

March 27, 1945.

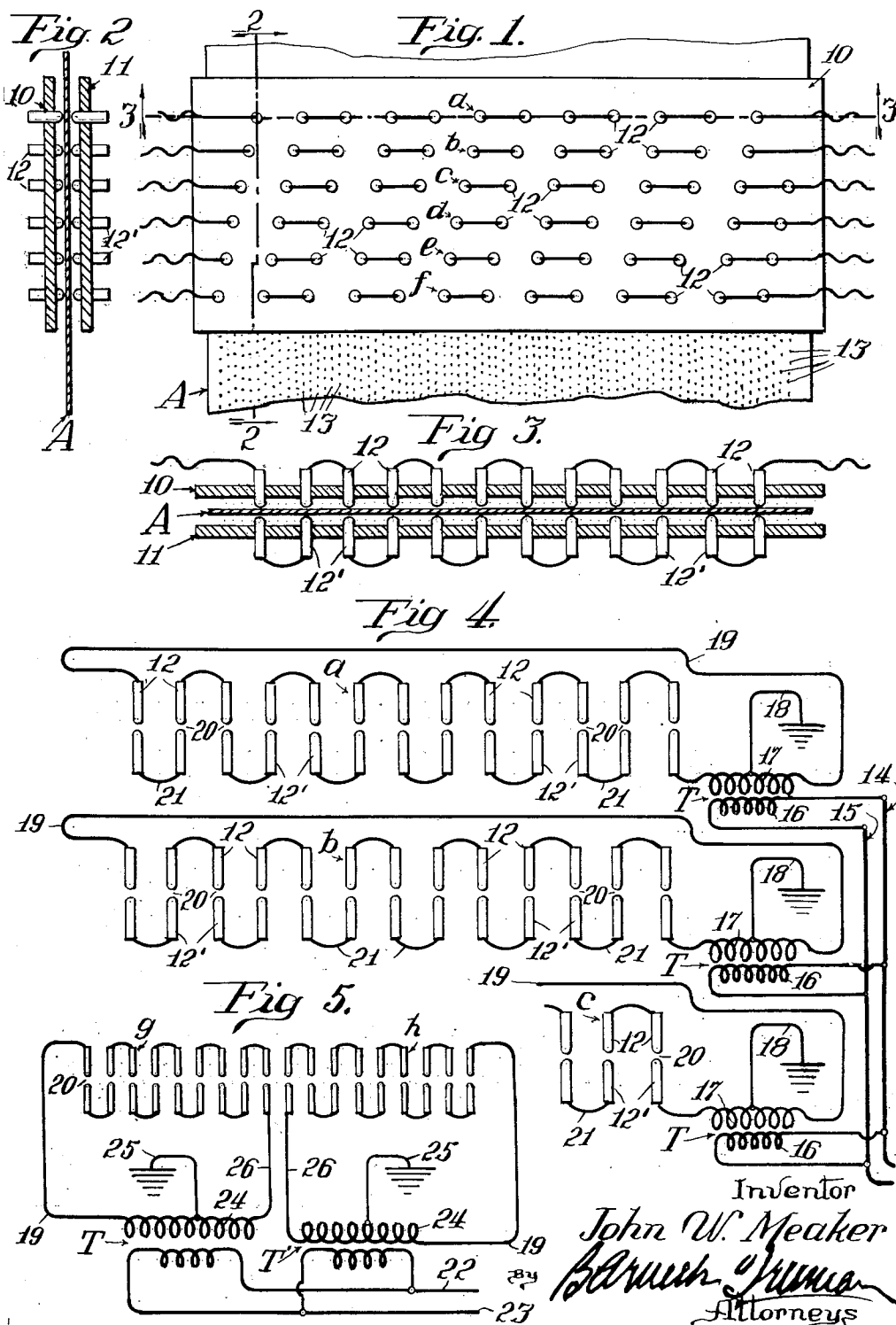
J. W. MEAKER

2,372,508

ELECTRICAL PERFORATION OF PAPER AND OTHER FABRICS

Filed Sept. 23, 1940

3 Sheets-Sheet 1



March 27, 1945.

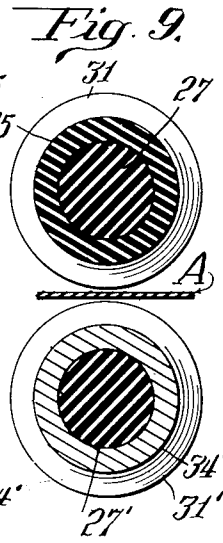
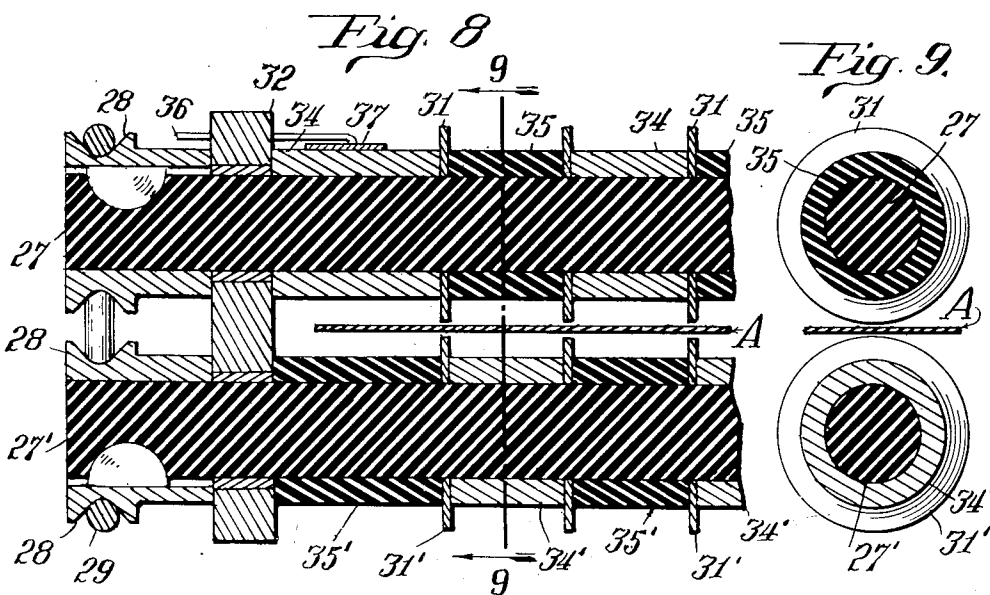
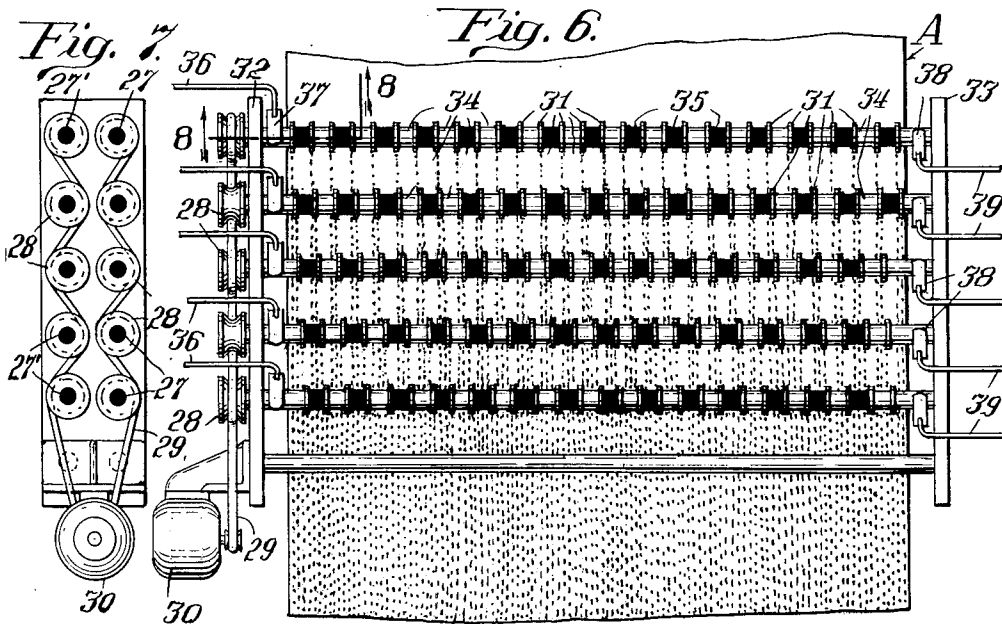
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Fig. 10.

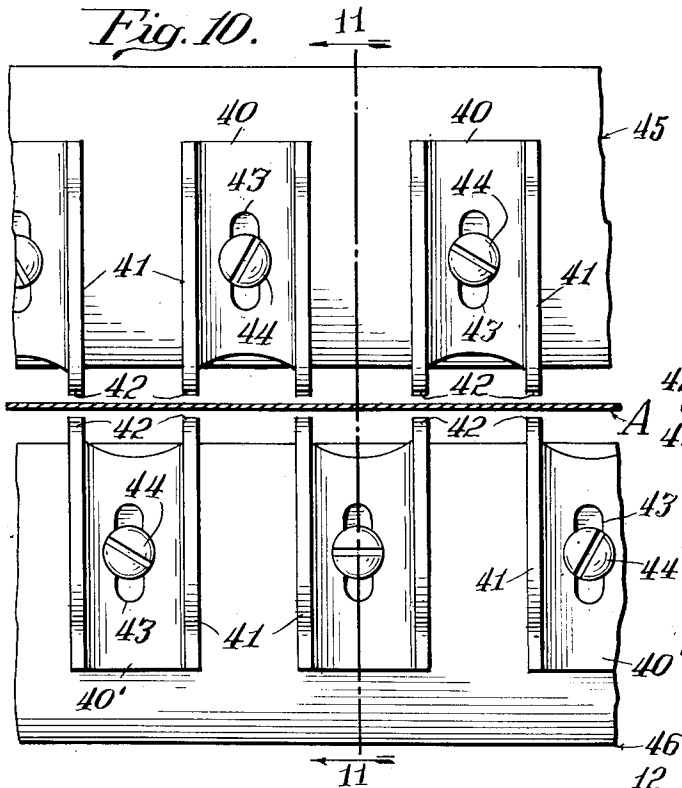


Fig. 11.

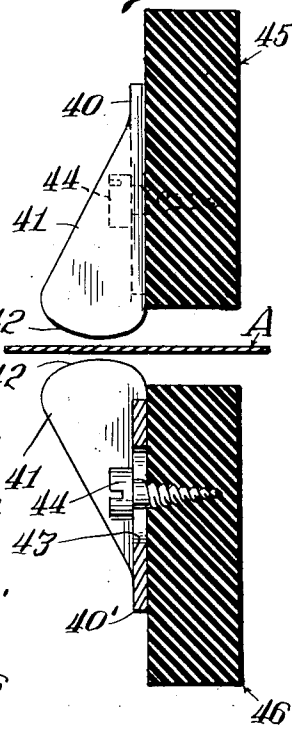
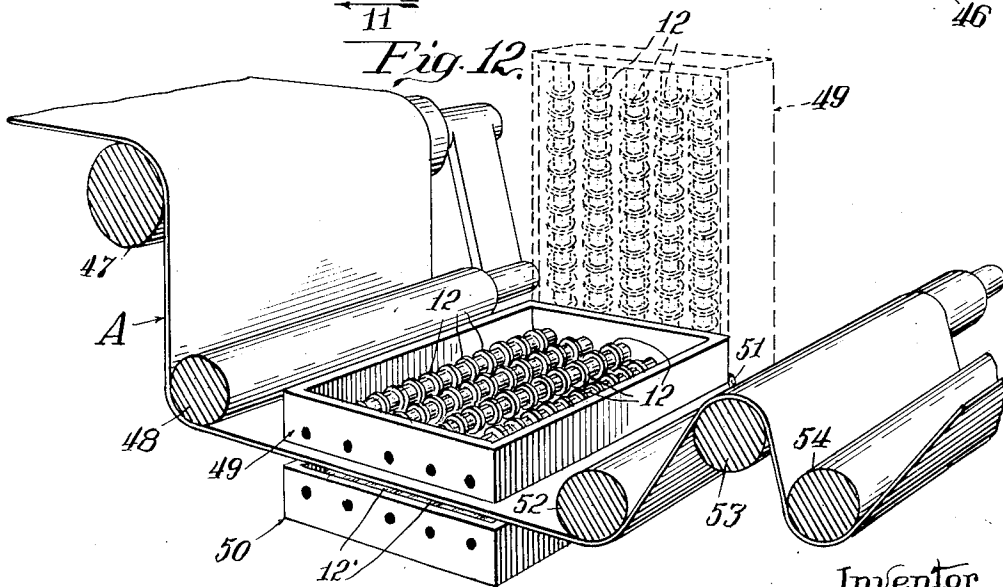


Fig. 12.



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UNITED STATES PATENT OFFICE

2,372,508

ELECTRICAL PERFORATION OF PAPER AND
OTHER FABRICS

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Application September 23, 1940, Serial No. 358,041

8 Claims. (Cl. 175-265)

This invention relates to the perforation of sheet material, such as paper, leather, artificial leather, textile fabrics and the like by electrical discharges which in passing through the material perforate it; and the primary object of the invention is to provide a new and improved method of, and apparatus for, forming perforations over an area of the sheet material, in distinction to making a single line of perforations, perforation by perforation; and to accomplish this rapidly and with the perforations as close together as may be desired, both transversely and longitudinally of the sheet of material.

To state the objects of the invention more specifically, one of such objects is to provide for moving the material to be perforated, for example a web of paper from a paper-making apparatus or, in the production of bags, the paper web going to the tuber, through a plurality of spark gaps between pairs of oppositely placed electrodes, which gaps are transversely arranged in respect to the direction of movement of the paper web or other material and across which the electric discharges take place simultaneously so that as the paper moves, the perforations are made both longitudinally and transversely thereof, that is, an area of the paper is pierced with the perforations.

Preferably where a large number of perforations closely spaced together is desired, for example in the manufacture of perforated paper bags, a plurality of sets or rows of spark gaps will be provided, across which the currents discharge simultaneously, with the gaps of one row offset with respect to the others. This will give closeness of spacing transversely of the web. Closeness of spacing longitudinally of the web is effected by employing intermittent or periodic electrical discharges at suitable frequencies relative to the speed of the web. By employing a plurality of offset rows of gaps, by running the paper at a high speed and by employing high frequency discharges, the material may be perforated rapidly with a large number of perforations per unit area.

The current used may be direct current interrupted by a breaker or by the action of the dielectric moving between opposed electrodes, i. e. the paper web itself. Or it may be alternating current of normal frequency or frequency higher or lower than normal. Preferably alternating current of ordinary frequency, for example 60 cycles per second is employed. The amperage will ordinarily be low, in the case of ordinary paper about 50 to 150 milliamperes, and is in-

creased or decreased to give larger or smaller perforations. The voltage is relatively high, necessarily, in order to overcome the combined dielectric strength of the air and sheet material in the gap. It may be in the order of 1,000 volts per gap. The appropriate voltage will depend upon the thickness of the material, or other characteristics determining the dielectrical strength of the material and of the air gap. The electrodes of each set or row of electrodes are arranged in series; or, in the case either of a large number of sets of gaps, required by a wide sheet, or if the dielectric strength of the material is excessive, the gaps may be divided into two or more series connected up to discharge simultaneously.

The invention is illustrated, somewhat diagrammatically, in certain preferred embodiments in the accompanying drawings in which:

Fig. 1 is a fragmentary plan view of a perforating apparatus constructed in accordance with the present invention.

Figs. 2 and 3 are sectional views on lines 2-2 and 3-3, respectively, of Fig. 1.

Fig. 4 is a diagram illustrating the electrical circuits of the apparatus shown in Figs. 1 to 3.

Fig. 5 is a diagram illustrating a modified arrangement intended particularly for a wide sheet of material or material of high dielectric strength, in which arrangement a row of spark gaps are divided into two series separately supplied with electric current.

Fig. 6 is a plan view of a modified form of apparatus characterized employing slowly rotated discs as electrodes.

Fig. 7 is an end view of the apparatus shown in Fig. 6.

Fig. 8 is a detail sectional view taken on line 8-8 of Fig. 6 but with the scale enlarged.

Fig. 9 is a sectional view on line 9-9 of Fig. 8.

Fig. 10 is a fragmentary view of a modified construction showing fixed but adjustable electrodes.

Fig. 11 is a sectional view on line 11-11 of Fig. 10 and

Fig. 12 is a view in perspective of a preferred arrangement for hinging one electrode carrying frame or support to the other so as to obviate the necessity of threading the web through the spark gaps.

Referring to the simple form of the invention disclosed in Figs. 1 to 4, inclusive: 10 and 11 designate two supporting members or boards of non-conducting material, Bakelite for example, through the space between which the paper web A is drawn by any suitable means (not shown). In the boards 10 and 11, which may be arranged

either vertically or horizontally, are mounted, adjustably if desired, a plurality of rows or sets of electrodes arranged in pairs to provide spark gaps. In the drawings there are shown six rows or sets of electrodes designated *a, b, c, d, e* and *f*, respectively; the electrodes mounted on member 10 being designated by numerals 12 and those on member 11 by numerals 12'. The pairs of electrodes in each set are connected together in series, as indicated in Fig. 4, and are arranged so that the spark gaps provided by the several sets or rows of electrodes *a, b, c, d, e* and *f* are offset laterally with respect to each other, whereby the perforations 13 (Fig. 1) made in the paper A are much closer together than it would be practical to make them by means of a single row of gaps.

Fig. 4 illustrates the electrical connections for three of the sets or rows of electrodes *a, b* and *c*. Connected in parallel with the supply leads 14 and 15 are the primary coils 16 of high voltage transformers T. The secondary coils 17 of the transformers T are preferably connected at their center points to ground, as indicated at 18, in order to keep the maximum potential above ground as low as possible. The pairs of electrodes 12, 12' are arranged in series with the secondary coil in each case. That is, conductor 19 connects one end of the secondary coil 17 of the transformer to one of the electrodes 12. The current jumps the gap 20 between this electrode and the oppositely placed electrode 12', then goes through conductor 21 to the adjacent electrode 12', across the second gap 20 to the next electrode 12 and so on back to the secondary coil 17 of the transformer.

If continuous or direct current is applied to such a system and the web or sheet moved through the gaps, rows of perforations are produced by the drawing out of the arcs to the extinction point and the restriking through a new path. The spacing of the transverse rows of perforations longitudinally of the web is in this case determined by the dielectric strength of the web and the speed at which the web is drawn through the spark gap system. The higher the dielectric strength of the material, the wider apart will be the rows of perforations. This is due to the fact that the higher potential required for break-down will permit greater extension of the arc before extinguishing.

If alternating currents are employed the voltage rises and falls twice per cycle so that with a voltage properly calculated for the dielectric strength of the sheet, one row of perforations will be formed for each half cycle. For example, if 60 cycle current is employed, 120 rows of perforations are produced per second; or if the sheet is running 100 feet per minute, six rows of perforations per inch are produced. It is clear that there may be employed a plurality of such spark gap systems all operating simultaneously to obtain whatever pattern of perforations may be desired. In Figs. 1 to 4, inclusive, it may be assumed that the gaps are spaced one inch apart across the sheet and six rows or sets of such gaps employed, the pairs of electrodes of each row being offset laterally from the preceding row by one-sixth of an inch. Under these circumstances six rows of perforations per inch are produced in a sheet running at 100 feet per minute by a 60 cycle current, and there will be a perforation in the center of each one-thirty-sixth square inch of the entire sheet or 36 perforations per square inch. Under these conditions of high frequency relative to the speed of movement

of the paper web, successive electrical discharges will act upon areas of the sheet already perforated by previous discharges to make additional perforations. By employing higher frequencies and more circuits greater pore density (perforations per unit area) or the same pore density at higher running speeds can be obtained. However, the highest pore density that can be produced by electric perforation is limited by the dielectric strength of the sheet. Perforations cannot be made closer than this no matter how high a spark frequency is employed. This is because of the tendency of successive discharges to pass through previously made perforations when extremely high potential is required to pierce the material.

It will be understood that all of the spark gaps 20 break down simultaneously. According to the preferred method just described, which takes advantage of the relatively high frequency of ordinary service alternating currents, obviating the necessity of using special generating apparatus, it is possible by the use of suitable transformers to pierce a sheet of material, moving at a high speed, with a large number of perforations per unit area which will be distributed with relative uniformity. For example, it is possible to so perforate a paper web at the ordinary running speed with which it comes from the paper making machine; or in the manufacture of bags to so perforate the paper web at the speed at which it is fed to the tuber. Such operation and result are not possible where the distribution of perforations is effected by a mechanical movement of one or both of the electrodes to produce, successively, a series of perforations transversely of the sheet.

In cases where extremely wide sheets are used or materials of high dielectric strength are to be perforated (such for example as the perforation of four sheets at a time for use in making multiple ply bags), it is possible to use two or more transformers connected respectively with two series of spark gaps, as shown in Fig. 5, whereby, in the case of a wide sheet, twice the number of perforations per row may be obtained without increasing the maximum potential above ground. In Fig. 5 the leads are indicated at 22, 23 and the two transformers at T, T'. The center points of the secondary coils 24, 24' of the transformers are preferably grounded as indicated at 25. The spark gaps are divided into two sets, one, designated *g*, being connected with the secondary coil of transformer T, and the other *b*, being connected with the secondary coil of transformer T'. The inner leads 26, 26' from secondary coils 24, 24' are operated in phase to prevent flash over at the center of the gap system.

Figs. 6 to 9, inclusive, illustrate a perforating machine in which the electrodes consist of discs which are preferably, but not necessarily, rotated, slowly, to minimize the effect of erosion in altering the gap spacing and to reduce localized heating. Figs. 6 and 7 show five pairs of shafts 27, 27' provided with pulleys 28 for a belt 29 driven by motor 30. The arrangement of the electrode discs 31, 31' on the shafts 27 is shown in detail in Fig. 8. Each shaft 27 or 27', as the case may be, is composed of Bakelite or other non-conducting material, 32 designates one of the supporting frame members for the shafts, which shafts may, of course, have suitable bearings in this and the other frame member 33. The electrode discs 31, 31' are arranged between

alternating metal sleeves 34, 34' and sleeves 35, 35' made of non-conducting material.

Referring to Fig. 8, the current from conductor 36 (Fig. 6) goes by brush 37 to the left hand sleeve 34, thence to the left hand disc 31 and through the paper A to the opposite disc 31' on shaft 27', then through the metal sleeve 34' on shaft 27' to the next disc 31', to the right on shaft 27', then through the paper A to disc 31 on shaft 27, and so on to brush 38 and conductor 39 (Fig. 6). The disc electrodes on the other shafts 27, 27' are connected together in the same manner.

The discs on the several sets of pairs of shafts, five sets being shown, are arranged in offset relation to each other so as to bring the perforations close together laterally across the paper sheet; the arrangement being equivalent in this respect to the arrangement of Figs. 1 to 4. The expedient of rotating the discs continuously may be omitted, in which case the discs will preferably be adjustable intermittently by hand, or otherwise, to compensate for erosion.

Figs. 10 and 11 illustrate a different construction in which the electrodes consist of metal plates 40, 40' provided with ears 41 having rounded under surfaces 42. These devices are slotted at 43 and adjustably secured by screws 44 to oppositely arranged boards of non-conducting material 45, 46 between which the paper sheet A or other material is moved. The members 40, 40' are in alternate arrangement on the boards 45, 46 so that a path for the current is provided having spark gaps in series as in the other forms of the invention.

In Fig. 12 is shown, somewhat diagrammatically an arrangement whereby threading of the paper web through the opposite banks of electrodes is obviated. The paper web A is shown as passing over rollers 47, 48, and then between two frames 49, 50 on which are mounted disc electrodes 12, 12' in the arrangement shown in Figs. 6 to 9, inclusive. The upper frame 49 is hinged at 51 to the lower frame 50 so that it may be turned back, as shown in dotted lines in Fig. 12, in starting up the machine or in case of breakage of the web. The paper web passes from the perforating machine over rollers 52, 53, 54, one or more of which may be driven to forward the web. The arrangement of the rollers is, however, merely illustrative and optional. Any means may be used for moving the paper through the perforating machine. In other respects it is also to be understood that the hereinabove described embodiments of applicant's invention are purely typical and illustrative; the intention being to cover all equivalents and all modifications within the scope of the appended claims. By describing the arrangement of the electrodes as transverse to the direction of the movement of the material, it is not intended to limit the invention to an arrangement of rows of electrodes and spark gaps which are at right angles to the movement of the paper. The term transversely is used in the more general sense of crosswise of. The rows of perforations might be diagonal with respect to the line of direction of movement of the material, and this, in fact, would give the offsetting necessary to make possible close spacing transversely of the sheet or web. In fact, the gaps may be arranged to give any perforation pattern that may be desired; the fundamental principle being to produce a plurality of discharges through the material while the latter is being moved, which discharges take place simul-

taneously across the material relative to its direction of movement.

In applicant's apparatus the electrodes whether stationary or rotated, the latter to compensate for erosion, have sparking points in fixed relation instead of one electrode being moved with respect to the other to bring about the electrical discharges. It should be understood that other means than shown are available for obtaining the desired pulsating high potential required for the perforating discharges, such, for example, as the charging of a condenser through a resistor from a high potential source; or the use of a high frequency transformer or Tesla coil.

I claim:

1. Apparatus for perforating sheet material by areas which comprises: a pair of supporting members spaced for movement therebetween of the material to be perforated; a plurality of electrodes mounted on each member to form spark gaps with the electrodes on the other member; means for moving the material between said members; and means providing a hinged relation between said members.

2. In apparatus for perforating material, the combination of a pair of parallel shafts of non-conducting material; a plurality of disc electrodes on each of said shafts, the discs on one shaft being aligned with those on the other to provide spark gaps; and sleeves of metal and of non-conducting material in alternate arrangement on the shafts for spacing the discs whereby current can flow successively through said pairs of discs on the breakdown of said gaps.

3. Apparatus for perforating a sheet of material which comprises: means for imparting movement to the sheet in the direction of one of its area dimensions; a plurality of pairs of electrodes having sparking points in fixed relation, arranged in rows transversely of the direction of movement of the sheet and providing narrow spark gaps through which the sheet is moved and across which electrical discharges may arc, from electrode to electrode, through said sheet perforating the same; and means for causing high tension electrical discharges to cross said spark gaps simultaneously to form, as the sheet is moved, simultaneous perforations in each of several of said rows extending across the entire width of the sheet.

4. Apparatus for perforating a sheet of material which comprises: means for imparting movement to the sheet in the direction of one of its area dimensions, a plurality of pairs of electrodes having sparking points in fixed relation providing narrow spark gaps through which the sheet is moved and across which electrical discharges may arc from electrode to electrode through the sheet, perforating the same, said electrodes being arranged in rows transversely of the direction of the movement of the sheet in a plurality of sets which are in substantial parallelism with each other, with the pairs of electrodes of adjacent sets in staggered relationship, whereby the resultant perforations are brought closely together, transversely of the sheet; and means for causing high tension electrical discharges to cross said spark gaps simultaneously to form simultaneous perforations in each of several of said rows extending across the entire width of the sheet.

5. Apparatus for perforating a sheet of material which comprises: means for imparting movement to the sheet in the direction of one of its area dimensions; a plurality of pairs of electrodes

having sparking points in fixed relation, arranged transversely of the direction of movement of the sheet in a plurality of sets in substantial parallelism with each other with the pairs of electrodes of adjacent sets in staggered relationship, whereby the resultant perforations are brought closely together transversely of the sheet, said pairs of electrodes being electrically connected in a plurality of series groups, and providing narrow spark gaps through which the sheet is moved and across which electrical discharges may arc, from electrode to electrode, through said sheet perforating the same; and means for causing high tension electrical discharges to cross said spark gaps simultaneously to form, as the sheet is moved, simultaneous perforations in each of several of said sets extending across the entire width of the sheet.

6. Apparatus for perforating a sheet of material which comprises: means for imparting movement to the sheet in the direction of one of its area dimensions; a plurality of pairs of disk-like electrodes which have sparking points in fixed relation but are rotatable to minimized erosion and consequent alterations in the width of the spark gaps between the electrodes, arranged transversely of the direction of movement of the sheet and providing narrow spark gaps through which the sheet is moved, and across which electrical discharges may arc, from electrode to electrode, through said sheet perforating the same; and means for causing high tension electrical discharges to cross said spark gaps simultaneously to form, as the sheet is moved, a plurality of perforations through said sheet distributed two dimensionally over an area thereof.

7. Apparatus for perforating a sheet of material which comprises: means for imparting movement to the sheet in the direction of one of its

area dimensions; a plurality of pairs of electrodes having sparking points in fixed relation, arranged transversely of the direction of movement of the sheet and providing narrow spark gaps through which the sheet is moved and across which electrical discharges may arc, from electrode to electrode, through said sheet perforating the same; and means for causing high tension electrical discharges across said spark gaps simultaneously to form, as the sheet is moved, a plurality of perforations in said sheet distributed two dimensionally over an area thereof; said electrodes composed of a plurality of members each consisting of an attaching plate and a pair of spaced projecting ears, said members being arranged in staggered relationship with each other so that opposite ears are in alignment one with the other to form said spark gaps and provide for a series arrangement, electrically, of the spark gaps.

8. Apparatus for perforating a sheet of material which comprises: means for imparting movement to the sheet in the direction of one of its area dimensions; a plurality of sets of aligned pairs of electrodes having sparking points in fixed relation, with the sets in substantial parallelism with each other and arranged transversely of the direction of movement of the sheet and with the electrodes of each set arranged and connected to provide a plurality of narrow spark gaps in series with each other through which the sheet is moved and across which electrical discharges may arc, from electrode to electrode, through said sheet perforating the same; and means for causing high tension electrical discharges to cross the spark gaps to form a plurality of perforations through the sheet distributed two-dimensionally over an area thereof.

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