermined difference frequency the limiter-discriminator circuit produces no output voltage. However, when an object capable of disturbing the field of the probe 8 is within the limited region adjacent the end of the probe the frequency of the signal produced by the first resonating circuit is changed. This follows from the facts that an object, such as a wire, in the field of the probe changes the effective capacity of the probe and that the capacity of the probe partially determines the frequency at which the resonating circuit operates. In particular, when the wire 7 shown in Fig. 1 passes the end of the probe the frequency of the current in the first resonating circuit will be lowered. Inasmuch as the heterodyne circuit produces a signal which is the difference between the fre-

quencies of the currents in the first and second resonating circuits, the intermediate frequency will be lower and a pulse of positive output voltage will be produced by the discriminator circuit. This voltage pulse can be used to drive any suitable type of counter or other display device.

In this embodiment the drive of a suitable decade counter 112 is connected between the junction 111 through a low pass filter comprising the resistance 113 and the shunt capacitor 114. This filter blocks any extraneous high frequency signals from the counter but permits the desired voltage pulses to pass. Counters of the type shown are entirely conventional and are manufactured by such companies as the Potter Instrument Co. of Great Neck, New York. Other types of display devices may be used in place of the counter.

It should be noted that for every entry of a wire into the field of the probe one and only one output pulse will be produced and the counter will advance only one count. Furthermore, because the probe has relatively small capacity under ordinary conditions, the introduction of an object into the field of the probe causes its capacity to change by fairly large amounts. The sensitivity of the first resonating circuit to objects in the probe field is accordingly quite high and the reliability of the instrument is correspondingly high.

Of course, the inductors and capacitors which are the frequency determining elements of the first and second resonating circuits are made adjustable within limited ranges so that the circuitry may be made to operate under optimum conditions. Similarly the coupling transformers between the several stages of the circuits are adjustable. However, over long periods of operation there will be an ordinarily unavoidable tendency for the frequencies of the oscillator circuits to drift due to temperature variations and aging of the components. In this particular embodiment we provide an automatic frequency control circuit for the second resonating circuit. This control circuit is arranged to adjust the frequency of the second resonating circuit so that there is automatic correction of any long term tendencies of the circuitry to cause the discriminator to produce an output voltage when there is no object in the probe field. However, this control circuit does not respond to the short term pulses which are developed in response to the presence of an object, such as a wire, in the field of the probe.

The active component of the automatic frequency control circuit is the triode vacuum tube 115. This tube is arranged as a variable reactance tube and is effectively in shunt with the inductance 37 and capacitance 38 in the grid cathode circuit of the oscillator tube 36. Bias voltage for the grid 116 of tube 115 is derived from the D.C. output voltage of the discriminator circuit. The lead 117 from the junction of resistance 113 and capacitance 114 is connected to the input of a resistance-capacitance network having a long time constant. This network comprises the series resistances 118, 119 and the shunt capacitances 121, 122, 123. The output of the network is connected through grid resistor 120 to the grid 116. The purpose of the network is to apply to grid 116 only those components of the discriminator output voltage which persist for a longer time than the duration of a counting pulse and which are indicative of drift of one or both of the oscillator frequencies from their normal operating frequencies.

The cathode 124 of tube 115 is connected to ground through resistance 125 in parallel with capacitance 126. Plate 127 is connected to the power supply lead marked B+ through an R.-F. choke 128, the purpose of which is to raise plate 127 above the low impedance of the power supply at the 100 megacycle operating frequency of the oscillator tube 36. The plate 127 is also coupled to the grid 41 of oscillator tube 36 through capacitance 129.

In operation this portion of the circuit effectively varies the frequency determining characteristics of the parallel inductance 37 and capacitance 38 when bias voltage from the discriminator circuit is applied to grid 116. As previously stated only discriminator voltages which persist for a time longer than the duration of a counting pulse are impressed on grid 116 and the reactance of the tube 115 is made to change so that the operating frequency of the controlled oscillator beats with the operating frequency of the probe oscillator to produce a beat frequency of 10.7 megacycles. So long as this beat frequency is held at 10.7 megacycles about which the discriminator circuits are tuned the discriminator produces no output voltage capable of biasing the reactance tube.

We have now described in detail a particular embodiment of our invention and we have described the manner in which it operates. It should be apparent to those persons who are familiar with the turn counters presently used in conjunction with coil winding apparatus that our invention eliminates the sources of trouble which are inherent in conventional counting apparatus. Moreover, a counter according to our invention is not subject to the limitations placed on winding speeds by conventional counters and it functions as well on uninsulated wire and conductive objects as on insulated wire and non-conductive objects.

Those skilled in the art will recognize that other types of resonating circuits and mixer circuits as well as other forms of probes may be employed in practicing our invention the scope of which is not intended to be limited to the specific details of the illustrative embodiment described above. The invention is defined in the following claims.

We claim:

1. Apparatus for counting turns of wire as the turns are wound on a toroidal core by a circular shuttle winding means, which apparatus comprises a capacitive probe adapted to be mounted adjacent the plane of the circular shuttle, a first vacuum tube oscillator circuit having said probe operatively connected in the frequency determining portion thereof and adapted to vary the resonant frequency of said circuit from a first predetermined frequency upon the introduction into proximity to said probe of a wire being wound by said shuttle, a second vacuum tube oscillator circuit adapted to operate at a second predetermined frequency normally differing from said first frequency by a difference frequency, means for mixing the output signals of said first and second oscillators to produce a beat frequency signal, means responsive to said beat frequency signal for producing a direct current output signal the amplitude of which is related to the frequency of said beat frequency signal, said amplitude being substantially zero when the frequency of said beat frequency signal is equal to the difference frequency and means responsive to said direct current output signal for indicating a change in the amplitude thereof.

2. Apparatus according to claim 1 in which said probe comprises a length of coaxial cable.

3. Apparatus according to claim 1 in which said means responsive to said beat frequency is a limiter-discriminator circuit.

4. Apparatus according to claim 1 in which said means responsive to the direct current output signal is a counter.

5. Apparatus according to claim 1 in which said means responsive to said beat frequency signal is a limiter-discriminator circuit which produces an output voltage pulse when said beat frequency signal departs from the difference frequency and in which said means responsive to said direct current output signal is a counter.

6. Apparatus according to claim 1 and which further comprises means responsive to said direct current output signal and operatively connected to said second oscillator circuit for varying the operative frequency thereof to maintain said beat frequency signal substantially equal to

said difference frequency when a wire being wound is not in proximity to the probe.

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