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3,017,486

PERFORATION OF WEBS BY ELECTRICAL DISCHARGES

Filed March 23, 1960

2 Sheets-Sheet 1

Fig. 1.

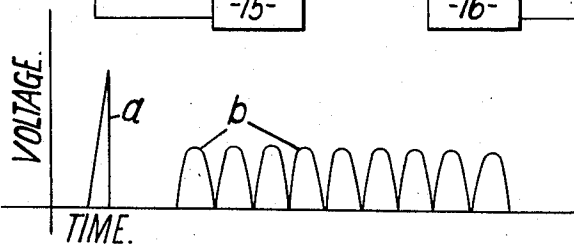
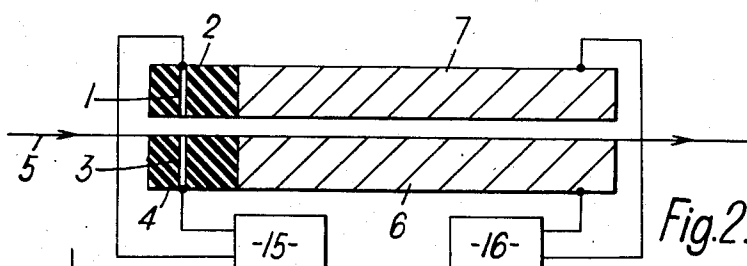
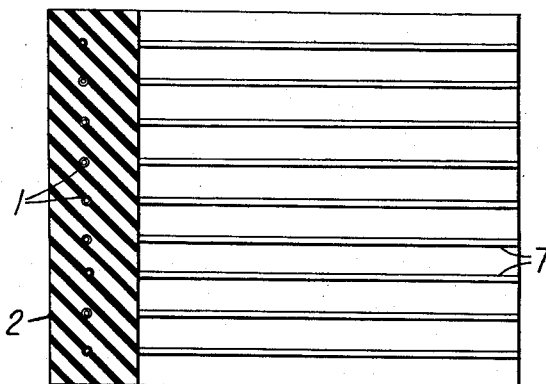


Fig. 3.

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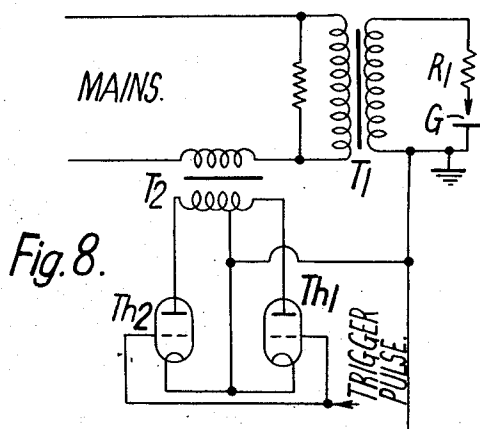
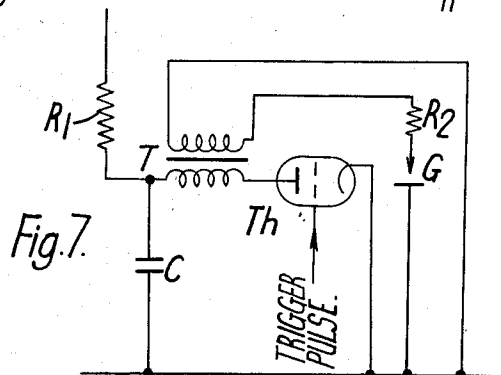
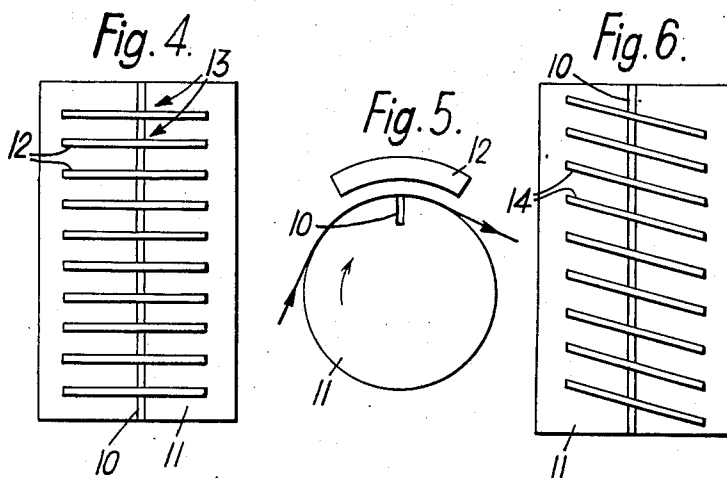
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PERFORATION OF WEBS BY ELECTRICAL DISCHARGES

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9 Claims. (Cl. 219-19)

This invention relates to a method of perforating sheet material, for example to produce spaced transverse lines of weakness, along which the material subsequently may be severed.

The method according to the present invention comprises applying a series of electrical pulses across extended electrodes between which the material passes so that successive discharges between the electrodes occurs at points which are progressively displaced in the direction of movement of the material. In this way successive discharges can be made to pass through a hole made by the first discharge and to enlarge this hole, or, by progressive displacement in a direction transverse to the direction of movement of the material, a transverse row of perforations is formed as the material moves forward.

The perforations may extend in a straight line across the material in a direction normal to the movement thereof or, alternatively, the line of perforations may extend diagonally across the material or may have any chosen configuration.

For electrically homogeneous material, that is to say material in which there are no natural discharge sites, for example waxed paper or cellophane, in order to ensure that the successive discharges between the electrodes are progressively displaced in the direction of movement of the material, a row of pilot holes may be formed by passing electrical discharges between co-operating electrodes having sharply defined points of coincidence. Thus, the pilot holes may be produced by applying a high voltage electrical pulse of short duration between a line electrode below the moving material and a series of needle electrodes arranged in a transverse row, with respect to the direction of movement of the material, above the line electrode. The subsequent successive electrical discharges will then be progressively displaced in the direction of movement of the material to such an extent that they will take place through the pilot holes. One of the electrodes, or series of electrodes, between which the subsequent successive electrical discharges occur, may be a base plate extending across the whole width of the web, in which case the other electrodes may be line electrodes, aligned in the direction of movement of the web with the needle electrodes responsible for the pilot holes. The discharges between the base plate and line electrodes are of greater energy and of greater duration than the discharges which make the pilot holes and are, therefore, suitable for enlarging the pilot holes.

For porous materials, for example thin paper materials, in which the material texture is such as to present a large number of possible discharge sites, the successive discharges are caused to be displaced progressively in the direction of movement of the material by arranging for a transverse line electrode to travel with the web so that it remains in register with the holes produced by the first of the discharges. The other electrodes may be fixed and each may be extended to form a line electrode in the direction of movement of the material. Each line electrode may be arranged obliquely with respect to the direction of movement of the material to produce a series of perforations in a transverse row with electrical discharges occurring between the moving line electrode

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and the fixed line electrodes during movement of the web.

In order that the invention may be better understood, several embodiments of apparatus for performing the present invention will now be described with reference to the accompanying schematic drawings in which:

FIGURE 1 is a plan view of one arrangement of electrodes;

FIGURE 2 is a side elevation of the arrangement of electrodes shown in FIGURE 1;

FIGURE 3 shows the sequence of electrical discharges between the arrangement of electrodes shown in FIGURES 1 and 2;

FIGURE 4 is a plan view of an alternative arrangement of electrodes;

FIGURE 5 is a side elevation of the alternative arrangement of electrodes shown in FIGURE 4;

FIGURE 6 is a plan view of a further alternative arrangement of electrodes;

FIGURE 7 shows a diagram of an electrical circuit for producing high voltage discharges of short duration, and

FIGURE 8 is a diagram of an electrical circuit for producing lower voltage discharges of longer duration.

The arrangement of electrodes shown in FIGURES 1 and 2 is suitable for perforating a web of electrical homogeneous material in which there are no natural discharge sites. A transverse row of fixed needle electrodes 1 is housed in an insulator 2 above a fixed transverse line electrode 3 housed in an insulator block 4 and a web 5 of paper is fed between the needle electrodes 1 and line electrode 3. The needle electrodes 1 are connected to a common voltage source 15 but are electrically separated from each other by means of resistors of high value (not shown). A high voltage impulse *a* of short duration (FIGURE 3) is applied between the needle electrodes 1 and the line electrode 3 by the source 15 resulting in the passage of a number of separate, but substantially simultaneous, electrical discharges through the web between these electrodes, the positions of the perforations, which are produced in the web, being determined by the positions of the needle electrodes. The high voltage impulse is repeated at intervals corresponding to the required spacing of the transverse row of perforations, the duration of these intervals depending upon the speed at which the web passes between the electrodes 1 and 3. The perforations produced in this manner are not in themselves sufficient to produce the requisite weakening of the web to provide a line of weakness, but since they present an array of electrically vulnerable points in the web it is possible to follow the initial discharges with further pulses or series of pulses of longer duration but lower voltage, which effectively increase the size of the original perforations. These "follow-up" pulses *b* (FIGURE 3) are applied by means of a further voltage source 16 between a metal base plate electrode 6 over which the web 5 runs after having been formed with pilot holes by the needle electrodes 1 and a row of line electrodes 7 above the web, each of which is aligned with a corresponding needle electrode 1 in the direction of movement of the web (see FIGURE 1). The successive discharges produced by the "follow-up" pulses then travel along the line electrodes with the movement of the pilot holes in the web. It will be appreciated that an advantage of using an arrangement of electrodes as shown in FIGURES 1 and 2 is that electrode wear is spread over the comparatively large areas of the line electrodes 7 and base electrode 6.

In material which is not electrically homogeneous, for example, tissue paper, discharge between co-operating electrodes tends to occur at points determined by local variations in both the configuration of the electrodes and

in the material itself. This means that if the line and base plate electrodes as shown in FIGURES 1 and 2 are used when the web is moving at a high speed, successive discharges occur in the same region of the electrodes and the energy is used in producing a number of small perforations at different natural discharge sites along the web, instead of enlarging the pilot holes first produced.

In an alternative arrangement of electrodes this is overcome by using a line electrode 10 which moves with the web (see FIGURES 4 and 5). This electrode 10 is set in a roller 11 made of an electrically insulating material over which the web passes. The roller is rotated at a peripheral speed corresponding to the surface speed of the web. This conveniently may be done by mounting the roller freely in support bearings so that it is frictionally rotated by the travelling web. A number of fixed line electrodes 12, of arcuate shape, are arranged side by side and parallel to the direction of movement of the web and lie above the roller 11. With this arrangement electrical discharges can take place only between the moving transverse line electrode 10 and the registering points, indicated at 13, of the longitudinal line electrodes 12. The discharges are, therefore, accurately sited and are progressively displaced with the movement of the web. The perforations may be modulated in size by varying the number and form of the applied pulse.

In another arrangement employing a transverse line electrode 10 set in a roller 11 which is rotated at a peripheral speed corresponding to the surface speed of the travelling web, the fixed electrodes are obliquely arranged with respect to the direction of movement of the web; such an arrangement of oblique electrodes 14 is shown in FIGURE 6. When a number of pulses are applied to the fixed electrodes 14 the discharges occur at sites determined by the positions of intersection of the moving transverse line electrode 10 and each of the obliquely arranged electrodes 14. With successive impulses each position of intersection moves across the web and a succession of perforations are, therefore, made in line across the web. Thus a number of perforations, progressively displaced in a direction perpendicular to the direction of movement of the web, are produced between the line electrode 10 and the fixed electrodes 14. The distance of separation of these perforations will depend upon the frequency of the pulses and the angle of inclination of the electrodes, together with web speed. In some instances, these perforations may be made to merge and thus take the form of extended slots.

The high voltage, short duration pulses applied to the needle electrodes 1 of FIGURES 1 and 2 may be either unidirectional or high frequency. The latter may be generated by conventional pulsed high frequency generators and the former by discharging a capacitor C by means of thyatron Th through the primary winding of a step-up pulse transformer T. Such a circuit is shown in FIGURE 7 in which R₁ is a charging resistor and R₂ is a discharge limiting resistor; the discharge gap is shown at G.

The "follow-up" pulses between the electrodes 6 and 7 of the arrangement shown in FIGURES 1 and 2 and the pulses applied to the electrodes, 10, 11 and 14 of the arrangement shown in FIGURES 4, 5 and 6, are of lower voltage than those applied to the needle electrodes 1 and may be delivered directly from a step-up mains transformer T₁ (FIGURE 8) which is switched by means of a circuit employing a switching transformer T₂ and a pair of thyatrons Th₁, Th₂, the anodes of which are connected to the ends of the secondary winding of the switching transformer T₂. The primary winding of the switching transformer T₂ is connected in series with the primary winding of the step-up transformer T₁ and represents a high impedance in this circuit when the thyatrons are non-conducting. When a pulse is applied to the grids of the thyatrons to render them conductive, the secondary winding of the switching transformer T₂ is effectively short circuited and the pri-

mary winding thereof then represents a low impedance in the circuit of the step-up transformer T₁.

One application of the invention is in the marking of webs to indicate faults in the web which have been independently detected. The detector apparatus generates an electric "fault" signal which controls the production of a series of electrical discharges which form a hole in the web at the side of the fault. The base electrode may be a small metal wheel driven by the web and the upper electrode may be an arcuate line electrode arranged to lie in the direction of movement of the web so that its arc follows the contour of the metal wheel. The perforation may then be detected by a photoelectric device.

If pulses of higher frequency are required the power may be delivered from power oscillator circuits.

We claim:

1. A method of perforating sheet material, comprising moving a length of material between the electrodes of an electric discharge device, applying to electrodes of the device first pulses of high voltage and short duration to produce pilot holes in the material, subsequently applying between electrodes of the device pulses of greater energy and longer duration to produce electric discharges which are progressively displaced in the direction of movement of the material and which pass through the pilot holes in the latter.

2. A method according to claim 1, in which the first discharge is produced between co-operating electrodes having sharply defined points of coincidence.

3. Apparatus for perforating sheet material, comprising first electrodes arranged above and below the path of the material and having a sharply defined point of coincidence, second electrodes arranged above and below the path of the material and having a line of coincidence in the direction of movement of the material which is aligned with the point of coincidence of said first electrodes, means for applying a high voltage pulse to said first electrode to produce a pilot hole in the material, and means for applying pulses of greater energy to said second electrodes to produce discharges which enlarge the pilot hole.

4. Apparatus according to claim 3, in which said first electrodes comprise on one side of the path of the material a line of needle electrodes and on the other side of the path of the material a line electrode coincident with the row of needle electrodes.

5. Apparatus according to claim 3, in which said second electrodes comprise on one side of the path of the material a series of line electrodes arranged in the direction of movement of the material and on the other side of the path of the material an electrode in the form of a base plate.

6. Apparatus for perforating sheet material of the kind having natural discharge sites for electric discharges, comprising means for moving the material to be perforated through an electrode system including a fixed line electrode which is arranged on one side of the path of the material and which extends in the direction of movement of the material and an electrode on the other side of the material which has a point of coincidence with said line electrode which is arranged to move in the direction of and at the speed of the material to be perforated, said apparatus further comprising means for applying a plurality of successive electric pulses to said electrodes, whereby successive discharges take place through the same point in the material.

7. Apparatus for forming a row of perforations in a length of sheet material of the kind having natural discharge sites for electric discharges, comprising means for moving a length of material between a set of parallel line electrodes which are arranged on one side of the path of the material and which extend in the direction of movement of the material and a transverse electrode on the other side of the path of the material, whereby the points

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of coincidence of the parallel electrodes and the transverse electrode form a transverse line, means for moving the transverse electrode at the speed of, and in the direction of movement of, the material to be perforated and means for applying a plurality of successive electrical pulses to the electrodes whereby successive discharges from each of the parallel electrodes to the transverse electrode take place through the same point in the material.

8. Apparatus according to claim 7, in which said transverse electrode is in the form of a conductive bar which is arranged in the periphery of a rotatable drum, over which the material passes and which is parallel to the axis of the drum.

9. Apparatus for forming a row of perforations in a length of sheet material comprising a plurality of fixed parallel line electrodes arranged obliquely to the direction of movement of the material and a transverse electrode arranged on the opposite side of the path of move-

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ment of the material from said parallel electrodes, means for moving said transverse electrode in the direction of and at the speed of movement of the material, and means for applying a succession of electric pulses between said parallel electrodes and said transverse electrode, whereby successive electric discharges between any one of the parallel electrodes and the transverse electrode form a series of adjacent transversely spaced perforations.

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