Feb. 23, 1960 J. R. HORSCH 2,926,057

FACSIMILE APPARATUS

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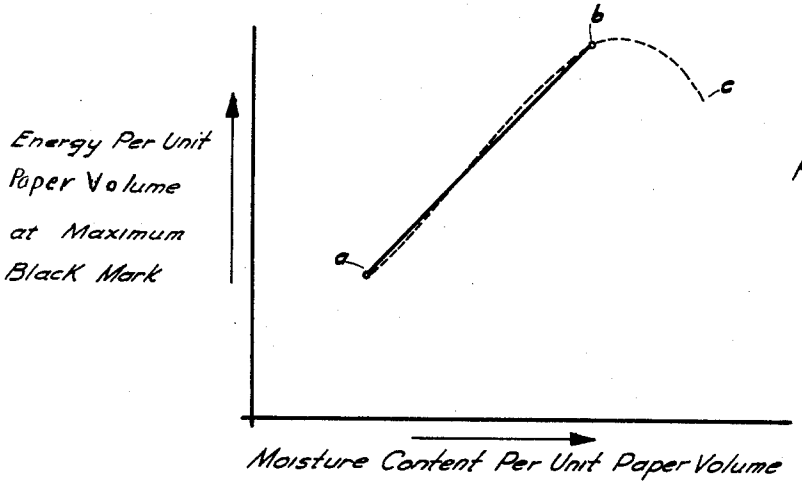


FIG. 1.

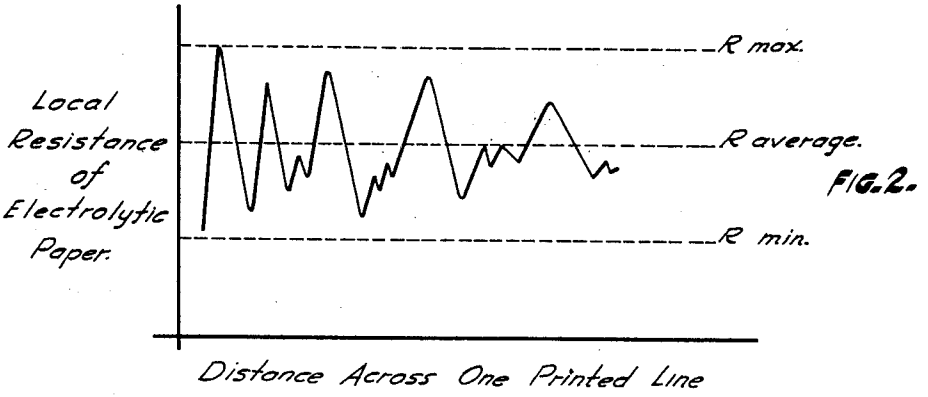


FIG. 2.

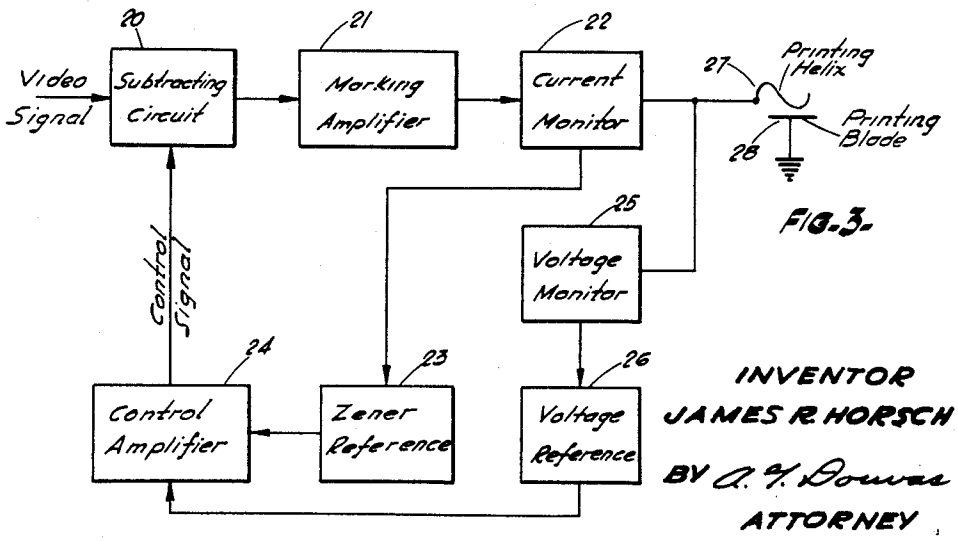


FIG. 3.

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FACSIMILE APPARATUS

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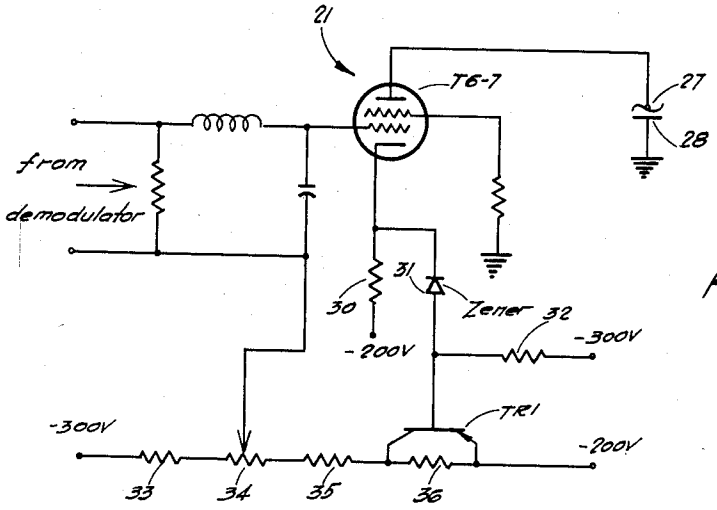


FIG-4

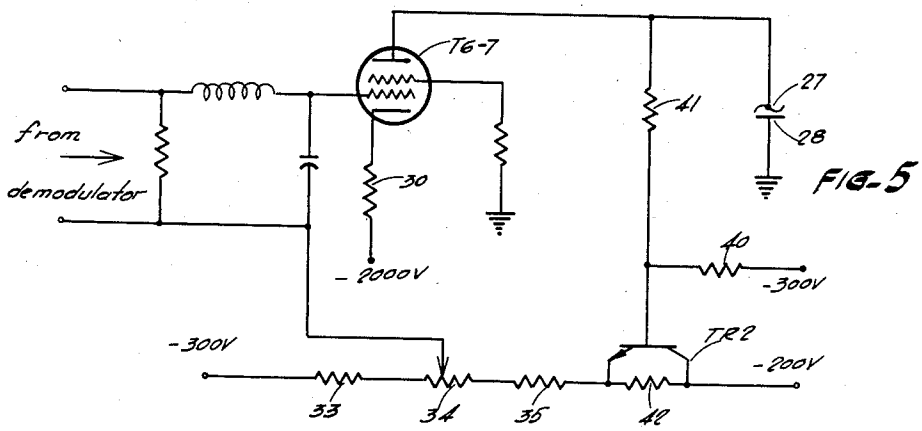


FIG-5

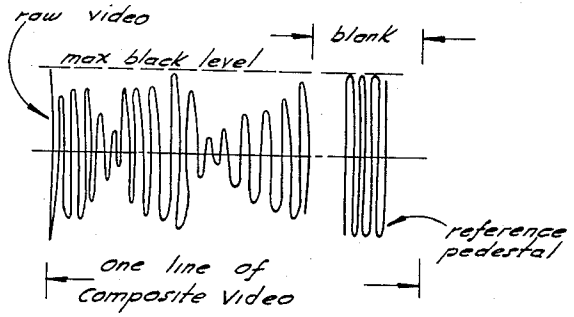


FIG-6

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FACSIMILE APPARATUS

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FIG. 9

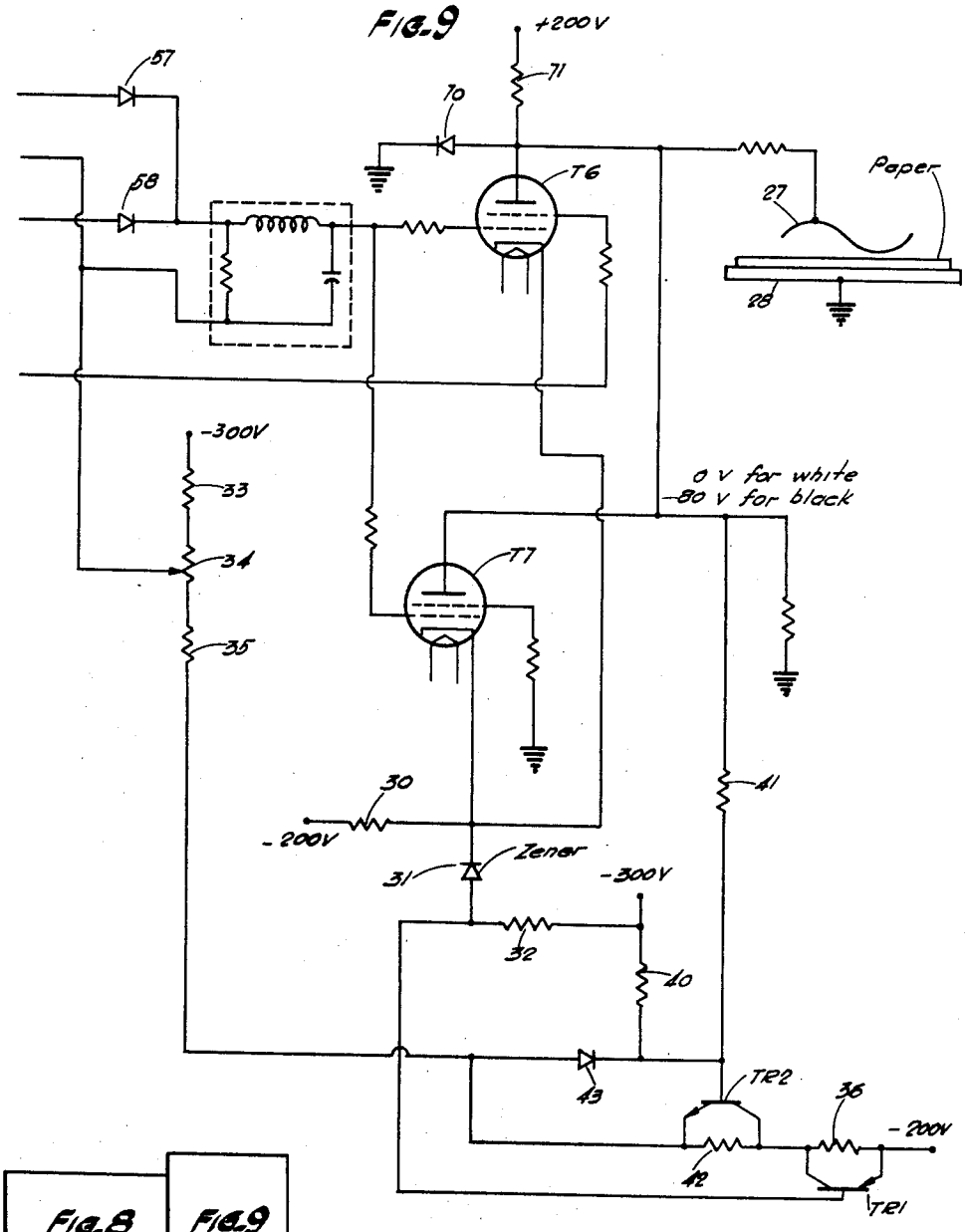


FIG. 8 FIG. 9

FIG. 7

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FACSIMILE APPARATUS

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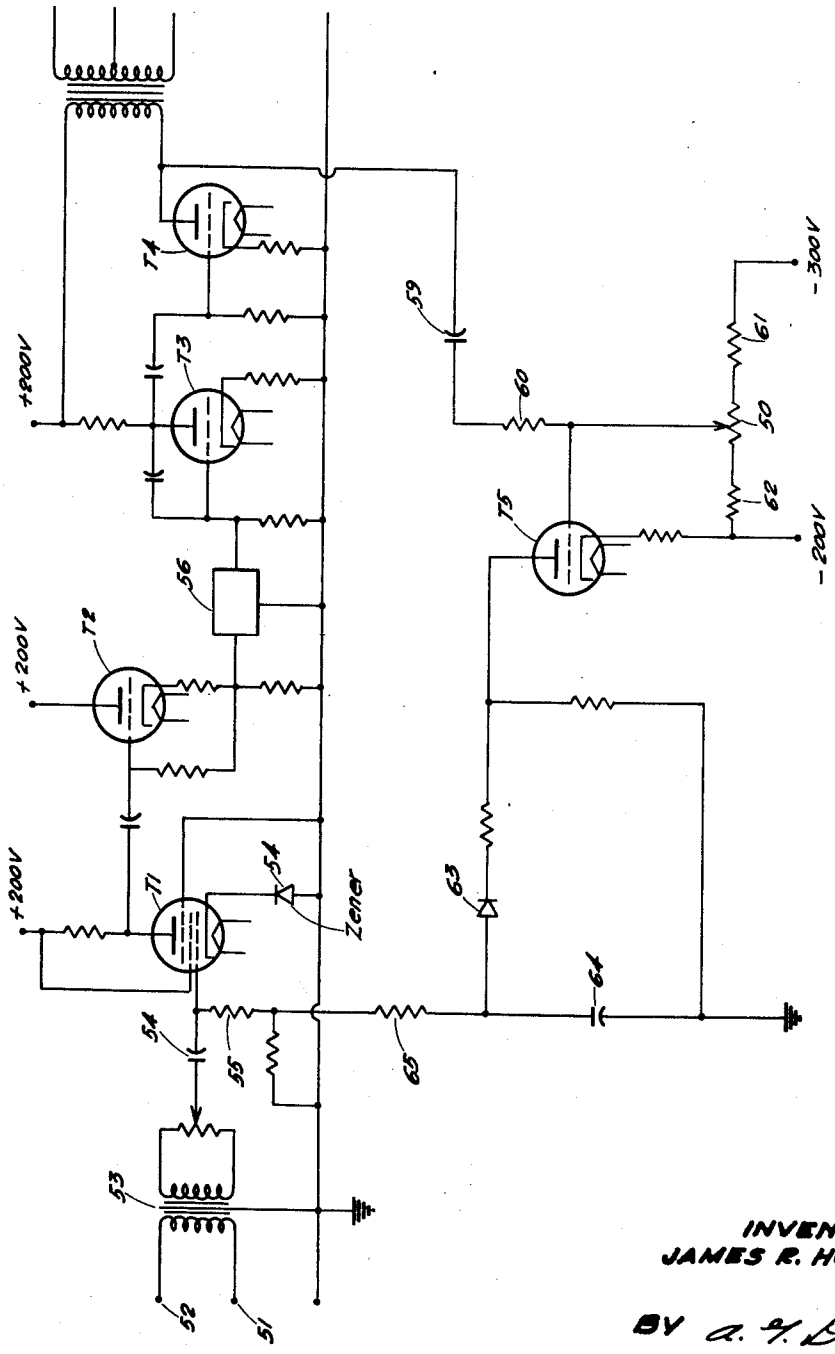


FIG. 8

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FIG. 10

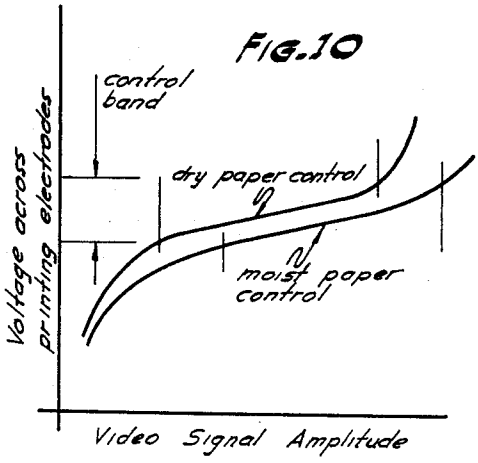
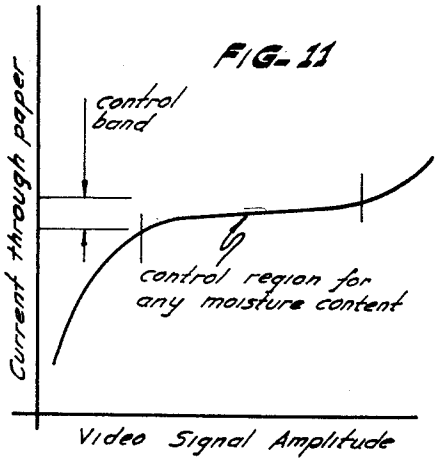


FIG. 11



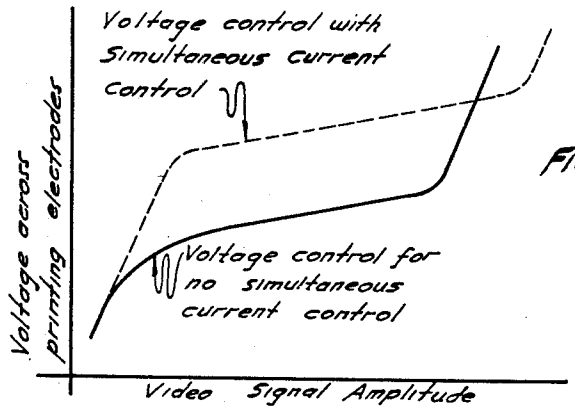


FIG. 12

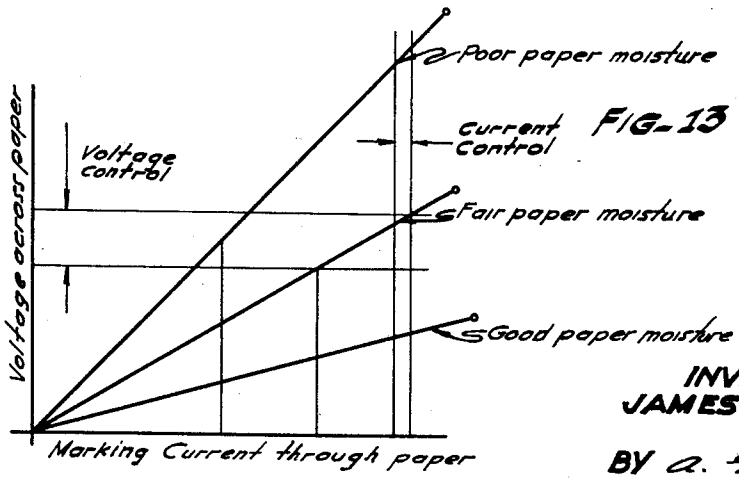


FIG. 13

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United States Patent Office 2,926,057
Patented Feb. 23, 1960

2,926,057

FACSIMILE APPARATUS

James R. Horsch, Elmhurst, Ill., assignor to Stewart-Warner Corporation, Chicago, Ill., a corporation of Virginia

Application August 1, 1957, Serial No. 675,638

9 Claims. (Cl. 346—74)

This invention relates to facsimile apparatus, and in particular to an improved arrangement for controlling the application of current and voltage to electrolytic copy paper employed in facsimile reproductions.

A number of recording techniques for facsimile signals have been developed in the art. One of these utilizes an electrolytic paper of such nature that metallic ions are conveyed during printing from a solid printer blade into an aqueous catechol saturated paper. (A catechol is a chemical compound which reacts with metallic ions in such a way as to produce solid areas of color.)

When recording is accomplished on catechol saturated paper, several factors are pertinent in the derivation of optimum marking. It has been determined empirically that removal during marking of a particular fraction of the moisture content in the electrolytic paper will lead to a more desirable mark than will boiling away more or less than this optimum fraction. The amount of moisture which will boil away from the paper is determined primarily by the amount of energy which is dissipated per unit volume of the paper during marking. In order then that the desired fraction of moisture leave the paper, it becomes necessary to control the amount of electrical energy which is incident on the paper as it is marked.

The problem is somewhat complicated by the fact that the paper exhibits local inhomogeneity which occurs as the printing electrodes move from fiber to fiber. The electrical conductance of the paper shows a corresponding variation locally and in this way requires an amount of electrical energy per unit volume which varies also locally. Thus an optimum control system which will so control the marking amplifier as to produce an optimum black signal across any paper fiber must sense the instantaneous resistance of the paper to the flow of electrical charge and must produce a marking power which will vary accordingly.

Examples of control devices which meet this requirement of the electrolytic paper to one degree or another are to be found in facsimile equipment as currently produced. As a general rule, these control devices operate in parallel with the electrolytic paper and act in such a manner as to absorb a fraction of the marking amplifier output power which is more or less dependent upon the condition of the particular paper and particular fibers being marked. This method of control has two distinct disadvantages, both of which are overcome by the subject matter of the present invention.

The first disadvantage is that the electric circuitry of the marking system is required to operate continuously at maximum power output; i.e., control occurs at the level of maximum power in the marking system. Consequently the electronic equipment is operating at maximum heat dissipation during the marking of maximum black and the temperature rise of the equipment is maximized. In this case it becomes necessary to isolate the paper, its moisture being subject to greater evaporation at higher temperatures, by suitable thermal design. In the majority of higher speed equipments which have been marketed, an unsatisfactory thermal condition has resulted and moisture has been lost by the paper before it reaches the marking electrodes, with the net result that poorer than optimum marking is obtained.

The second disadvantage with the present method of control is that it tends to produce across the paper being marked a constant potential rather than a constant current through the paper. Since the marking process is one of electrolytic conduction, a significantly more uniform mark will result from a control of marking current than from the control of marking voltage.

Accordingly, a principal object of this invention is to provide an improved facsimile recorder which will be more tolerant of those paper variations which are to be found in practice so as to provide a more uniform and optimum marking for papers of varying characteristics.

Another object of this invention is to control the marking current and voltage of a facsimile system at a comparatively lower power level so that thermal dissipation in the electronic portions of the system is minimized and is never more than that which is required for producing the desired marking on the paper itself.

Another object of this invention is to prevent overload or burning of the recording sheet in an electrolytic facsimile recording scanner due to static or other transient signals in the system.

Another object of this invention is to provide protection for the paper whenever the recording electrode of the scanner leaves the paper momentarily as in bouncing.

Another object of this invention is to render less critical the setting of the gain controls and other means for determining the recording current in an electrolytic or similar facsimile recording system.

Another object is to provide a facsimile recorder with an automatic gain control system which is referenced to a portion of the transmitted signal so as to produce on the recording medium a mark which bears an adjustable relationship to the density of the copy being transmitted.

A preferred embodiment of this invention features a control utilizing semi-conductor devices which sense both the potential developed across the paper being marked and the current through this paper. This control produces a bias signal which alters the video signal applied to a marking amplifier in such a way as to cause both marking voltage and current to remain within those limits which will produce an optimum and uniform mark in the following manner.

In particular, in electrolytic copy paper having good to fair moisture contents, a video signal applied to the marking amplifier normally produces a copy which varies in uniformity and density with that of the transmitted copy. In the event, the video signal exceeds an allowable value tending to develop an excess current through the paper, producing paper burning, the current control limits the marking current to a safe and constant value which will produce uniform marking density for papers having moisture contents which vary from good to fair.

In the event, the moisture contents of the papers vary from fair to poor (dry), then the voltage control limits the voltage applied to the paper being marked to a constant narrow range or band of values which will produce an optimum black mark for the paper being marked, assuming that a video signal of substantial amplitude is being applied to the marking amplifier.

Another feature of this particular embodiment relates to a comparison of the reference portion of the video signal with an internal standard which controls the gain of the amplifier in such a way that the reference portion of the signal must assume a value which bears a direct relation to the setting of control. This enables the recording density to vary in correspondence with the transmitted density until the current and/or voltage controls

are rendered operative to produce the operation set forth above.

In order that all of the features for attaining the objects of this invention may be readily understood, reference is herein made to the drawings wherein:

Fig. 1 shows the relationship between the energy per unit volume in the recording paper for optimum black marking as a function of the moisture content of the paper;

Fig. 2 shows the manner in which the local resistance of the recording paper varies from element to element (assuming uniform moisture);

Fig. 3 is a block diagram of the marking control apparatus;

Fig. 4 is a simplified schematic diagram of the marking control apparatus shown in combined Figs. 8 and 9 and emphasizing the means of current control;

Fig. 5 is a simplified schematic diagram of the marking control apparatus shown in combined Figs. 8 and 9;

Fig. 6 is a diagram of the envelope of a typical composite facsimile signal;

Fig. 7 is a diagram of assistance showing the manner in which Figs. 8 and 9 are combined to form a complete schematic;

Figs. 8 and 9 when combined in accordance with the diagram of Fig. 7 form a schematic circuit of a facsimile recorder incorporating the invention herein;

Fig. 10 is a diagram showing the control characteristics of the voltage control independently;

Fig. 11 is a diagram showing the control characteristics of the current control independently;

Fig. 12 is a diagram showing a composite control characteristic for simultaneous operation of the voltage and current control; and

Fig. 13 is a diagram showing the superposition of the control characteristics and the volt ampere characteristics of various recording papers.

Referring now to Fig. 1 of the drawings, a graph is shown therein which discloses the relationship of required energy per unit paper volume for producing an optimum black mark, to the moisture content per unit volume of the paper. Two curves are shown. The solid curve represents an optimum control for maximum black; the dotted curve represents control which is obtainable with the particular embodiment of the invention described. It should be noted that results obtained with this embodiment closely approximate the optimum over the region which may be considered as useful for the facsimile process. The solid curve is approximately a straight line because a given amount of energy will boil away an amount of water which is directly proportional to this energy. If energy per unit volume which is greater than this optimum value is incident on paper, too much of the water will be boiled away and paper burning will result. If less energy than that represented by this optimum is incident on the paper, a mark will be obtained which is less black than that of which the paper is capable of producing. Generally speaking, in the portion of the broken line curve extending from *a* to *b* the voltage control is operative as hereinafter outlined to produce an optimum black mark, and in the portion extending from *b* to *c* the current control is operative to produce a mark of uniform density.

In practice it is found that only a limited range of moisture contents—as an example, from 30% by weight to 45% by weight—will allow electrolytic papers to be used in facsimile recorders. An important factor which limits the maximum amount of moisture in the paper is the strength of the paper itself. A factor which enters into the lower limit is the limited solubility of the catechol used.

Fig. 2 is an illustration of the manner in which paper resistance varies from point to point across one line of this paper due generally to fiber variations, with uniform moisture per unit volume assumed. This figure is also illustrative of the aforementioned requirement placed on the control system; namely, that the marking current be maintained essentially invariant for a given signal from one marking point to the next in order to obtain uniform marking.

In order that there be no confusion concerning the relationship of the gross characteristic of the paper shown in Fig. 1 and the local characteristic of the paper shown in Fig. 2, it must be pointed out that the marking control system should be such as to produce for a given video signal a given marking current in the paper up to the point at which the energy per unit volume dissipated locally in the paper exceeds that value which is given by the curve of Fig. 1. The clear implication of this statement is that the marking amplifier must show the highest possible internal impedance under normal marking conditions, but must show a greatly reduced internal impedance under the abnormal marking condition of excessive energy dissipation.

It may be noted in Fig. 2 that the maximum resistance, R_{max}, is at least twice the minimum resistance, R_{min}. For a given marking current the energy per unit volume in the R_{max} region will be the same as the energy per unit volume in the R_{min} region. The control circuit will determine if the energy per unit volume at R_{max} is greater than that represented by the curve of Fig. 1 and, if so, it will make the marking current in the R_{max} region less than the marking current in the R_{min} region. At the same time it must be recognized that a deterioration of copy will result from a reduction of current in the R_{max} areas whenever the paper moisture is lower than optimum. However, this deterioration will be minimized by the control circuitry to be described, and will be less than that which is demonstrated by any of the prior art systems.

Fig. 3 shows in block diagram form how voltage and current are monitored by this invention to derive a control signal which subtracts proportionately in circuit **20** from the facsimile video signal. The plate current of the marking amplifier **21** is monitored in **22** by means of a resistor, the voltage drop across which is compared in **23** with the Zener (breakdown) potential of a reference (breakdown) diode. The voltage is monitored directly in **25** and compared in **26** with one of the regulated supply voltages. The control amplifier **24** consists of two transistors, one PNP for the current control, and the other NPN for the voltage control. The action of either of these transistors is to create an effective increase in the negative bias potential applied to the marking amplifier.

Fig. 4 is a schematic of a portion of the marking amplifier and control circuitry which effects control of paper marking through helix **27** and printing blade **28**. Resistor **30** monitors marking current. Zener diode **31** establishes a standard against which the voltage drop across resistor **30** is measured. Resistor **32** causes transistor TR1 to be normally conducting so that the potential drop from its collector to its emitter is nearly zero. Hence, in the absence of excessive current through resistor **30**, the base, emitter and collector of transistor TR1 are all at minus 200 volts. The bias which appears at the control grid of the marking amplifier tube T6–7 is then determined by the voltage division of serially connected resistors **33**, **34** and **35**. However, when an excessive current flows through resistor **30**, Zener diode **31** conducts and overcomes a portion of the forward bias on transistor TR1 so that a potential difference appears from the emitter to the collector and an equivalent resistance including that of resistor **36** is inserted in series with the bias circuit. Since this resistance is inserted in the positive side of the bias resistance divider, the control grid of the amplifier tube T6–7 will be biased more negatively which is in such a direction as to cause an effective decrease in the level of the video signal applied from the demodulator to the marking amplifier tube T6–7. Maximum feedback

and control occur when transistor TR1 has been completely cut off and resistor **36** has been inserted into the circuit. The value of resistor **36** determines the maximum feedback which this circuit can display.

Fig. 5 is a schematic of a portion of the marking amplifier and control circuitry which effects control of the marking voltage applied between helix **27** and printing blade **28**. Resistors **40** and **41** are chosen so that for normal marking voltages TR2 will be held conducting. Thus its base, emitter, and collector will be at the same potential; namely, minus 200 volts, and resistors **33**, **34** and **35** continue to determine the negative bias on the marking amplifier tube. However, if an excessive voltage appears across the paper, resistors **40** and **41** divide this voltage in such a way as to cause TR2 to conduct less current and again increase negatively the bias on the amplifier. It must be noted, however, that as the voltage drop acros resistor **42** increases from zero to some divided value, this amount of control voltage also appears as a change in the emitter voltage of transistor TR2 and it requires a corresponding change in marking potential in order for the feedback action to occur. As a result the voltage feedback is a proportional control which extends over a much wider region than does the current control which is also proportional over a very narrow region. A further consequence of this method of control is that when a current feedback has been obtained, i.e., excessive current is going through the paper, the voltage feedback circuit will be rendered inoperative except under the extreme condition of an order of magnitude or more increase in paper resistance as noted in conjunction with the description for Fig. 13.

In normal operating practice, the parameters of vacuum tubes and passive circuit elements, such as resistors and capacitors, are subject to significant variation from one unit to the next. In addition, transmission circuits are possessed of gains which vary from circuit to circuit and from atmospheric condition to atmospheric condition. If the facsimile system is to reproduce at the recorder an image whose density bears a direct relation to the density of the copy being transmitted, it is necessary that a reference signal be transmitted along with the video information and that this reference signal be used by the recorder in order to establish the absolute level of the composite video message. In a preferred recorder circuit of this invention shown in Figs. 8 and 9, an automatic gain control system operates on the composite video, which is shown in Fig. 6, in such a manner as to cause the level of the reference pedestal, which appears at the output of tube T4 (Fig. 8), to assume a value which is determined exclusively by the setting of the density control **50** (Fig. 8). The gain of the carrier amplifying circuit comprising tubes T1 through T4 and associated components is automatically controlled to be such that the operator has an absolute control over the density of black in reproduced copy as related to the copy being scanned at the transmitter.

The automatic gain control system picks out the maximum black, i.e., maximum carrier amplitude in the transmitted signal, compares this with the setting of density control **50** and amplifies any difference in such a manner as to cause the gain of tube T1 to be increased or decreased, as required, in order that the reference level and the reference pedestal amplitude be the same. Once this action has taken place on the reference pedestal, then the raw video, as shown in Fig. 6, has been given an absolute level from which printed copy may be derived. In order that this reference pedestal be able to occupy a unique position in the composite video signal, it is centered in the blank period which normally occupies about 10% of the line for transmission of one video line, and the pedestal itself is made to occupy about 3% of the line length. It must be pointed out that the reference pedestal in the composite video signal is derived from the same photocell as is the raw video. This is so that the reference pedestal will always represent the maximum black of which the transmitting system is capable.

Figs. 8 and 9 show a complete schematic diagram of a facsimile recorder. The signal, from the communications link, is incident on terminals **51** and **52** of input transformer **53**. Its impedance level and its amplitude are changed by transformer **53** which applies it to the grid of tube T1, a semi-remote cutoff pentode. A Zener diode **54** is placed in the cathode circuit of T1, which causes T1 to be biased to a minimum voltage equal to the Zener voltage of the diode. This limits the maximum sensitivity of the amplifier so that noise signals will not be picked up and amplified as if they were composite video. The transformer **53** and amplifier T1 are coupled through a capacitor **54** in order that a controlled voltage may be introduced at the grid of T1 through resistor **55**. The signal once having been amplified by T1, has its impedance transformed by cathode follower T2 and fed into filter **56**, after which it is amplified linearly by tubes T3 and T4.

The output of T4 is fed simultaneously to three places. One of these is the video demodulator which separates the video modulation from its carrier. The second is a hold-in circuit (not shown) which demodulates the video from its carrier and causes a relay to be closed when composite video is present. The video demodulators are diodes **57** and **58**. The third place to which the amplified signal goes is through isolating capacitor **59** and isolating resistor **60** to the grid of the automatic grid gain control tube T5 to which grid is also connected the automatic gain control reference voltage derived from the resistive voltage divider **62**, **50** and **61**.

Whenever the amplitude of the modulated carrier is greater than the magnitude of the reference signal derived from potentiometer **50**, T5 will conduct through diode **63**, this will cause charging of the automatic gain control storage capacitor **64**. Accumulation of charge on capacitor **64** causes a potential difference across its terminals, which potential difference is applied through resistors **55** and **65** to the grid of T1. When the gain of T1 is thus varied, the amplitude of signal at the plate T4 correspondingly is varied, and when the correction is of sufficient magnitude diode **63** will cease conduction and the system will have stabilized at one level of gain. Since the reference pedestal in the composite video signal is at least as great as any other portion of the signal, the automatic gain control circuit will always refer to this pedestal.

The operator of the recorder may find it necessary to adjust the relationship of the recorded density to the scan density. This can be accomplished by changing the setting of potentiometer **50**, which then compares the reference pedestal with a different level of voltage, and causes stabilization of the amplifier gain at a different value.

Once the signal has been established in absolute magnitude by means of the automatic gain control circuit, it can be demodulated and applied to the grid of the marking amplifier, comprising tubes T6 and T7. These tubes are used in parallel in order to generate the required marking current without exceeding the maximum plate dissipation of the tube type. The control circuitry, as described with reference to Figs. 4 and 5, determines if the applied voltage or the applied current to the paper is excessive. If either is found to be excessive, then a proportional control, as shown in Fig. 4 or Fig. 5 (Fig. 4 describing the current control and Fig. 5 the voltage control), is subtracted from the incoming video signal and the voltage or current developed across the paper is correspondingly reduced to a value which is tolerable. It should be noted that resistors **36** and **42** are connected in series in the composite current and voltage control. Diode **43** prevents excessive back bias on transistor TR2.

Fig. 10 is a diagram showing the control character-

istics of the voltage control system independently of current control. It should be noted that the voltage control band is relatively broad and that for both dry and moist papers the control band is not entered into until a substantial video signal amplitude has been attained. Dry paper causes shift of the controlled portion of the curve to the left so that a smaller video signal amplitude is required to effect voltage control. Moist paper causes a shift of the controlled portion of the curve to the right so that a larger video signal amplitude is required to effect voltage control.

Fig. 11 is a diagram showing the control characteristics of the current control independently of voltage control. It should be noted that current control is substantially independent of the moisture content of the paper after the video signal amplitude enters the control region. The curve of Fig. 11, however, shows a different or shifting voltage control characteristic for papers having different moisture contents.

Fig. 12 shows the composite action of the voltage and current control circuits. If the current control is operating and producing a reduced video signal, then the voltage control operates at a level which is increased by the magnitude of the current control. It is significant to observe that the configuration of the voltage control transistor TR2 as an emitter follower yields a band of voltage control which is significantly broader than the band of current control developed by transistor TR1 which is connected in a grounded emitter configuration.

As shown in Fig. 12, if the current control is operative at the same time, a voltage characteristic correction is required. The voltage control characteristic for any degree of paper moisture will be displaced diagonally upwards and to the right from the characteristic which would be exhibited under the condition of no simultaneous current control.

The shift of the voltage control curves has particular significance with respect to the production of optimum copy, since good paper will then be marked locally at all points under current control only.

Figure 13 shows the separation of voltage and current control regions by varying paper moisture content. Good paper moisture will cause control to be entirely within the current control region. Poor paper moisture will cause control to be entirely within the voltage control region. And fair paper moisture will cause control in regions which can be either voltage or current or both. The current control band is narrower than the voltage control band as shown in Figures 10 and 11 and as described previously in the text. As a consequence, the voltage control does not cause a unique relationship between paper moisture and marking current. Rather, the marking current is confined to a similar band, the limits of which are determined by the intersections above and below of the paper resistance curve and the voltage control band extremes. If the operator sets the density control for a higher video drive, control will occur near the top of the voltage control band. If the operator sets the density control for a lesser video drive, control will occur around the lower limit of the voltage control band. Since the current control band is also of finite width, though much narrower, a similar, though much restricted, variation will occur within this band.

One of the problems of high speed printing using a combination of drum helix and spring welded printer blade is that the printer blade bounces. When bouncing, the printer blade loses contact with the paper momentarily on a periodic basis and the effective resistance of the printing medium is grossly increased momentarily also. It is under this condition that both the current and voltage controls will operate together in order that the energy released by the marking is such as to remain below that value which will produce charring of the paper. From a standpoint of safety, if an operator should accidentally come in contact with the printing electrodes when no paper would be causing a shunting action, the power would likewise be limited to a value consistent with sustaining life. Diode 43 is functional during voltage control in that it prevents the base to collector voltage of TR2 from becoming excessive.

Diode 70 and resistor 71 produce a linearizing of the recorded gray scale in the region of very low transconductance of T6 and T7 and at the same time prevent reverse current between the helix and the printer blade with its attendant deterioration of the helix.

While there has been described what is at present believed to be the preferred embodiment of the invention, it will be understood that various changes and modifications may be made therein; and it is contemplated to cover in the appended claims all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In a recorder in which a facsimile video signal drives a marking amplifier to generate marking current and voltage for electrolytic copy paper, the improvement comprising a current control connected to said marking amplifier and actuated in response to a predetermined value of marking current passing through said copy paper to maintain said marking current at a substantially constant value for papers having a first range of moisture contents, and a voltage control connected to said marking amplifier and actuated in response to the application to said copy paper of a voltage in excess of a predetermined value to limit said marking voltage to narrow range of values for papers having a second range of moisture contents.

2. In a recorder in which a facsimile video signal drives a marking amplifier to generate marking current and voltage for electrolytic copy paper, the improvement comprising a current control connected to said marking amplifier and actuated in response to a predetermined value of marking current passing through said copy paper to maintain said marking current at a substantially constant value for papers having good to fair moisture contents, and a voltage control connected to said marking amplifier and actuated in response to the application to said copy paper of a voltage in excess of a predetermined value to limit said marking voltage to a specified narrow range of values for papers having fair to poor moisture contents.

3. In a recorder in which a facsimile video signal drives a marking amplifier to generate marking current and voltage for electrolytic copy paper, the improvement comprising a current control connected to said marking amplifier and actuated in response to a substantial value of marking current passing through said copy paper to maintain said marking current at a substantially constant value for papers having good to fair moisture contents, and a voltage control connected to said marking amplifier and actuated in response to the application to said copy paper of a substantial voltage to limit said marking voltage to narrow range of values for papers having fair to poor moisture contents.

4. In a recorder in which a facsimile video signal drives a marking amplifier to generate marking current and voltage for electrolytic copy paper, the improvement comprising a current control connected to said marking amplifier to limit the maximum value of marking current passing through said copy paper to a substantially constant value of papers having good to fair moisture contents, and a voltage control connected to said marking amplifier to limit the maximum voltage applied to said copy paper to a substantially constant range of values for papers having fair to poor moisture contents.

5. A facsimile recorder employing electrolytic copy paper comprising a marking amplifier including a vacuum tube having at least anode, cathode and control

grid electrodes, a pair of electrodes for receiving the copy paper therebetween connected in series with the anode-cathode space path of said vacuum tube, an input circuit applying a demodulated facsimile video input to the cathode-control grid space path of said vacuum tube, a voltage divider connected to said input circuit and applying a bias voltage to said vacuum tube, a marking current limiting control including a PNP junction transistor having at least emitter, base and collector electrodes, a resistor directly shunting said emitter and collector electrodes and connected in series with said voltage divider, means including a breakdown diode applying to the base of said PNP transistor a voltage proportional to the paper marking current when the diode is at its breakdown potential, a marking voltage limiting control including an NPN junction transistor having at least emitter, base and collector electrodes, a resistant directly shunting said emitter and collector electrodes of said NPN transistor and connected in series with said voltage divider, and means applying to the base electrode of said NPN transistor a voltage proportional to said marking voltage.

6. A facsimile recorder employing electrolytic copy paper comprising a marking amplifier including a vacuum tube having at least anode, cathode and control gride electrodes, a pair of electrodes for receiving the copy paper therebetween connected in series with the anode-cathode space path of said vacuum tube, an input circuit applying a demodulated facsimile video input to the cathode-control grid space path of said vacuum tube, a voltage divider connected to said input circuit and applying a bias voltage of said vacuum tube, a marking current limiting control including a first junction transistor having at least emitter, base and collector electrodes, a resistor directly shunting two of said transistor electrodes and connected in series with said voltage divider, means including a breakdown diode applying to the third electrode of said transistor a voltage proportional to the paper marking current when the diode is at its breakdown potential, a marking voltage limiting control including a second junction transistor having at least emitter, base and collector electrodes, a resistor directly shunting said two of said second transistor electrodes and connected in series with said voltage divider, and means applying to the third electrode of said second transistor a voltage proportional to said marking voltage.

7. A facsimile recorder employing electrolytic copy paper comprising a marking amplifier including a vacuum tube having at least anode, cathode and control grid electrodes, a pair of electrodes for receiving the copy paper therebetween connected in series with the anode-cathode space path of said vacuum tube, an input circuit applying a demodulated facsimile video input to the cathode-control grid space path of said vacuum tube, a voltage divider connected to said input circuit and applying a bias voltage to said vacuum tube, a marking current limiting control including a first junction transistor having at least emitter, base and collector electrodes, a resistor directly shunting two of said transistor electrodes and connected in series with said voltage divider, means applying to the third electrode of said transistor a voltage proportional to the paper marking current, a marking voltage limiting control including a second junction transistor having at least emitter, base and collector electrodes, a resistor directly shunting two of said second transistor electrodes and connected in series with said voltage divider, and means applying to the third electrode of said second transistor a voltage proportional to said marking voltage.

8. A facsimile recorder employing electrolytic copy paper comprising a variable gain marking amplifier including input and output circuits, a pair of electrodes for receiving the copy paper therebetween connected to the output of said marking amplifier, means applying a demodulated facsimile video signal to the input circuit of said marking amplifier, a voltage divider connected to said input circuit and applying a bias voltage to said marking amplifier, a marking current limiting control including a PNP junction transistor having at least emitter, base and collector electrodes, a resistor directly shunting said emitter and collector electrodes and connected in series with said voltage divider, means including a breakdown diode applying to the base of said PNP transistor a voltage proportional to the paper marking current when the diode is at its breakdown potential, a marking voltage limiting control including an NPN junction transistor having at least emitter, base and collector electrodes, a resistor directly shunting said emitter and collector electrodes of said NPN transistor and connected in series with said voltage divider, and means applying to the base electrodes of said NPN transistor a voltage proportional to said marking voltage.

9. A facsimile recorder employing electrolytic copy paper comprising a variable gain marking amplifier including input and output circuits, a pair of electrodes for receiving the copy paper therebetween connected to the output of said marking ampilfier, means applying a demodulated facsimile video signal to the input of said marking amplifier, a voltage divider connected to said input circuit and applying a gain control voltage to said marking amplifier, a marking current limiting control including a first transistor having at least emitter, base and collector electrodes, an impedance element shunting two of said transistor electrodes and connected in series with said voltage divider, means to the third electrode transistor a voltage proportional to the paper marking current, a marking voltage limiting control including a second transistor having at least emitter, base and collector electrodes, an impedance element shunting two of said second transistor electrodes and connected in series with said voltage divider, and means applying to the third electrode of said second transistor a voltage proportional to said marking voltage.

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