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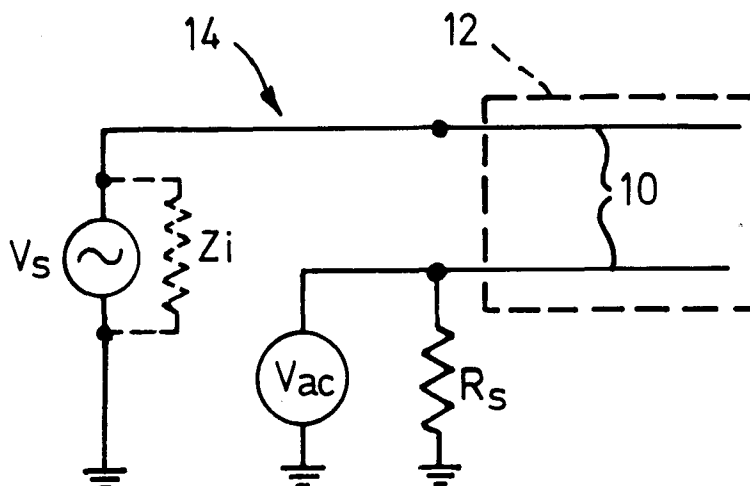
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(54) Short detection circuit for ink jet printer

(57) A detection technique comprises a plurality of closely spaced, continuous detection electrodes placed immediately below and along the length of a charge plate in an ink jet printing system. The detection electrodes typically comprise parallel conductors. A circuit is provided for monitoring the conductivity between the electrodes. The electrodes are electrically isolated from

one another when properly placed on the catcher surface. If the conductivity, as measured by the circuit, rises above a predetermined threshold level it is an indication that some amount of unwanted ink is present at the location of the conductors. This signals improper print head operation requiring a print head shut-down and/or clean cycle.

**FIG. 1**

Description

Technical Field

The present invention relates to planar charging and deflection print heads that require a means of detecting unwanted ink on a charge plate during start-up and printing and, more particularly, to improved detection of misplaced ink in the charge plate region of such printing systems.

Background Art

In continuous ink jet printing, ink is supplied under pressure to a manifold region that distributes the ink to a plurality of orifices, typically arranged in a linear array (s). The ink discharges from the orifices in filaments which break into droplet streams. The approach for printing with these droplet streams is to selectively charge and deflect certain drops from their normal trajectories.

In the field of ink jet printers, it is desirable to be able to detect unwanted ink on the charge plate during start-up and printing. The unwanted ink may be a mist build-up on or near the charge leads, but is usually an accumulation of ink on or near the charge leads caused by a crooked jet or improper start-up. The unwanted ink on the charge plate causes an electrical short between the charge leads and ground, causing print defects and physical damage to the charge plate due to unwanted current flow.

Existing charge lead short detect schemes rely on a measurement of the current drawn from the charge plate voltage supply by conductive ink bridging a charge lead to some nearby ground. This requires the current measurement to take place during the nonprint state when the charge lead voltages are all nonzero. There are several problems with the present short detect scheme.

One problem with the present short detect scheme is that timing the current measurements with non-print times can be tedious to perform on long arrays, especially with possible segmented phasing. Another problem is that if the amount of ink bridging the charge leads to ground is small enough, then the current drawn from the charge lead power supply can be below the threshold needed to signal an improper condition due to high ink path resistance. Therefore, the threshold current for detecting a "short" must be made as small as possible. This is limited greatly by the externally induced noise created by the charge driver switching slew rates. This allows small, high resistance ink paths to exist without being detected for some amount of time, causing ink build-up and charge lead deplating to take place until a more catastrophic failure occurs. Additionally, if a jet is in the beginning phases of crashing where ink is only being placed at the lower portion of the charge plate region, without actually electrically contacting the charge

lead, it is not detected and the print head is allowed to function even though a print problem may exist, or until a much more damaging condition is created from ink accumulating in the charge plate area.

It is seen then that there is a need for an improved means of detecting unwanted ink on the charge plate during start-up and printing.

Summary of the Invention

This need is met by the short detect technique according to the present invention, wherein misplaced ink in the charge plate region is detected, without regard to print pulse timing or charge lead short circuit to ground.

In accordance with one aspect of the present invention, a detection means comprises a set of closely spaced, continuous parallel conductors placed immediately below and along the length of the charge plate, as short detection electrodes. Additionally, a circuit is provided for monitoring the conductivity between the electrodes. The electrodes are electrically isolated from one another when properly placed on the catcher surface. If the conductivity, as measured by the circuit, rises above a predetermined threshold level it is very likely that some amount of ink is present at the location of the conductors. This is an indication of improper print head operation and should signal a print head shut-down and/or clean cycle.

Accordingly, it is an advantage of the present invention that it continuously monitors for ink accumulation in the charge plate area. It is a further advantage of the present invention that the electrically isolated monitoring circuit does not depend on current being drawn by the charge lead potential for detection. The circuit can also be made very sensitive to the presence of ink without being greatly affected by the electrical noise produced during printing. It is an object of the present invention that a jet impacting on the charge plate below the charge leads is as readily detected as a jet impacting on the charge leads.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawing and the appended claims.

Brief Description of the Drawing

Fig. 1 illustrates a short detection circuit, according to the present invention;

Fig. 2 is a side view of a continuous ink jet system of the type suitable for use with the short detection circuit of Fig. 1;

Fig. 3 illustrates the location of short detection electrodes associated with the short detection circuit of Fig. 1;

Fig. 4 illustrates a flex circuit for fabricating the short detection electrodes of Fig. 3;

Fig. 5 illustrates an alternative fabrication method for the short detection electrodes of Fig. 3;

Figs. 6, 7, and 8A and 8B illustrate various alternative embodiments of the short detection circuit of Fig. 1, in accordance with the present invention; and Fig. 9 illustrates voltage produced across a sensing resistor during a print head start-up simulation.

Detailed Description of the Preferred Embodiments

This present invention allows for detection of misplaced ink in the charge plate region, without regard to print pulse timing or charge lead contact with the ink. Detection electrodes 10, as illustrated in Fig. 1, detect the presence of ink on or close to charge leads 16. If ink is present on or very close to the leads, there is a problem with the printhead which needs to be corrected. The detection electrodes 10 are situated inside box 12. Outside box 12 is illustrated a detection circuit 14 used for monitoring conductivity between charge leads 16. Voltage source V_s and associated internal impedance Z_i provide an oscillating potential between leads 10. The conductivity between the leads is monitored by measuring the voltage drop across resistor R_s with voltmeter circuit V_{ac} . When the conductivity decreases between the detection leads due to the presence of a conductive fluid, such as ink, an increase in the current through R_s is produced, yielding an increase in the voltage measured by V_{ac} .

The present invention relates to the type of continuous ink jet system illustrated in Fig. 2. A plurality of jets is created at high spatial resolution by a drop generator, which stimulates the natural break-up of jets into uniform streams of droplets. A plurality of conducting elements, or charge leads 16, are located on a planar charge plate 18. A plurality of streams of drops 20 are supplied by drop generator 22. A plurality of independently switchable sources 24 of electrostatic potential are supplied to the plurality of charge leads 16. A catcher 26 intercepts the slightly deflected streams of drops. The plurality of streams of drops impacting on the catcher forms a film of ink 30, which in turn forms a flow of ink 28, sucked away from the face of the catcher by a vacuum. Reference number 32 represents the area on the catcher at which the deflected drops impact the catcher and merge together to form a film of ink on the catcher face. The undeflected ink drops then print the image on substrate 34.

The present invention comprises a set of closely spaced, continuous parallel conductors placed immediately below and along the length of the charge plate 18, to operate as short detection electrodes 10. Fig. 3 shows the location of short detection electrodes 10, situated just below and along the entire length of charge plate 18. The electrodes can be any suitable electrodes, such as 2 mil diameter copper wires. The electrodes may be secured by any suitable means, such as epoxy, at each end of the array.

The electrodes can be fabricated as a flex circuit 36 that is attached as a separate component to the catcher/

charge plate assembly with an appropriate attachment means 38, such as epoxy, as in Fig. 4. The flex circuit 36 of Fig. 4 comprises detection electrodes 10 as two flat conductive elements fixed on a thin dielectric substrate, with connections for the external sensing circuit.

Fig. 5 shows an alternative fabrication method comprising a dielectric 40 sandwiched between electrodes 10, which comprise two thin conductive plates. The edges of the plates form the sensing electrodes. This structure is inserted between the catcher 26 and the charge plate 18 during charge plate bonding, with connection electrodes provided at any point convenient for the subsequent electronics to access. The flex circuit sandwiched dielectric-type configurations allow a relatively small potential difference to be used between the sensing electrodes by the sensing circuit, producing a greatly reduced electrochemical reaction between the ink and the electrodes (when ink is present) as compared with that obtained by currently used short detect circuits.

Another embodiment of the detection circuit 14, illustrated in Fig. 6, has the electrodes 10 connected to either terminal of one set of windings of a transformer 42. This embodiment is novel in that the conductivity sensing circuit eliminates a direct electrical connection of the detection leads 10 to conductivity measuring circuitry. When operating properly, the winding of transformer 42 would be an open circuit. When ink bridges the detector electrodes 10, this circuit would be completed, which could be sensed by an impedance measuring circuit 44 connected to the second set of windings. As will be obvious to those skilled in the art, any suitable impedance measuring means, such as an impedance bridge circuit comprised of inductors, capacitors, and resistors, could be used, as well as various known sophisticated integrated circuit versions of the impedance bridge.

Fig. 7 shows another embodiment of circuit 14 wherein the detection relies on a battery-like response caused by ink 46 bridging dissimilar metals, referenced as detection leads 10' and 10". When ink joins the detection electrodes 10' and 10", a voltage is produced which can be detected. Hence, in Fig. 7, the detector electrodes 10' and 10" are dissimilar metals which, when bridged by an alkali or acidic ink 46, would produce an emf in a battery-type chemical reaction. This emf is then detected by a voltage sensing circuit 48. As will be obvious to those skilled in the art, any suitable voltage sensing means could be used, such as a standard operational amplifier circuit configured with resistors and capacitors as a high input impedance voltage measuring device. Alternatively, the emf sensing device could be a single integrated circuit chosen for the specific purpose of measuring small voltages. The advantage of the circuit embodiment illustrated in Fig. 7 is that it does not require a test voltage to be placed on the detector electrodes, allowing a completely passive input circuit design.

Yet another embodiment of the short detect circuit

14, according to the present invention, is illustrated in Figs. 8A and 8B. The circuit 14 of Figs. 8A and 8B utilizes a single electrode 10 in place of the pair of electrodes illustrated in Figs. 1, 6 and 7. This single electrode 10 is placed, by means of a voltage divider or equivalent circuit, at a potential between ground (catcher face potential) and the charge plate lead 16 potential. By noting the polarity of the current generated in the circuit connected to the lead, it can be ascertained whether the misplaced ink is bridging the electrode and charge plate or electrode and catcher. This is in addition to the somewhat simplified implementation obtained from using only a single lead.

Fig. 9 shows the voltage produced (V_{ac}) across sensing resistor R_s of Fig. 1 during a print head start-up simulation on a print head test stand. The sequence of events recorded in Fig. 9 are as follows. Initially, there was cross flush of the print head where ink is flowing from the orifice plate, over the charge plate and down the face of the catcher. In this state, ink is also flowing over the short detect electrodes, resulting in a relatively high conductivity between the wires. This produces a relatively high voltage across R_s , as indicated by the signal in region A of Fig. 9.

Region B of Fig. 9 shows the signal voltage across R_s produced when the print head has been taken out of the cross flush state and into the jetting and charge plate drying state. Here, jets have been started by closing the outlet valve and the catcher heater has been turned on. At about $t=2$ minutes, a very sharp decrease in V_{ac} occurs, indicating the conductivity between the sensing electrodes has decreased dramatically. This is due to the ink in the area of the sensing electrodes running off/drying, producing the low conductivity state.

At approximately $t=3.3$ minutes, the print head alignment was disturbed in a way to produce one to two jets just beginning to impact on the lower portion of the charge plate. This, in turn, caused a small amount ink to run down the surface of the charge plate/catcher and over the sensing electrodes. The presence of ink immediately raises the conductivity between the electrodes, as is indicated in part C of Fig. 9. This abrupt increase in V_{ac} indicates an improper condition on or near the charge plate and can be used to signal that a shut down condition exists.

After the "short" is detected, the print head alignment is changed to eliminate the crashing jet condition. At about $t=3.8$ minutes, V_{ac} decreased to near zero. This obtains from the runoff/drying of the ink which accumulated during C. Therefore, the circuit recovers when an abnormal condition is removed.

The present invention comprises detection lead or leads positioned immediately below the charge plate on which a portion of any unwanted ink will likely be deposited; and an electrical circuit which monitors the conductivity of the area between the detection electrodes. The circuit monitors the conductivity between the electrodes 10. The electrodes are electrically isolated from one an-

other when properly placed on the catcher surface. If the conductivity, as measured by the circuit, rises above a predetermined threshold level, it is very likely that some amount of ink is present at the location of the conductors. This is an indication of improper print head operation and should signal a print head shut-down and/or clean cycle.

In a preferred embodiment of the present invention, the circuit for monitoring the conductivity between the electrodes is isolated (floating) from the charge driver potential so that in the case of a large mass of ink bridging the charge leads and short detect electrodes, no large currents are produced in either the charge lead(s) or the sensing electrodes.

The sensing circuit of the present invention can be, but is not restricted to, an ac signal with a frequency and amplitude chosen to provide maximum short detect sensitivity with high noise rejection. For example, a circuit functioning in a manner similar to a lock-in amplifier would reject all signals at frequencies other than that used for monitoring the conductivity between the sensing electrodes. Various embodiments of the circuit are illustrated in Figs. 1, 6, 7, 8A and 8B. However, it will be obvious to those skilled in the art that various other circuit configurations may be used without departing from the scope of the invention. The specific circuit selected for any given application typically depends on the electrical conductivity of the fluid.

Industrial Applicability and Advantages

The present invention is useful in the field of ink jet printing, and has the advantage of continuously monitoring for ink accumulation in the charge plate area. The present invention has the further advantage of providing an electrically isolated monitoring circuit which is not dependent on current being drawn by the charge lead potential for detection. It is a further advantage that the circuit can be made very sensitive to the presence of ink, without being greatly affected by the electrical noise produced during printing. Finally, it is an advantage of the present invention that a jet impacting on the charge plate below the charge leads is detected as readily as a jet impacting on the charge leads.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that modifications and variations can be effected within the spirit and scope of the invention.

Claims

1. A detection means for detecting ink formed on a charge plate of a printhead in an ink jet printing system having a catcher, the charge plate having associated charge leads, the detection means comprising:

at least one detection electrode placed below
and approximately along a length of the charge
plate; and
a circuit for monitoring electric loading of the at
least one detection electrode.

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2. A detection means as claimed in claim 1 wherein
the at least one detection electrode comprises at
least one closely spaced continuous parallel con-
ductor, closely spaced to the charge electrodes. 10
3. A detection means as claimed in claim 1 wherein
the at least one detection electrode comprises at
least one short detection electrode. 15
4. A detection means as claimed in claim 3 wherein
the at least one short detection electrode is situated
on a catcher surface.
5. A detection means as claimed in claim 1 wherein 20
the at least one detection electrode comprises a first
detection electrode and a second detection elec-
trode.
6. A detection means as claimed in claim 5 wherein 25
the circuit for monitoring conductivity comprises a
circuit for monitoring conductivity between the first
and second electrodes.
7. A detection means as claimed in claim 5 wherein 30
the second detection electrode comprises a print-
head component.
8. A detection means as claimed in claim 7 wherein 35
the printhead component comprises a conductive
catcher face of the catcher.
9. A detection means as claimed in claim 8 wherein
the catcher is metal. 40
10. A detection means as claimed in claim 5 wherein
the second detection electrode comprises an exter-
nal charge plate heater.
11. A detection means as claimed in claim 10 wherein 45
the external charge plate heater is located under the
charge leads.

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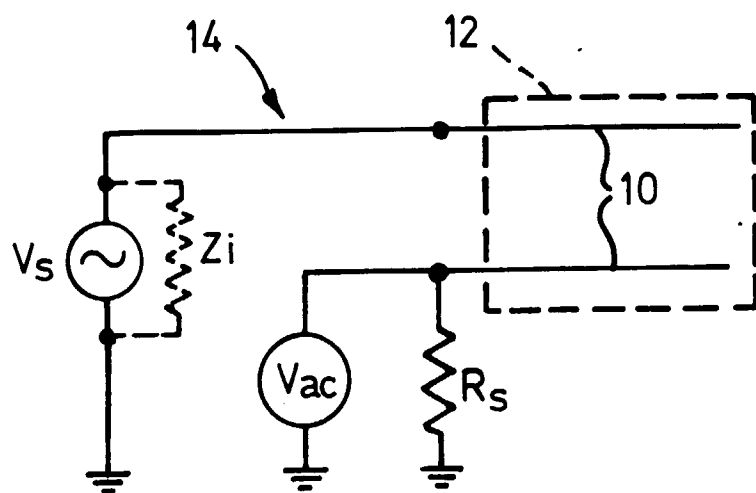


FIG. 1

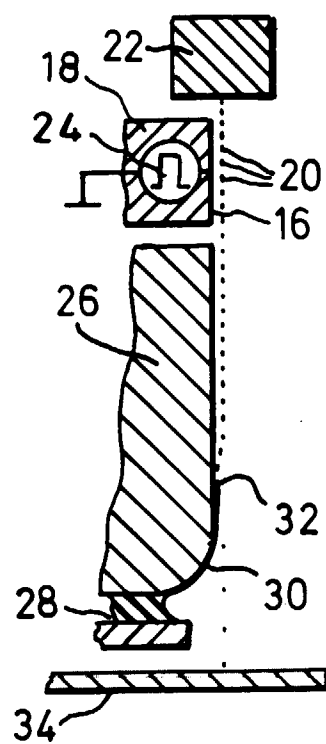


FIG. 2

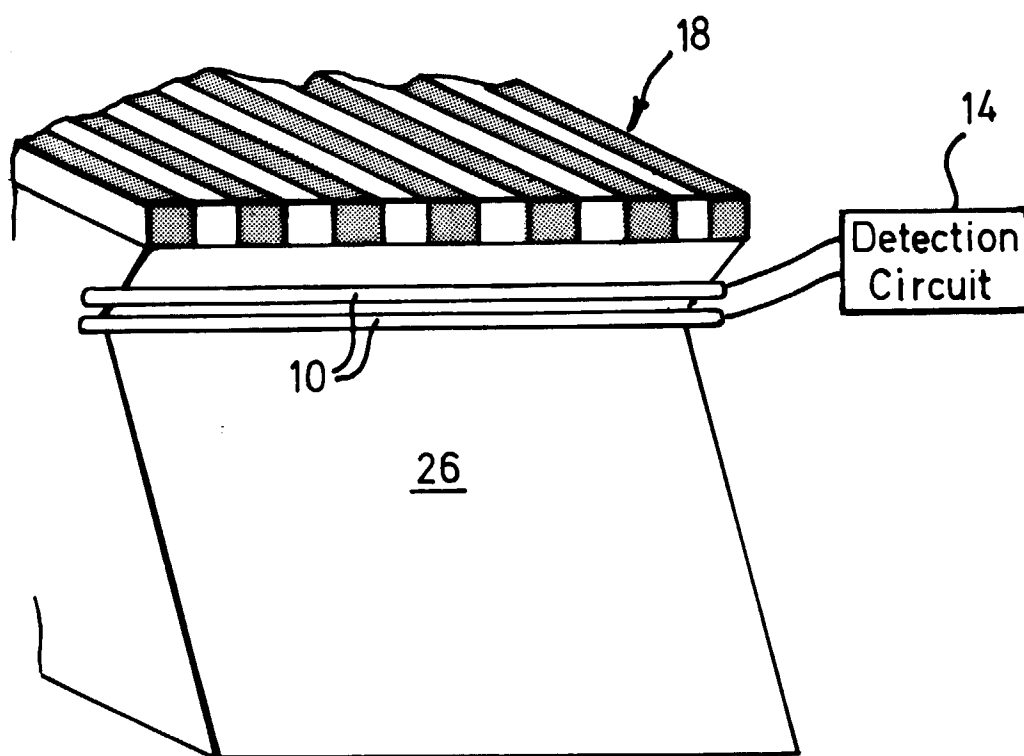


FIG. 3

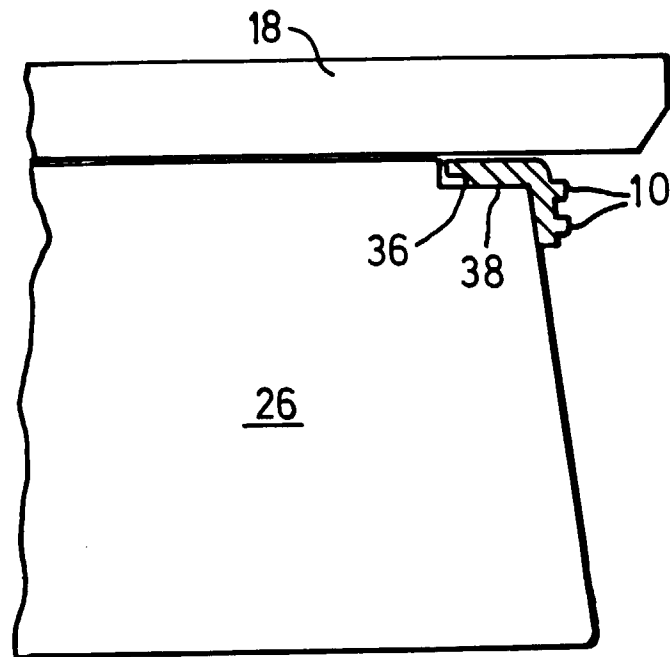


FIG. 4

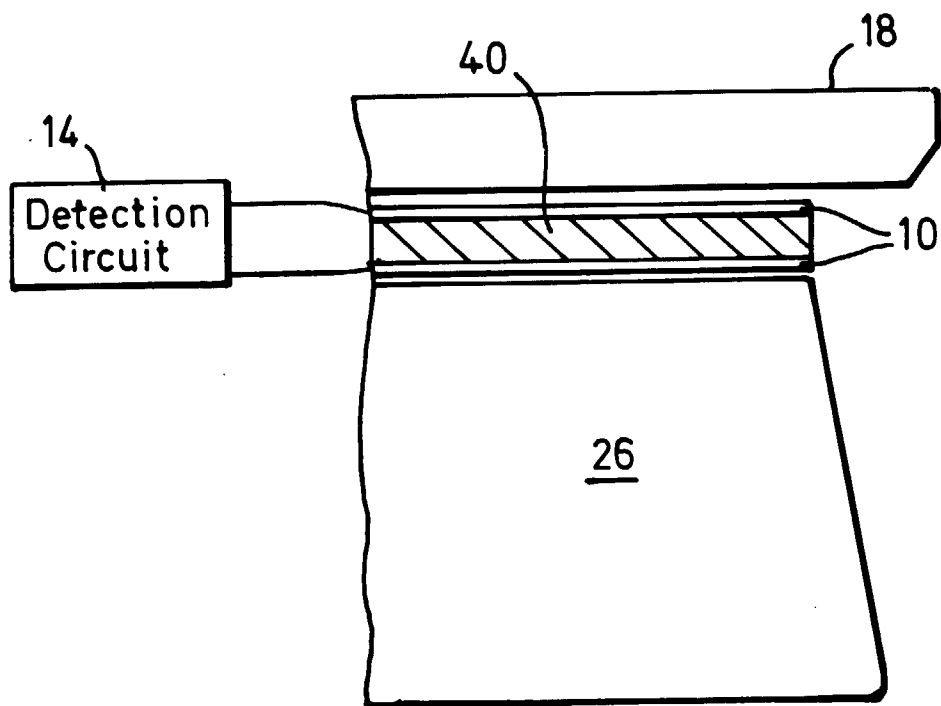


FIG. 5

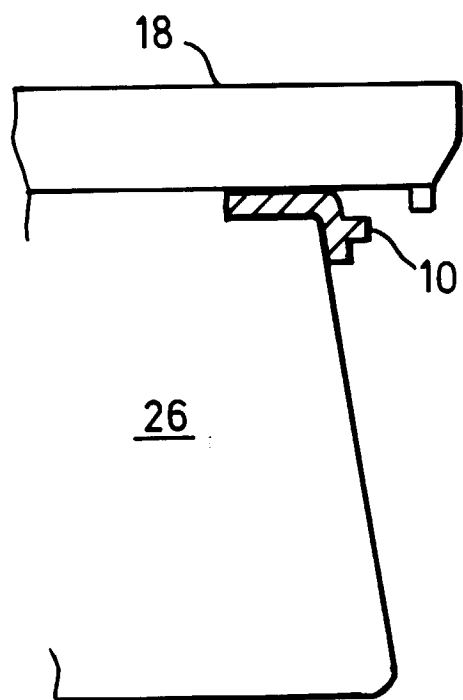
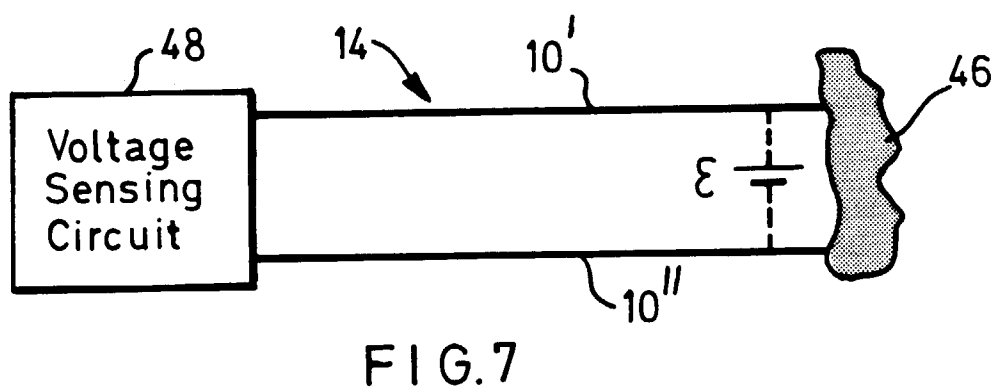
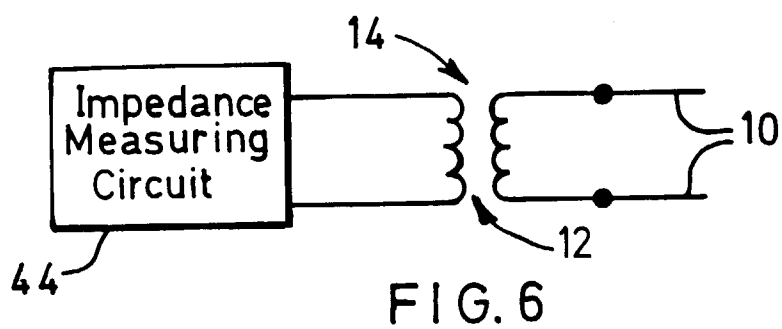


FIG. 8A

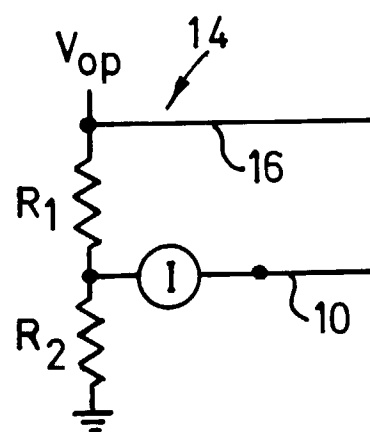


FIG. 8B

FIG. 9

SHORT DETECT OUTPUT
vs
Time
10sec/cm
0.5v/cm

