United States Patent

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[72] Inventors **Michael F. Baumann**
Reading;
Thomas S. Loane, Wyomissing, both of, Pa.

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[73] Assignee **Wyomissing Corporation**
Continuation-in-part of application Ser. No. 738,171, June 19, 1968, now abandoned.

[54] **DEVICE FOR THE VISUAL PRESENTATION OF ELECTRONIC INTELLIGENCE**
1 Claim, 4 Drawing Figs.

[52] **U.S. Cl.** ..... **346/74 E,** 340/173 R, 346/74 SC, 346/77 R
[51] **Int. Cl.** **G01d 15/06,** G01d 15/02, G11b 9/00
[50] **Field of Search** ..... 340/173, 173 LT, 173.2; 346/74 E, 74 ES, 74 SC, 74 SB, 77

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Primary Examiner—Bernard Konick
Assistant Examiner—Gary M. Hoffman
Attorney—Synnestvedt & Lechner

ABSTRACT: A system for recording information onto a sheet of material is provided by forming a plurality of closely spaced electrical junctions that are normally nonconductive but that selectively may be raised to a conductive state. The passage of current through the junctions is effective to alter certain properties of the junction such as electrical, mechanical or chemical, and enable the recording or retrieval of information.

The junctions are defined by a series of linear conductors located in a first plane, a second series of linear conductors angularly oriented to the first conductors located in a second plane parallel to the first plane, and a material having different electrical properties, preferably a dielectric material, positioned between the first and second planes.

Pressure forces generated variously by mechanical, chemical or electromagnetic energy are utilized to program the junctions.

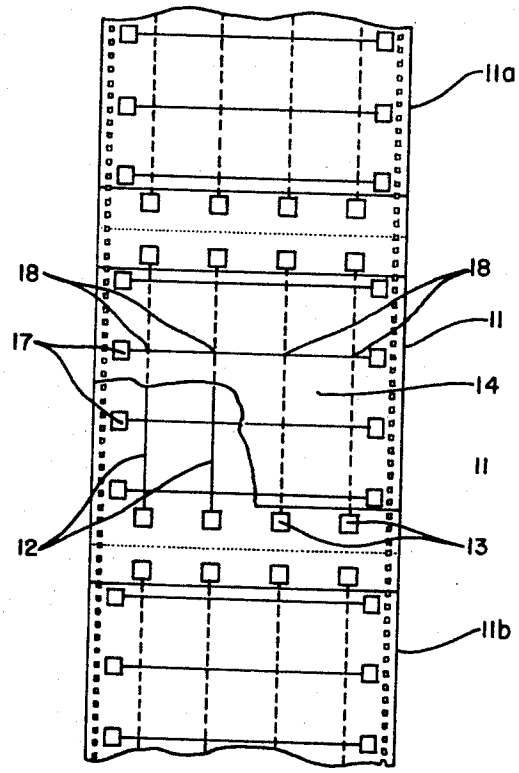
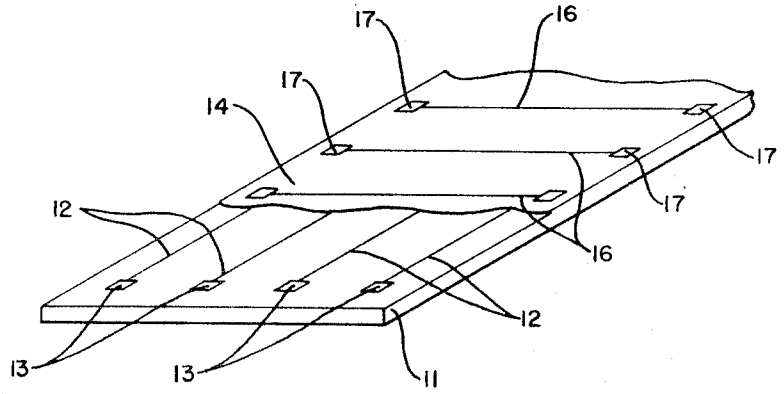


FIG. 1



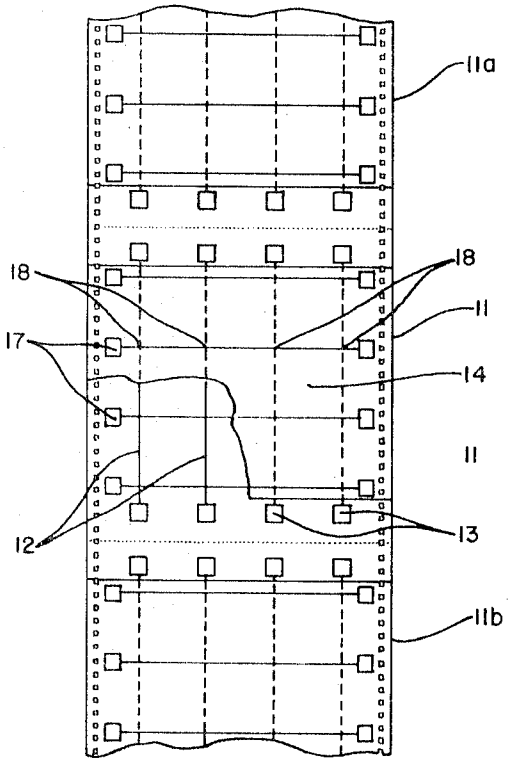


FIG. 2

INVENTORS
MICHAEL F. BAUMANN
THOMAS S. LOANE

Synnestvedt & Lechner

ATTORNEYS

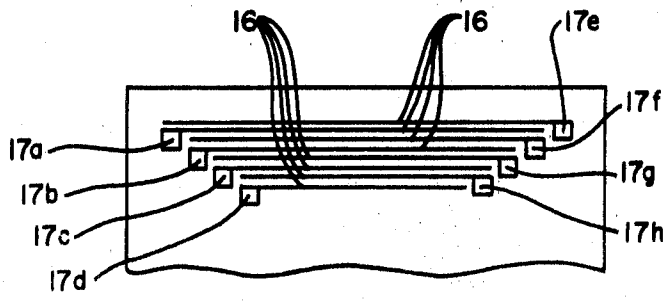


FIG. 3

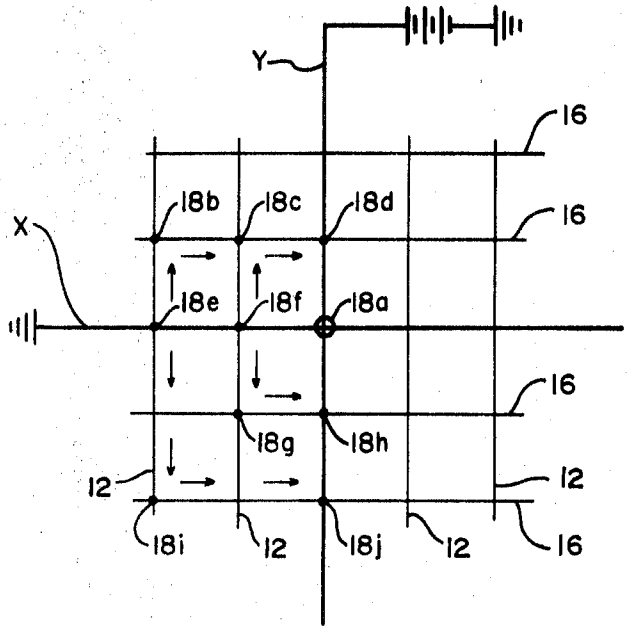


FIG. 4

INVENTORS
MICHAEL F. BAUMANN
THOMAS S. LOANE

Synnestvedt & Lechner
ATTORNEYS

DEVICE FOR THE VISUAL PRESENTATION OF ELECTRONIC INTELLIGENCE

This application is a continuation-in-part of our copending application Ser. No. 738,171, filed June 19, 1968 now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to methods and means for recording on and retrieving information from a sheet of material by electromagnetic, mechanical or chemical means. More particularly, this invention relates to methods for storing or reproducing information by use of a system comprised of a series of electrically responsive coordinates that are arranged to record intelligence variously in written, printed or pictorial form on a substrate, such as a sheet of paper.

2. Description of the Prior Art

In man's quest to record information and communicate with others, many mechanical devices have been designed to reduce the burden of recording information by written script. Typewriters are commonly used to reproduce documents if only a few copies are desired, and printing presses may be utilized to produce unlimited copies of a desired work. In more recent times, office copying equipment has become available that will provide limited copies of documents as by thermal or xerographic means.

More recently, in the present electronic age, it became necessary for man to communicate with computers. Only then did the limitations of the existing means to record information and transmit it in written form become painfully clear. The typewriters, printing presses and duplicating equipment suddenly became antiquated by the fantastic pace set by computers. These methods are slow, both in recording and retrieving information, and, in the case of printing and typewriting, considerable training and skill is required to obtain minimum levels of efficiency.

Consider that the computer's speed in processing and recalling data from its memory unit has, within the last decade, been reduced to times measured in nanoseconds. When this is compared with human capabilities for recording or retrieving information, for example, 10 or 12 characters per second by the fastest typist, it can be appreciated that the difference between man and machine is measured by many, many orders of magnitude.

For this reason, it has proved impractical to pass information between people and computers by any form of direct communication. Because of the tremendous speed mismatch, it is customary to talk with the computer only during an emergency, as when a response by a person is absolutely necessary for the computer to continue operating. In this situation, the computer must wait for a decision, and, while it stands idle for only a matter of a few seconds, thousands upon thousands of computations could have been made while it was waiting for the operator to reach a decision.

Because of this speed mismatch, it is conventional to talk to a computer, or have it talk to us, by some indirect means of communication. Generally, such indirect communication makes use of punched cards, punched paper tape, or magnetic tape. This enables us to generate vast quantities of information while the computer is busy doing other tasks, and, after the information has been stored in an intermediate medium at the relatively slow human rate, the information is fed to the computer at a much faster rate, thus enabling the computer to operate more efficiently. Conversely, information produced by the computer can be stored in an intermediate medium and then reproduced for slow assimilation by people at a later time so that the computer is not held up. The information that is stored on the intermediate medium may be presented in useful form by character-by-character printing devices such as typewriters, or by printout devices that are capable of printing whole lines at a time. While the very sophisticated of these latter devices reach what seems to be fantastic rates, sometimes exceeding several thousand lines per minute, they are still incredibly slow as compared with the output capacity of the computer.

The above printing devices for computer-human communication are also limited in that they can record intelligence essentially in alphanumeric characters. If a geometric input is desired, it may be necessary to use such devices as plotting boards, and, in order to obtain a geometric display from the computer, cathode-ray tubes may be used. The latter may also be used to display alphanumeric characters, but this use is considerably limited in that it does not provide a permanent record and the quantity of information that it reproduces is limited to that which can be displayed on a single screen at a given moment.

A number of other recording or indicating systems have been proposed and used with varying degrees of success. Some of these make use of styli, both single and multiple, which generate patterns as by the localized discharge of electricity. These and other electrical discharge devices have generally proved unsatisfactory due to many mechanical problems. The points are subject to considerable damage and wear that is caused by the repeated discharge of electricity. Also, the points frequently heat up and, if the temperature becomes sufficiently high, the entire system must be temporarily shut down and cooled. Similar disabilities resulting from arcing and the discharge of electricity may effect coordinate-type plotting boards.

OBJECTS OF THE INVENTION

Accordingly, it is an object of this invention to provide improved methods and means for rapidly displaying, recording, storing and retrieving information.

Another object of this invention is to provide inexpensive methods and means that may rapidly record, store, display, or reproduce intelligence in any form, be it written, typed, printed, or of artistic or geometric design.

Another object of this invention is to provide rapid and inexpensive methods and means whereby information, including pictures and geometric forms, can readily be transmitted electronically from one location to another.

Another object of this invention is to provide improved methods and means to communicate information to and receive information from a computer, which information may be in handwriting, printing, a drawing, or of geometric design.

Another object of this invention is to provide improved methods and means for communicating with computers at high rates whereby intermediate input/output mediums may, to a large degree, be made unnecessary.

Another object of this invention is to provide a memory unit.

Another object of this invention is to provide methods and apparatus for reproducing documents at almost instantaneous rates.

Another object of this invention is to provide methods and means for electrically recording information as may be used, for example, in continuous recording instrumentation.

These and objects of this invention are achieved by providing a coordinate system comprised of conductive elements that define a plurality of normally nonconductive junctions that may be selectively raised to a conductive state. When at the level of conduction, intelligence can be recorded or retrieved. The intelligence may be recorded, for example, by changing the electrical properties of the junction, by altering the physical characteristics of the junction, or by altering the visual properties of the junction. The intelligence may be retrieved, for example, by optical means or electrically by measuring the altered electrical properties of the junctions.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view, partially cut away, of a recording device constructed in accordance with this invention.

FIG. 2 is a view in plan of a series of the recording devices shown in FIG. 1.

FIG. 3 is a plan view of a portion of a recording device illustrating means for attaching electrical terminals.

FIG. 4 is a schematic view in plan, of several selected junctions of a recording device illustrating certain current flow through the junctions.

With reference to FIG. 1, there is generally shown a sheet of material **11** having mounted thereon a series of linear conductive elements **12–12**. Associated with each of the conductive elements **12–12** is an electrical terminal **13–13**. Overlying the conductors **12–12** is a layer of dielectric material **14**. Adhered to the upper surface of the dielectric material **14** are a series of second linear conductive elements **16–16** arranged at right angles to the first conductive elements. Each of the conductive elements **16–16** has attached thereto a terminal on either end.

As can best be seen in FIG. 2, the projection of the conductive elements **12–12** and **16–16** onto a single plane establishes a series of intersections, herein referred to as junctions, **18–18**. For convenience of description, these junctions are sometimes defined as resulting from the intersection of the two series of conductive elements, although it will be understood that the conductors do not actually intersect except as projected onto a common plane.

As shown in FIGS. 1 and 2, the series of conductive elements **16–16** are illustrated as having electric terminals **17–17** on both margins of the sheet. Actually, this is not required and a preferred embodiment for locating these terminals is shown in FIG. 3. Here a series of conductive elements **16–16** are connected only on one of their ends with a terminal **17–17**. Four terminals are shown in each margin of the sheet and alternating conductors **16–16** connect to terminals on the opposite side of the sheet. As will readily be apparent in considering FIG. 3, this arrangement allows for providing terminals of modest size, even though the conductive elements **16–16** are closely spaced with relationship to each other.

Considering the recording device of FIGS. 1 and 2 in somewhat more detail, it may be convenient to use a comparatively thin, flexible material for fabricating the substrate **11**. Paper is particularly desirable due to its inexpensiveness and the facility with which it may be handled and the conductive elements printed thereon. Other materials, such as plastics or metals, may also be used, particularly if more permanency is desired.

The series of conductive elements **12–12** are preferably spaced quite closely to each other, as are conductive elements **16–16**. In one preferred embodiment of this invention, the parallel conductive elements are laid down on the paper by means of printing processes such as offset or rotogravure. By using conductive materials as the "ink," lines can be laid down in close proximity to each other, for example, about 100 to 200 lines per inch. As will later become apparent in the discussion of this invention, the positioning of lines so close together enables obtaining extremely fine fidelity in reproductions made by these devices. If such fidelity is not required, the lines can be spaced much further apart.

The conductive lines may be laid down by a number of well-known processes. Metal and ceramic substrates lend themselves particularly well to plating, etching, and vapor deposition processes.

As each of the parallel elements **12–12** must be insulated from themselves, it is important that the substrate **11** to which they are attached be nonconductive. Alternatively, if a conductive material, such as a metal foil, is used for the substrate, it should be first coated with an insulating material so that the electrical integrity of the conductive elements **12–12** will be maintained.

The dielectric material **14** serves primarily to insulate the conductive materials **16–16** from the conductive elements **12–12**. In the preferred practice of this invention, this dielectric material is selected so that, under normal conditions, no current will flow at the junctions **18–18** of the several conductive elements. However, the dielectric will have a predeterminable breakdown voltage so that, on order, the junctions **18–18** can be raised to a conductive level.

In many applications, as will later be described, it is useful to program the junctions by altering, preferably raising, the dielectric strength of the junctions **18–18**. This may be accomplished through the application of pressure in such forms as electromagnetic, mechanical, or chemical energy. One convenient means by which this may be accomplished is to include a reactive material within the dielectric **14** that is sensitive to the application of these forms of pressure. When the pressure is applied, the reactive material is caused to react, either with itself or the dielectric material, and the dielectric strength of the junction may be altered. For example, the dielectric material may be a partially reacted or "B-staged" epoxy. When an imposed voltage overcomes the dielectric strength of the epoxy, current will flow and the I^2R loss will liberate heat and cause the epoxy to cure more fully.

Another simple means by which an alteration in the dielectric strength of the junction may be achieved is to include a blowing agent within a plastic matrix. When the junction becomes conductive, the heat generated by the I^2R loss (and/or by an exothermic chemical reaction at the junction that is initiated by the current flow) will cause the blowing agent to decompose or volatilize, the plastic matrix to foam, the intersecting conductive elements **12–12** and **16–16** to separate from each other, and the dielectric strength of the junction to increase.

As will be readily apparent to one skilled in the art, many different kinds and frequencies of electromagnetic energy may be utilized to effect alteration of the dielectric strength of the junction. Direct current voltage is perhaps most convenient, although frequencies ranging from high frequency sound through the visual band and into high frequency radiations may be employed.

If visual energy is utilized to alter the electrical properties of the junction, it may be convenient to include within the dielectric certain light-sensitive materials, such as cross-linking agents, that will become reactive upon actinic stimulation.

If the voltage at which a given junction becomes conductive (sometimes hereinafter referred to as the "breakdown voltage") is adjusted to be sufficiently high, a "punch-through" effect may be achieved in which the dielectric material in immediate proximity to the junction is actually dissipated with a consequent reduction in the dielectric strength of the junction.

Another means by which the dielectric of the junction may be changed is by purely chemical means. For example, if the dielectric is comprised of a reactive resinous material, the resin may be caused to react by wetting the junction with a curing agent. Thus, a liquid diamine may be included within a capillary marking device and the marking device manipulated to move across the surface of the sheet and impregnate the diamine into selected junctions. If the junctions are comprised of a reactive material, such as a urethane or an epoxy, the diamine curing agent will be effective to cure the resins and so alter the dielectric properties of the junctions.

Mechanical means may be used to modify the electrical properties of the junction. For example, a sharp stylus may be used to remove portions of the conductive elements at the junction or the conductive elements may be caused to be dislodged at isolated areas by impaction. In either case, the effective dielectric strength of the junction will become infinite.

As an example of electromechanical means that may be used to vary the electrical properties of the junction, the conductive elements **12–12** may be electrically connected to one terminal of a voltage source and the conductive elements **16–16** connected to the other terminal of the voltage source. The voltage is controlled to be below that level at which any of the junctions are conductive, but under the pressure of a stylus or other writing instrument. The individual conductive elements are forced closer together, thus reducing the dielectric strength of the junction until current begins to flow. The passage of electricity through the junction may trigger a chemical reaction, such as one of those disclosed above, and thus vary the impedance of the junction by a combined mechanical-electrical-chemical manipulation.

In addition to altering the electrical properties of the junction, it is frequently desirable to provide visual evidence of the fact that the junction has been raised to a level of conductivity. By this means, the information recorded on the sheet may be read visually as well as electrically.

The sheet of material may be treated with a heat-sensitive material, such as used in thermal reproduction devices, and the area proximate the junction darkened by heat generated through the flow of current at the junction. One particularly effective manner for accomplishing this result by use of a controlled resistance at the junction is further developed and claimed in the U.S. patent application of Coco et al. Ser. No. 796,434 filed on Feb. 4, 1969, assigned to the assignee of the present invention.

By another method, the dielectric may be given a dark color, at least at its upper surface, and then coated with a blushed coating. The discharge of electricity at the junction will either melt or blast off the coating, thus exposing the dark undercolor.

It is also possible to provide chromatic changes at the junctions by including heat-sensitive materials that will either react or decompose due to the momentary current flow at the junction to produce a change in color. If full color reproduction is desired, the junctions can be programmed in sets of three in which each set contains a material that is capable of reacting to form a process color. If the junctions are spaced closely to each other, the process colors will yield a high fidelity color reproduction.

Referring to FIG. 4, the operation of the device of this invention can better be understood. There is here illustrated in greatly magnified and schematic form, a series of horizontally disposed conductive elements **16–16** that overlie a series of horizontally disposed conductive elements **13–13**. One of the conductive elements **13**, designated "Y," is attached to a grounded source of voltage, and one of the conductive elements **16**, designated "X," is connected to ground. The conductive elements X and Y intersect to form a junction **18***a* having a dielectric value of D. Similarly, all other intersections of conductive elements **16–16** with conductive elements **13–13** have the same dielectric value. When the voltage imposed upon conductive elements X and Y becomes sufficiently large, the dielectric breakdown of the dielectric material will be exceeded and the junction **18***a* will become conductive. At this time, the properties of the junction may be modified, as discussed above.

Note that certain other alternative routes are illustrated by which current theoretically can be conducted when conductive elements X and Y are energized. For example, one possible circuit is through junctions **18***f*, **18***c* and **18***d*. Another possible path is through junctions **18***f*, **18***g* and **18***h*. Another possibility is illustrated by junctions **18***e*, **18***i* and **18***j*. Still another possible route is through junctions **18***e*, **18***b*, **18***c* and **18***d*, and so on and so on. However, providing a certain critical voltage is not exceeded, these junctions will not become conductive when voltage is imposed upon conductive elements X and Y since, as can be observed, the total resistance to the passage of current through any of these loops must be at least three times that of the resistance to the flow of current at junction **18***a*. That is due to the fact that the resistance or impedance of each of these junctions is additive. Accordingly, if it is desired to effect a change at junction **18***a*, the voltage imposed upon conductive elements X and Y must be sufficiently high to overcome the dielectric strength of the junction. Further, this voltage must not exceed three times the minimum value or else the other junctions, as illustrated, will be raised to a level of conductivity and all selectivity and control will be lost.

For descriptive purposes, the conductive element Y of FIG. 4 is depicted as being connected to a constant source of e.m.f. and the conductive element X connected to ground. In actual practice, the constant source of e.m.f. may be replaced with a high frequency signal source supplemented by means to selectively connect output signals therefrom to the conductive member Y. The grounded connection of conductive element X may likewise be replaced by a suitable signal generating source with means being provided to selectively energize the conductive element X. The actual means and technique for effecting coincident energization at any one or more of the junctions defined by the intersecting conductive elements is well known in the art and need not be further elaborated upon here.

It is not necessary to alter the electrical properties of the junction in order to present a visual display. This is due to the fact that once current is caused to pass through the junction and a permanent visual indication is presented, the junction has performed its function and it is immaterial whether or not its electrical properties have been changed. However, when it is desired to retrieve information stored on the sheet by electrical means, the opposite is true and it becomes necessary that the electrical properties of the junction be altered so that they can be "read" electrically. Basically, this is accomplished by distinguishing their altered electrical properties from those junctions that were not raised to a level of conductivity and remain unaltered.

It is important, under certain circumstances, that the dielectric strength of the junctions not be decreased. For example, if the information is to be retrieved electrically and the dielectric strength of a plurality of junctions is decreased, these junctions will be more conductive and can short circuit the entire sheet of material, making it impossible to obtain any intelligence from the sheet electrically. On the other hand, referring again to FIG. 4, an increase in the dielectric properties of junction **18***a* will make it possible to obtain an accurate electrical reading. A small voltage can be applied at X and Y that will be just sufficient to raise a single junction to a level of conductivity. Under these circumstances, if the junction **18***a* has previously been raised to a level of conductivity, no current will flow since the modified dielectric properties of junction **18***a* will have increased the breakdown voltage. Also, current will not flow through any of the other possible branches since the minimum voltage necessary to reach a level of conductivity through at least three junctions will not be reached. On the other hand, if junction **18***a* has not been modified by the passage of current therethrough, the current imposed across X and Y will be sufficient to raise the junction to the level of conductivity. By these means, the history of the junctions can be discerned and the intelligence recorded thereon retrieved by use of the herein-described system of conductive coordinates. When reading the junctions in this manner, it may be desirable to do so with short impulses of current to avoid a heat buildup and further alteration of the junction.

It is well within the skill of the art to appreciate that a computer may be programmed to receive intelligence from a device of this sort by noting the coordinates of the junctions that have been altered. So, too, the output of the computer may be programmed in terms of coordinates that may cause electrical impulses to be sent to the sheet and cause the desired junctions to become conductive and visibly and/or electrically modified.

With regard to other uses that may be made of the recording device of this invention, it will readily be apparent that it will find utility as a copying device either for reproducing multiple copies of a document or for transmitting copies over considerable distances. Once the information has been recorded on the sheet, it is but a simple matter for an electrical device to scan the X and Y axes of the sheet and provide an input to an adjacent or remote station to duplicate the affected junctions on the master.

Still another application that can be made of this recording sheet is in continuously gathering data as from recording instruments. For example, continuous reading thermometers used in scientific or process control endeavors can continuously be plotted on sheets of this sort by a voltage representing the increment of time along one axis and a voltage corresponding to the temperature along the other axis. By such means, the mechanical difficulties normally encountered with a stylus and other marking devices are avoided and, at the

same time, the record can be fed, if desired, directly into a computer without further modification.

From the above, it can be seen that this recording device may be viewed as a pressure-sensitive paper that may be read electrically or, conversely, an electrically sensitive paper that may be read visually. In any case, due to the extreme rapidity with which the electrical impulses may be encoded or decoded from the paper, tremendous amounts of information may be continuously be fed to and recorded on such paper.

With reference to FIG. **2**, a continuous series of sheets **11–11** is shown. Note that each sheet contains its own group of conductive elements as well as its own electrical contacts **13–13** and **17–17**. These sheets are meant to be handled in a continuous manner as by feeding them into a device that momentarily makes contact with the conductive elements on a given sheet. By scanning the contractors **13–13** and **17–17**, preferably by electronic means, information can be recorded on or retrieved from the individual piece of paper almost instantaneously. Once this is done, the continuous web will be advanced and the next sheet placed in position to make electrical contact with the input or readout device. Movable contact devices that may be slid or rotated into electrical connection with the contactors **13–13** and **17–17** may also be used.

Essentially, as described hereinabove, the invention, in its preferred embodiment, differs from the prior art in that it embodies entirely within the article of the invention that means to generate an image of information to be recorded. Further, it does this in such a manner that a higher degree of resolution is obtained compared to that available through conventional techniques. Since the paper will essentially be used only a single time and is a disposable item, damage or wear to the junctions during recording or retrieving information becomes inconsequential as compared with other devices that require constant use of the same electrical elements.

While the preferred embodiment of this invention contemplates locating all of the circuitry in the paper, other methods can be used. For example, a heat-sensitive paper may be sandwiched between a pair of grids comprised of conductive wires. In this instance, the paper itself will serve as the material of different electrical properties located between the two series of conductive elements and, when the voltage is raised to a sufficient level, the dielectric of the paper will be overcome and the junction will become momentarily conductive.

By still another variation, a single grid of conductive lines can be laid down on the paper and then the paper moved in close proximity to an external grid of conductive elements, such as may be attached to an endless belt, to provide for the series of junctions.

As illustrated in the drawings, both sets of conductive elements are shown as printed on the same side of a sheet of paper and separated by a dielectric material. It is, of course, within the scope of this invention to locate one series of conductive elements on one side of the sheet of paper and the second series of conductive elements on the other side of the sheet of paper. Here, too, the paper may function as the dielectric material separating the two series of elements.

It should also be noted that the properties of dielectric, semiconductive and resistive materials encompasses a broad spectrum of electrical values. However, when using a material selected from one of these classes under a given set of operating conditions, such material may display properties similar to those of a material selected from another class that is being used under a different set of operating conditions. To this extent, under selected circumstances a material from one class may, for practical purposes, be considered to be functionally the equivalent of materials selected from another class.

Although certain embodiments of this invention have been shown in the drawings and described in the specification, it is to be understood that the invention is not limited thereto, can be rearranged, and is capable of modification without departing from the spirit and scope of the invention.

We claim:

1. A device for recording intelligence, variously in written, printed or pictorial form, on a sheet of paper, comprising:

a base sheet of a thermally reactive paper;

a first series of thin, spaced-apart, linear electrical conductors printed on one side of the sheet of paper;

an electrically insulating layer of a dielectric material covering the first series of linear conductors;

a second series of thin, spaced-apart, linear electrical conductors printed on the dielectric material and angularly oriented with respect to the first conductors;

contact elements associated with the individual conductors of both the first and second series of conductors in order to provide a coordinate system comprised of a series of electrical junctions that normally are nonconductive but that selectively may be raised to a conductive state when the breakdown voltage of the electrically insulating material is exceeded at a selected junction;

whereby, when the breakdown voltage of a selected junction is exceeded, heat will be generated at such junction to cause a visually observable change to take place in the thermally reactive paper adjacent such selected junction.