

March 13, 1956

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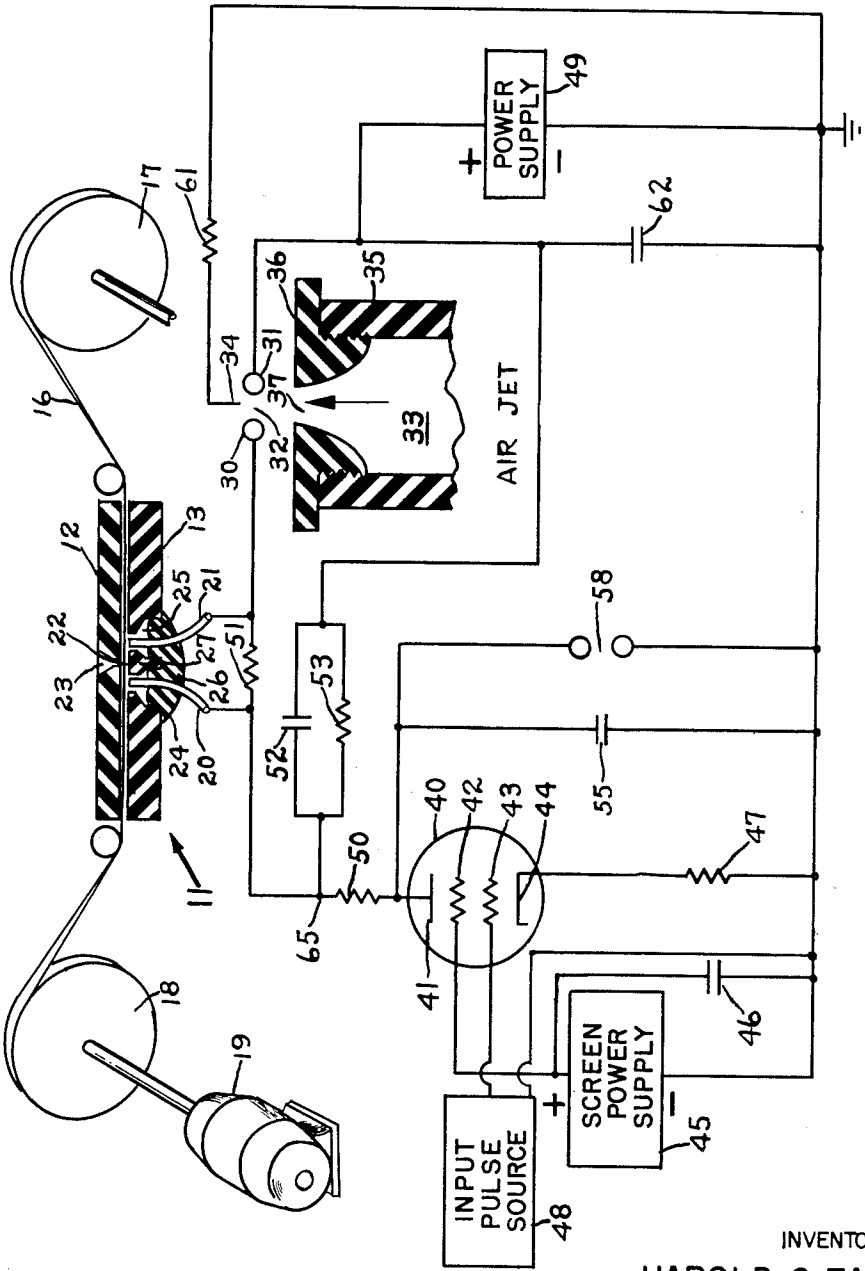
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HIGH SPEED PRINTING AND PERFORATING MACHINE

Filed May 16, 1952

4 Sheets-Sheet 1

FIG. 1



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4 Sheets-Sheet 2

FIG. 4

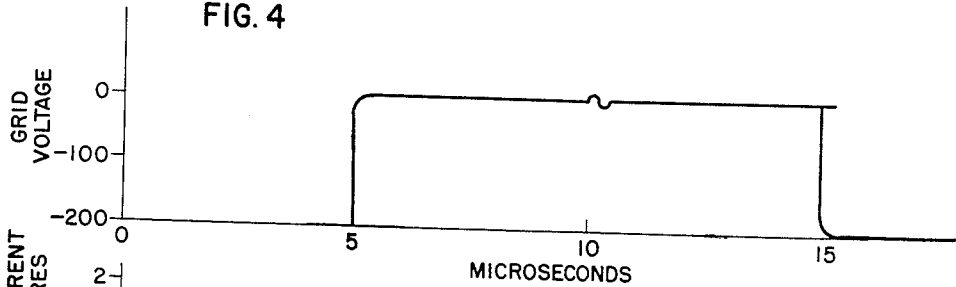


FIG. 5

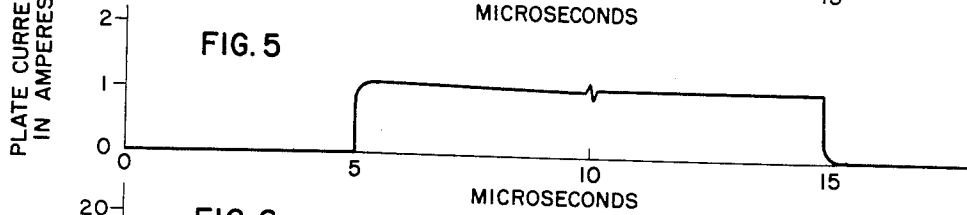


FIG. 6

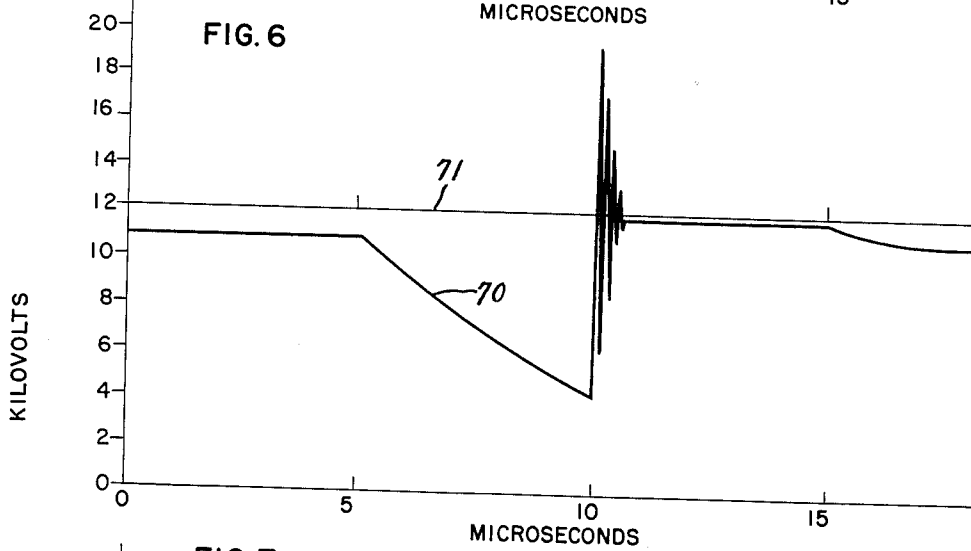
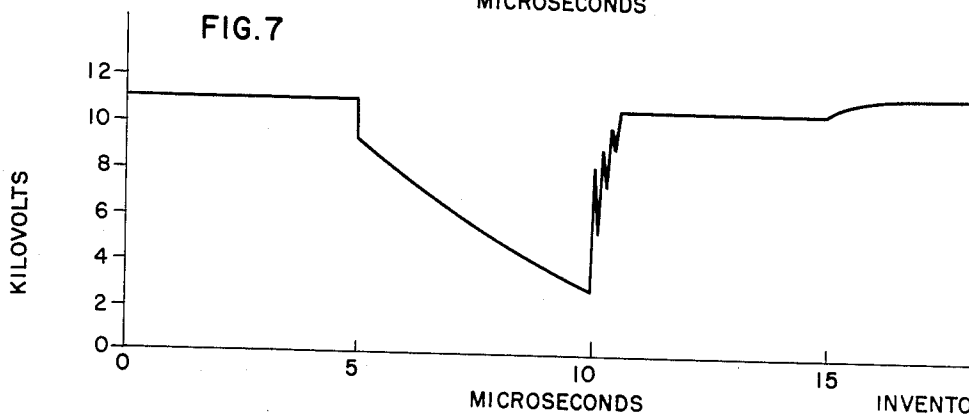


FIG. 7



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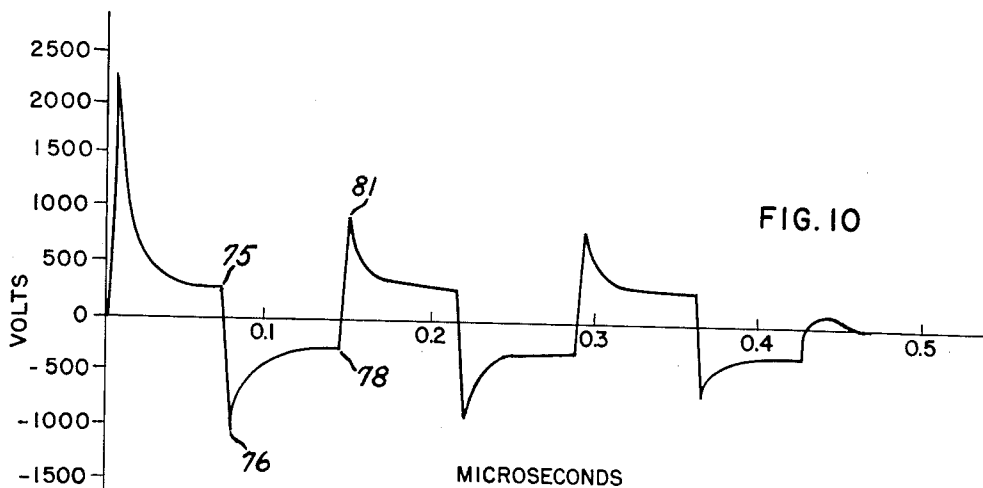
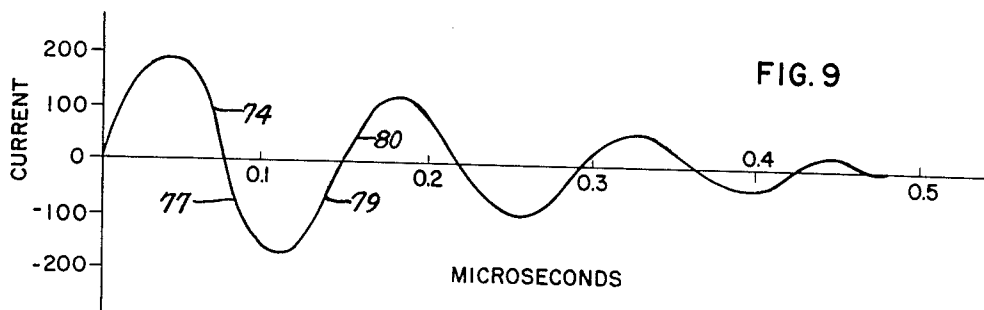
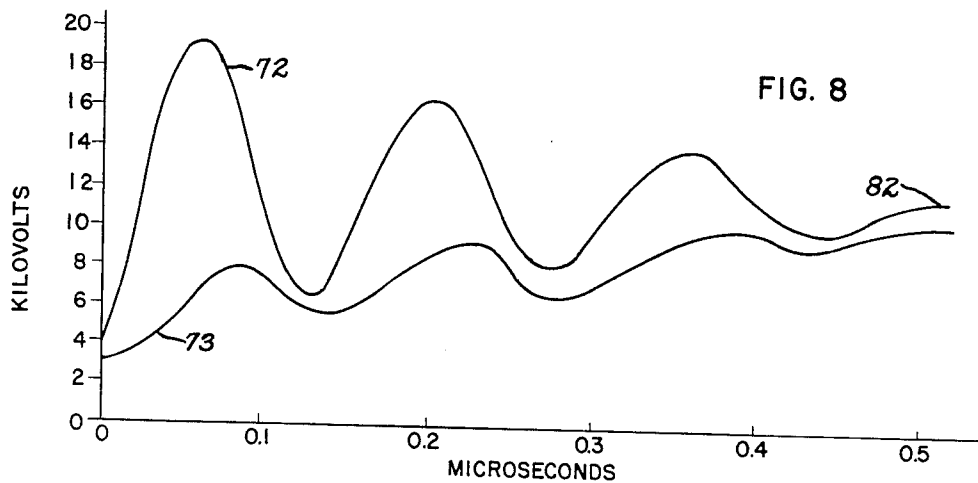
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FIG. 2

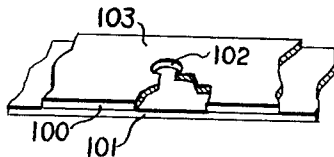
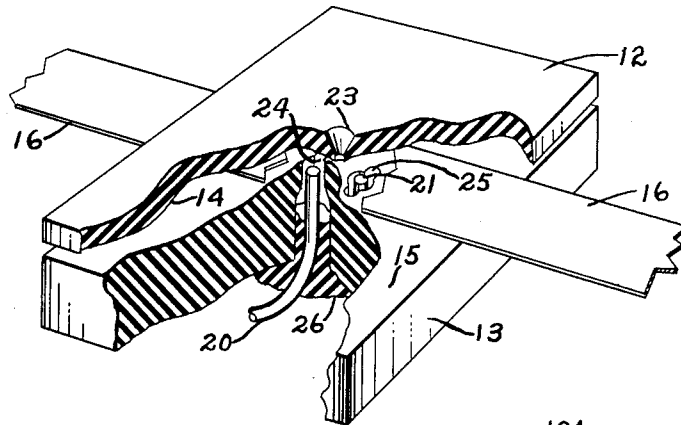


FIG. 12

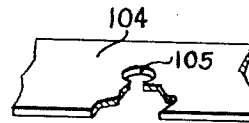


FIG. 13

FIG. 3

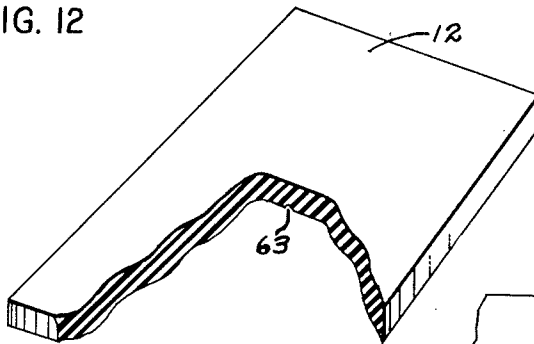
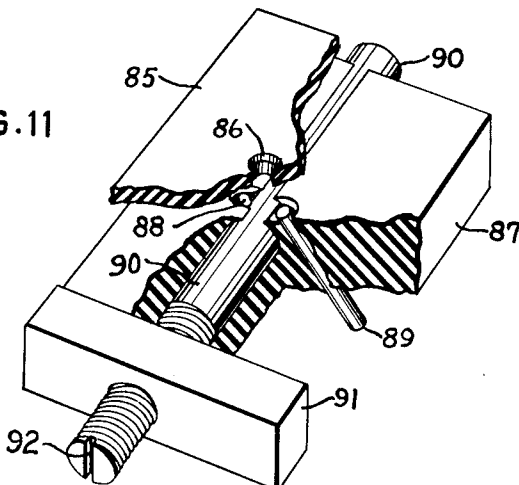


FIG. 14

FIG. 11



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## HIGH SPEED PRINTING AND PERFORATING MACHINE

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Application May 16, 1952, Serial No. 288,144

27 Claims. (Cl. 101-3)

This invention relates generally to high speed printing devices and more particularly to high speed printing devices utilizing the energy from an electric arc or spark discharge to produce physical indicia of intelligence on a record means.

There are at the present time available many types of computing machines capable of delivering information at a relatively high rate of speed. This information is usually imparted in the form of coded electrical impulses which, on many occasions, must be transformed into a more permanent form of intelligence. Such a more permanent form of intelligence may consist in perforations or embossments upon a tape and may form either letters and numbers or types of codes. There are disclosed in the prior art various methods of and structures for transforming the intelligence contained in electrical impulses onto tapes, cards, and other types of similar record media. Generally speaking, such transforming means have a serious disadvantage in that the speed with which intelligence can be recorded on the tape or card is frequently considerably less than the speed with which the computing machine can deliver said intelligence. It has, therefore, often been necessary to provide means for storing the information delivered from the computing machine until the tape or card is ready to record it in a more permanent form. Alternatively, systems have been devised whereby the computing machine is caused to wait while the tape is recording the intelligence. These methods for printing the intelligence on a tape or other recording media have apparent disadvantages. One means of obviating the above mentioned difficulties is a high speed printing device which will record intelligence upon a record medium such as a tape as rapidly as the intelligence is delivered from a computing machine.

One object of the present invention is to simplify and improve high speed printers generally.

Another object of the invention is to provide novel means capable of printing intelligence on a record medium such as a tape as rapidly as the intelligence is delivered from a computing machine.

Another object of this invention is to provide a relatively simple and inexpensive memory for a computing machine.

Still another object is to provide means for accurately reproducing intelligence from computing machines upon a tape at a speed equal to the speed with which the computing machine delivers the intelligence, either in the form of perforations, or embossments on a standard type tape such as paper, or windows in the coating of an opaque or translucent material provided on a tape made of a substantially transparent material.

A further object of the invention is to provide a novel method of forming perforations, embossments or transparencies in record means.

A more specific object of the invention is to provide a space adapted to receive a record medium such as a tape between two opposed faces thereof, of which one face is provided with printing means and the other face is provided with means for establishing the controlled arc or electrical discharge across the portion thereof which

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is opposite the printing means whereby, when an arc or an electrical discharge is struck across this portion, a sudden force will be created on the side of the record medium opposite the printing means to accelerate it toward the printing means to impel it thereagainst to record intelligence thereon.

More specific objects of the invention are to provide a partially confined space of which one face is provided with spaced apertures of which each has an electrode disposed therein for establishing an arc or an electrical discharge across an intervening portion, which is herein defined as the anvil, of the face between two electrodes to exert a sudden force against a record medium to accelerate it against a second face closely spaced from the first face and provided with a recess opposite the anvil, which recess, if in the form of a cavity, will produce an embossment having an outline corresponding with the outline of the recess on the record medium, or, if in the form of an aperture, will produce an aperture in, or an embossment on, the record medium depending on the material thereof and the intensity of the arc, or, if the record medium is of a transparent material having an opaque coating on the side facing the printing aperture, will cause a removal of a portion of the coating corresponding to the outline of the aperture to provide transparent windows in the medium.

These and other objects and features of the invention will be more fully understood from the following detailed description when read in conjunction with the drawings in which:

Fig. 1 shows a schematic view of an arc producing circuit and a sectional view of the printing structure;

Fig. 2 is a perspective view of the printing structure and the tape with portions thereof broken away;

Fig. 3 is a perspective view of an alternative form of a portion of the structure shown in Fig. 2;

Figs. 4, 5, 6, 7 and 8 show current and voltage time characteristics at various points in the control circuit;

Figs. 9 and 10 illustrate the current and voltage characteristics respectively of the air gap between a pair of electrodes when an arc is struck therebetween;

Fig. 11 is a perspective view of an alternative form of the printing structure shown in Fig. 2 provided with an expendable anvil;

Fig. 12 is a perspective view with a section broken away of a portion of one type of record medium which may be utilized, illustrating one kind of marking; and

Figs. 13 and 14 are respective views of another type of record medium which may be used, illustrating different kinds of markings.

In accordance with the invention there is provided a partially confined space between two surfaces for receiving a record medium and means for discharging an electric arc on one side of the medium to accelerate it toward and impel it with a substantial force against one of the surfaces, which will be termed the printing surface and which at this point is shaped so as to form a perforation or an embossment in the medium, as the case may be, in the manner which will be apparent from the following description.

In order to provide the partially confined space for the printing structure, a construction may be used such as that indicated in cross section at 11 in Fig. 1, and in perspective with parts broken away in Fig. 2. As shown, there is provided a pair of plate members 12 and 13, each having at least one planar smooth surface 14 and 15, respectively. The plate members are suitably mounted so that these smooth surfaces will face each other and will lie in parallel planes and spaced from each other by a distance sufficient to pass a record medium such as the tape 16 therebetween with a small clearance. Means may be provided for moving the tape through the space be-

tween the plates such as reels 17 and 18, the latter reel being driven by a motor 19.

For the purpose of creating a force on the tape to accelerate it against the printing surface 14, there is provided in the other surface a pair of spaced electrodes 20 and 21 forming an air gap 22 therebetween opposite the printing means on the printing surface together with means for causing a controlled electrical discharge across the air gap which will produce an instantaneous increase in pressure caused by expansion of gases due to the high temperature of the discharge. In the preferred embodiment illustrated the printing surface 14 is provided with printing means in the form of an aperture 23 disposed approximately opposite the mid-point between electrodes 20 and 21 in the discharge surface 15. Electrodes 20 and 21 are secured in mounting holes 24 and 25, respectively, provided in the plate member 13, and extend to a point just below the surface 15 thereof. The mounting holes 24 and 25 are made wider toward the back face of member 13 so as to permit the electrodes to be bent away from each other as shown in Fig. 1 so that the narrowest distance therebetween is at the upper ends thereof and in order to facilitate securing the electrodes in place by a sealing and insulating medium 26. The sealing medium for securing the electrodes in place may be sealing wax or other suitable insulating material, which will further decrease any tendency of the electrode structure to break down at any other place than across the ends thereof. The surface of the intervening member 27, which is herein referred to as the anvil, between the electrodes is shown as being co-extensive with the surface of the plate member but it may be given other configuration such as that of a blunted wedge, for example, if desired.

Plate member 13 is preferably made from a material having good electrical insulating properties and which is resistant to erosion by an electrical discharge and which is not otherwise adversely affected thereby. Glass bonded mica material available on the market under the trade name of "Mycalex" is suitable for the present purposes. Plate member 12 should also be made from a similar insulating material unless the tape 16 has high voltage breakdown properties in which case the plate may safely be made from a metal.

It will be noted that printing aperture 23 in the plate member 12 is widened out towards the back of the plate as it extends away from the printing surface in order that material which may be separated from the tape during the printing operation may be readily removed.

In the preferred embodiment of the invention the electrodes 20 and 21 are made from 0.015 inch diameter tungsten wire and the axes of the working portions thereof are spaced 0.065 inch apart. Plate member 12 may be fashioned from insulating plate member having a thickness in the order of 0.050 inch to 0.100 inch, and plate member 13 from an insulating plate of about 0.025 inch in thickness. The width of the mounting hole for electrodes 20 and 21 in plate 13 at their narrowest point may be made in the order of 0.016 inch, and the printing aperture 23 in plate 12 may have a diameter in the order of 0.016 inch. The distance between plates 12 and 13 may be the thickness of the tape plus approximately 0.0005 inch.

In order to cause a reproducible amount of energy to be delivered to the air gap 22 across electrodes 20 and 21 during each printing operation there is provided in circuit therewith electrodes 30 and 31 forming therebetween a control air gap 32. It is desirable that the control air gap will always break down when some fixed potential is applied across electrodes 30 and 31 and to this end there is provided an air jet generally indicated at 33, arranged so as to direct a stream of air through the gap to remove residual ions existing in the air gap from a previous discharge. In order to provide a controlled amount of negative ions in the gap to establish the desired breakdown voltage thereof there is provided a corona point 34 connected in the energizing circuit so as to cause a constant

discharge current of not more than 10 microamperes between the corona point and electrode 31. This current may be limited to the proper value by resistance 61, of appropriate value and voltage rating.

In the preferred embodiment described herein the electrodes 30 and 31 may be fashioned from  $\frac{3}{16}$  inch diameter tungsten rods. The air jet may consist of a tube 35 connected to a source of air under controlled pressure (not shown) and may be provided with nozzle 36 screwed onto the end of the air tube and provided with a centrally located orifice 37 directed toward air gap 32. Because of the high voltages involved it is preferable that the nozzle as well as the tube be made from insulating material such as Bakelite, for example. In the described embodiment an air orifice 37 having a diameter in the order of  $\frac{1}{4}$  inch and having air flowing therethrough at a velocity of from 5 to 10 meters per second, has been found sufficient to clear air gap 32 of residual ions between each printing operation provided that a suitable interval, for instance, an interval of 500 microseconds, elapses between any two successive printing operations.

There is also provided in accordance with the invention an electrical control circuit shown in Fig. 1 for applying across air gap 32 a potential sufficient to cause it to break down electrically when a trigger pulse is applied across a pair of input terminals to in turn cause an arc or a discharge to be established across printing air gap 22. The circuit includes a control vacuum tube 40 shown as a tetrode which may be of the kind manufactured by the Western Electric Company under their type No. 715B. Such a tube is provided with a plate 41, screen grid 42, control grid 43 and cathode 44, as well as a heater (not shown). The screen grid is shown as being connected to a screen grid power supply 45 shunted by a stabilizing capacitor 46. The cathode is connected to ground through a cathode resistor 47 and the control grid is connected to a source 48 of suitable input pulses. Each input pulse has a duration of 10 microseconds, and raises the grid voltage from -200 volts to zero bias for the duration of the pulse. The plate electrode is connected to a high potential power supply 49 through a plate isolating resistor 50 connected to the power supply through the arc or discharge circuit comprising spaced electrodes 20 and 21 shunted by resistor 51 in series with spaced control electrodes 30 and 31 shunted by parallel connected capacitor 52 and resistor 53. The tube is provided with a protective shunt circuit for by-passing high voltage and high frequency transients connected between plate 41 and ground and comprises a capacitor 55, shunted by the safety air gap 58. The high voltage power supply 49 is shunted by a stabilizing capacitor 62 which will store energy which may be drawn upon when the air gaps 22 and 32 break down.

It will be evident that the values of the various components used in the circuit will depend on the operating characteristics desired as well as on the particular tube used and the power supply voltages available. However, when used in conjunction with the printing structure described above a high voltage power supply 49 having a voltage of approximately 12,000 volts, a tube 40 of the 715B type wherein the screen voltage is maintained at approximately 300 volts positive by screen power supply 45 and the grid voltage is normally biased to 200 volts negative by the input pulse source 48, and an air gap 32 designed to break down approximately 8000 volts, the values of the components may be as follows:

| Resistor | Resistance Value | Capacitor | Capacitor Value      |
|----------|------------------|-----------|----------------------|
| 47       | 5 ohms           | 46        | 0.5 microfarad.      |
| 50       | 1,600 ohms       | 52        | 0.00073 microfarad.  |
| 51       | 100,000 ohms     | 55        | 0.000125 microfarad. |
| 53       | 12 megohms       |           |                      |
| 61       | 100 megohms      | 62        | 0.25 microfarad.     |

The operation of the embodiment illustrated in Fig. 1

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will now be described. Screen power supply 45 will maintain the screen grid 42 at a positive 300 volts, and, in the absence of an input pulse the input source 48 will maintain the control grid at a negative 200 volts. Under these conditions the tube 40 will be substantially cut off but a small cut-off current in the order of 100 microamperes will flow through the tube and through resistances 53, 50, and 47 from the 12,000 volt power supply 49. This current will cause a voltage drop across the 12 megohm resistance 53 of approximately 1200 volts whereby plate 41 of the tube will assume a potential of approximately 10,800 volts as indicated by curve 70, Fig. 6, between time zero and time 5 microseconds. The voltage drop which will exist across air gap 32, namely 1200 volts, will be insufficient to cause it to break down and hence no current will flow through resistance 51.

If now an input pulse of a magnitude and duration such as indicated in Fig. 4 is applied to grid 43 of tube 40 at time 5 microseconds, it will raise the potential of the grid to substantially ground potential and will cause an immediate increase in current flow through the tube as indicated at time 5 microseconds in Fig. 5, from a value of 100 microamperes to approximately one ampere. The one ampere current flow through 1600 ohm resistor 50 will develop thereacross a drop of approximately 1600 volts. This current constitutes primarily the charging current of capacitor 52, and the voltage at the juncture 65 between capacitance 52 and resistance 50 will begin to fall as the capacitor becomes charged and a voltage is developed thereacross as indicated by curve 70, Fig. 6, between 5 microseconds and 10 microseconds. Curve 71 indicates the voltage level of the high voltage source 49. From Fig. 1 it will be apparent that inasmuch as electrode 30 is connected to point 65 through resistance 51 the voltage appearing across electrodes 30 and 31 will be equal to the difference between curves 70 and 71 of Fig. 6, and it will be noted that at time 10 microseconds there will exist across the electrodes 30 and 31 a voltage of approximately 8000 volts. This voltage is sufficient, as above pointed out, to cause a breakdown across gap 32. The initial flow of current will pass through resistance 51 to develop almost immediately a voltage thereacross of sufficient magnitude to cause a breakdown to occur across printing air gap 22 between electrodes 20 and 21. The resistance across a spark gap is very low after a discharge has been established, and the air gaps 22 and 32, when broken down, will therefore be effectively electrically connected in series and substantially the same current having a magnitude as indicated in the curve of Fig. 9 will flow through both gaps. The discharge current across the gaps will be oscillatory transient in nature and will last for approximately 0.5 microsecond as indicated in Fig. 6.

Fig. 7 indicates the variations in the plate voltage of tube 40 during a cycle of operation and shows that the plate voltage decreases after the initial sudden drop mentioned above, along with the voltage of point 65, up until the time the air gaps 32 and 22 break down. The oscillatory transient fluctuations at point 65 as indicated at time 10 microseconds in Fig. 6 will be dampened at plate 41 by the filtering effect of capacitor 55 as indicated in Fig. 7. After the oscillations have ceased at time 10.5 microseconds, a current of approximately 1 ampere will flow across ionized gaps 32 and 22 and through resistor 50 and through the tube since the grid thereof is still maintained at ground potential by the input pulse. The total gap drop voltage is approximately 200 volts as indicated by the difference between curves 70 and 71 of Fig. 6 during this time interval.

After the termination of the input pulse the grid will again assume its normal 200 volts negative potential and will limit the current flow through the tube to approximately 100 microamperes and the initial quiescent conditions will be reestablished after a lapse of time of a few hundred microseconds.

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The sudden rise of the potential of plate 41 at time 10 microseconds will be reflected on the grid voltage and on the plate current as indicated by the small pip on the curves in Figs. 4 and 5.

Figs. 9 and 10 show the approximate current and voltage characteristics, respectively, which exist at the gaps 32 and 22 during their breakdown. The curves 72 and 73 of Fig. 8 represent an expansion of those portions of the curves of Figs. 6 and 7 wherein the oscillatory voltage transients in the voltage across the capacitor 52 and on plate 41, respectively, are illustrated. It can be seen from an examination of the curve of Fig. 10 representing the voltage drop across each of the air gaps 32 and 22, that during the breakdown of air gaps 32 and 22 the voltage appearing thereacross with respect to the 12,000 volt power supply 49 will be reversed in polarity several times. This oscillatory condition results from the inherent inductance in the circuit which is indicated in Fig. 1 in dotted lines. This inductance is so small as to be negligible for most purposes, but even if it is of a value of only about one microhenry, it will have an appreciable effect on the voltages which will appear across the air gaps when they break down. The voltages induced across this inherent inductance in the oscillatory circuit and the voltages which appear across the inherent resistance thereof during the oscillatory portion of the discharge account for the apparent discrepancy between the voltage across capacitor 52, as shown by curve 72 of Fig. 8, and the voltage across each of the gaps 22 and 32 as shown in Fig. 10. A periodic current will flow through the air gaps 32 and 22 in accordance with the air gap time current curve of Fig. 9. As the current approaches point 74, Fig. 9, it becomes insufficient to maintain an arc across the air gaps. Consequently at point 75 on the curve of Fig. 10 the voltage across the air gaps will drop rapidly to zero and will rise again with an opposite sign to point 76 as the ion current through the air gaps approaches point 77, Fig. 9. During the period of time between points 74 and 77, there will exist sufficient residual ions in the air gaps to sustain the current thereacross. Consequently it requires a lesser applied voltage across the air gaps to re-strike an arc than initially when fewer residual ions were present. The re-strike voltage is represented by point 76 of Fig. 10. As soon as the arc is re-struck, the voltage curve tends to return to its normal sustaining value until it reaches point 78 where again the current through the arc due to the transient oscillations occurring in the discharge circuit again begins to approach zero at point 79 at which time the arc is again extinguished and the voltage will again drop to zero. Then as the current reverses in polarity and begins to flow in the opposite direction to point 80 of a curve in Fig. 9 the voltage across air gaps 32 and 22 will again be built up to a point where the arc is re-struck at point 81, Fig. 10. This process is continued until the oscillations die out after a lapse of time of approximately .5 of a microsecond.

The printing operation takes place when the arc is struck across air gap 22 between electrodes 20 and 21. It was previously pointed out that the space between the tape 16 and the walls of the confined space defined by surface 14 of plate member 12, Fig. 2, and surface 15 of plate member 13 is in the order of 0.0005 inch. When the arc is struck across electrodes 20 and 21 an instantaneous increase in pressure will occur due to expansion of the confined gases between anvil 27 and the tape, and the latter will be accelerated toward and impelled with a substantial force against the printing surface 14, and a permanent indication will be made in the tape depending on the particular printing means provided on the printing surface. In order to produce on the record medium an imprint that is a clearcut replica of the printing means provided on the printing surface, it is essential that the air pressure be generated very suddenly, preferably corresponding to a rise of many atmospheres of pressure in a time interval in the order of a micro-

second. Such an explosive pressure is generated when a significant amount of stored energy is dissipated within a few microseconds in the small volume of the high resistance arc channel between the electrodes 20 and 21 thus producing a steep voltage gradient to heat the confined gases to a very high temperature. Legible printing without significant blurring is produced in the device in accordance with our invention when paper tape is moved therethrough at a speed of more than 250 feet per second. The spark duration is about two microseconds, the pressure wave will last somewhat longer or about three microseconds, producing a pressure of approximately 27 atmospheres against the paper. It will thus be appreciated that the device is capable of extremely rapid operation. In the embodiment illustrated in the Figs. 1 and 2, the printing means is shown as being an aperture extending through the plate member 13. Thus, if the aperture is circular in shape and if the discharge is of sufficient intensity to puncture the tape a circular hole will be formed therein. Therefore the aperture may be formed in any desired shape such as a letter, numeral or other intelligible symbol and a correspondingly shaped hole will be produced in the tape. If it is not desired to rupture the tape but merely to form an embossment thereon the intensity of the arc may be decreased to a point where it will not be able to puncture tape. If it is desired to form an embossment on the tape a concavity 63, Fig. 3, may be formed in the printing surface in place of the aperture. It will be evident that the embossment may be given any particular desired outline by properly shaping the outline of the concavity. The face of the concavity may, if desired, be cut or engraved with a pattern which then will be transferred to the face of the embossment formed on the tape.

It is also possible in accordance with invention to imprint the intelligence on the tape in the form of transparent windows which then may be sensed or detected by optical means. Thus if a tape of a transparent material is coated on the side facing the printing surface with an opaque material such as, for example, a metal oxide or a non-metallic material, the portions of the coating within the confines of the aperture or embossment may be caused to be separated from the tape by properly controlling the energy delivered to the tape by the arc discharge. The transparent window may be made in the form of a character such as a number, a letter, or other symbol as discussed above. Particularly in this latter case is it important that the printing aperture be flared away from the printing surface in order that the removed material may be disposed of from time to time to prevent it from clogging the aperture.

Three different types of markings which may be made on record media through the use of this invention are shown in Figs. 12, 13 and 14. Fig. 12 shows a record medium such as a tape 103 which comprises an opaque portion 100 and a transparent portion 101. When the tape 103 is impelled against the printing means, an area of the opaque portion 100, which is nearest the printing means, is knocked off the tape so as to leave a transparent window 103 therein. The tape may consist of a layer of transparent ethyl cellulose having a thickness of about .005 inch and a layer of aluminum having a thickness of about 5 microns. Other suitable materials may also be used.

Fig. 13 illustrates a record medium 104 in the form of a tape which has had an aperture 105 formed therein when the tape was impelled against the printing means. This tape may consist of paper or any other suitable material.

In Fig. 14 an embossment 106 is formed in a record medium such as a tape 107 when the tape is impelled against a printing means by the electric arc discharge. This tape may also consist of paper or any other suitable material.

It has been found that even when the anvil 27 which

is located between the electrodes 20 and 21 (Fig. 1), is made from the hardest material available on the market, repeated discharges across the surface thereof will after a period of time cause some erosion. It may therefore be found advantageous to employ a printing structure as shown in Fig. 11 provided with an expendable anvil which, when rotated, will present a new anvil surface and which is made of a material, such as mica, for example, that is resistant to erosion by electrical discharges. The printing plate 85 is provided with a printing aperture 86 and may in all respects be like printing plate 12 of Fig. 2. Spaced from printing plate 85 and having an upper flat surface substantially parallel with the under surface thereof is an anvil and electron supporting block 87. Spaced electrodes 88 and 89 may be supported in block 87 in substantially the same manner as electrodes 20 and 21 are supported in plate member 13 of Fig. 2, but they are formed so as to accommodate therebetween the cylindrical anvil member 90. The anvil member is rotatably mounted in block 87 so that the anvil surface located between the electrodes will extend slightly above the upper surface of the block. The end of the anvil member is threaded in an end plate 91 secured to block 87 in a suitable manner. The anvil member is provided with suitable means for rotating it such as, for example, a slot 92 for receiving the end of a screwdriver. Supporting block 87 and plate 85 may be made of a suitable insulating material as mentioned above with respect to plate members 12 and 13 of Fig. 2. End plate 91 may be made from metal or other material capable of being threaded. The various dimensions of the structure such as the size and spacing of the electrodes and the spacing between the juxtaposed surfaces of plate 85 and 87 may be the same as mentioned in connection with the structure shown in Fig. 2. When the anvil surface between electrodes 88 and 89 becomes eroded from the electrical discharges thereacross a new anvil surface may be provided by simply rotating the cylindrical anvil member. The pitch of the thread on the anvil member should be selected so that each complete revolution of the member will advance it by a distance sufficient to present a new surface between the electrodes. After the whole surface of the anvil member has been used up, the member may readily be replaced. The construction shown in Fig. 11 has the advantage over that shown in Fig. 2 in that it makes it unnecessary to replace the entire lower electrode supporting member when the anvil surface has become so pitted as to appreciably reduce the efficiency of the apparatus.

Although a particular type of printing structure and associated discharge means have been described herein, it will be apparent to those skilled in the art that various changes and modifications may be made therein. For example, the recording medium has been described to be in the form of a tape, but it may be made in any form as long as it can be accommodated within a confined space suitable for producing printing in the manner described and it may be made of any material on which an impression can be formed by the printing surface by the application of an electrical discharge on the other side of the medium. The structure for forming the printing space has been described as being made from insulating material, but is mainly for the sake of convenience and safety and it will be evident that as long as the plates are not grounded or in any other manner connected in the circuit, or as long as they are not likely to be contacted by the operator, they may be made from a conducting material as well. The structure forming the printing space is shown as being made from two separate plates, but it will be apparent that only the opposed surfaces thereof forming the confined space are pertinent, and it will also be apparent that such structure may be made in a single piece as well as from more parts than the two parts shown.

It has been found that when using the construction

described above, a tape can be perforated, embossed, or windows made therein in the form of intelligible characters while the tape is traveling at speeds in excess of 200 feet a second.

The input pulses applied to grid 43 from input pulse source 48 can be delivered in the form of a code such as, for example, a binary code. Alternatively, five pairs of electrodes, five anvils and five printing dies can be arranged in parallel so as to independently print five sets of holes, windows or embossments onto a wide tape passing thereacross. The five pairs of electrodes may be individually actuated by separate arc producing circuits which feed intelligence to the printing unit in accordance with a standard teletype code.

It is to be understood that the specific forms of the invention herein described are but preferred embodiments thereof and various changes may be made in the control circuit described, the elements used and the materials and dimensions mentioned without departing from the spirit and scope of the invention.

We claim:

1. Printing apparatus comprising a body having a pair of closely spaced juxtaposed surfaces forming an at least partially confined space therebetween, said space containing heat expansible gases, printing means associated with one of said surfaces, means for establishing a controlled electric discharge across a portion of the other of said surfaces, and means for permitting a record medium to be inserted between said discharge portion of said other surface and said printing means of said one surface whereby an electric discharge across said discharge portion will heat and expand the gases in said space to impel said record medium against said printing means to record intelligence thereon.

2. Printing apparatus comprising a body having a pair of closely spaced juxtaposed surfaces having an at least partially confined space therebetween, said space containing heat expansible gases, means for permitting a record medium to be inserted between said surfaces, a pair of spaced electrodes communicating with said space through one of said surfaces, printing means in the other of said surfaces and disposed substantially opposite the surface between said electrodes, and circuit means including a source of power connected to said electrodes for producing a controlled electrical discharge thereacross for impelling a record medium inserted between said means against said printing surface.

3. Printing apparatus comprising a first plate of insulating material having one major surface thereof comprising a substantially smooth plane, a second plate of insulating material having a major surface thereof comprising a substantially smooth plane, said first and second plates being arranged so that the smooth major surfaces thereof are opposed and lie in two substantially parallel planes to form an at least partially confined space therebetween, said space containing heat expansible gases, said two smooth major surfaces being spaced a distance apart sufficient to allow a record medium such as a tape to pass therethrough, said first plate having a plurality of apertures therein, said plurality of apertures being divided into pairs, an electrode positioned in each of said apertures, the electrodes of each pair of apertures being spaced to form a discharge gap therebetween across the intervening portion of said surface of said first plate and individual printing aperture in the smooth surface of said second plate for each pair of apertures in said first plate, said aperture in said second plate positioned so as to be substantially opposite to the midpoint between a pair of apertures in said first plate, and circuit means to create an arc across a pair of electrodes to cause intelligence to be recorded on a record medium present between said first and second plates by impelling said record medium against said surface of said second plate and said printing aperture thereof.

4. Printing apparatus in accordance with claim 3

where in said individual aperture in said second plate consists of an opening through said second plate.

5. Printing apparatus in accordance with claim 3 wherein said aperture in said second plate consists of a depression in said second plate of a depth sufficient to cause embossment of said record medium.

6. Printing apparatus in accordance with claim 3 wherein said aperture in said second plate consists of an opening through said second plate in the form of an intelligible character.

7. Printing apparatus comprising a pair of plates positioned so that a major surface of a first of said plates is opposite a major surface of a second of said plates, said two major surfaces being substantially smooth planes and being substantially parallel to each other to form an at least partially confined space therebetween, said pair of plates being spaced apart a distance approximately equal to the thickness of a record medium which is to be passed therebetween plus a distance large enough to sustain an electric arc discharge, a first plate of said pair of plates having a pair of apertures therein, a first pair of electrodes, one of said pair of electrodes being positioned within each aperture to provide a discharge gap therebetween across the intervening portion of said surface of said first plate, the ends of said electrodes being below the said smooth plane surface of said first plate, said second plate having a printing aperture in the said substantially smooth plane major surface thereof in a position substantially corresponding to the midpoint between the pair of apertures in said first plate, a capacitance, a first circuit means for charging said capacitance, a second circuit means comprising said electrodes for discharging said capacitance, the energy released between said electrodes when said capacitance is discharged being sufficiently large to cause a record medium interposed between said surfaces to be impacted against said printing aperture to be physically marked thereby.

8. Printing apparatus in accordance with claim 7 wherein said second circuit means comprises said first pair of electrodes, and a second pair of electrodes electrically connected in series, said second pair of electrodes including means for regulating the energy delivered to the gap between said first pair of electrodes when said first pair of electrodes breaks down electrically.

9. Printing apparatus in accordance with claim 3 wherein said first plate and said second plate are of glass bonded mica.

10. Printing apparatus in accordance with claim 3 wherein said apertures in said second plate consists of openings through said second plate, said openings having a shape perimeter in accordance with the shape perimeter desired to be recorded on the record medium.

11. Printing apparatus comprising a body having a pair of spaced juxtaposed surfaces defining an at least partially confined space therebetween arranged for receiving recording means, said space containing heat expansible gases, at least one pair of spaced electrodes communicating with the space between said surfaces through one of said surfaces, printing means associated with the other of said surfaces and disposed substantially opposite a point between each pair of electrodes, replaceable means disposed between pairs of electrodes to form an anvil surface therebetween, and circuit means including a source of power connected to said electrodes for producing a controlled electrical discharge thereacross to heat and expand the gases in said space for impelling record means disposed between said surfaces against said printing means.

12. Printing apparatus comprising at least one pair of spaced electrodes, an anvil surface disposed between said electrodes, printing means in juxtaposed relation with said anvil surface and spaced therefrom to form an at least partially confined discharge space therebetween, said space containing heat expansible gases, and circuit means including a source of power connected to said electrodes for producing a controlled electrical discharge thereacross to

heat and expand the gases in said space for forcibly impelling record means disposed between said anvil surface and said printing means against said printing means.

13. Printing apparatus in accordance with claim 12 including a removable member disposed between at least one pair of electrodes and carrying said anvil surface.

14. Printing apparatus comprising a first plate with one of the major surfaces thereof being a substantially smooth plane surface, a second plate with one of the major surfaces thereof being a substantially smooth plane surface, said first and second plates being positioned with the said substantially smooth major plane surfaces opposite each other and lying in substantially parallel planes to form an at least partially confined space therebetween, said first plate having a plurality of first apertures therein, said first apertures being divided into pairs of apertures, an electrode within each of said first apertures, the electrodes of each pair of apertures being spaced to form a discharge gap therebetween across the intervening portion of said surface of said first plate, said second plate having a printing aperture positioned so as to be substantially opposite the midpoint of the associated pair of apertures in said first plate, circuit means creating an electrical discharge between any pair of electrodes associated with said pair of apertures in said first plate for impelling record means disposed between said surfaces against said printing aperture, and means comprising a renewable anvil surface, said renewable anvil surface existing between individual electrodes of each pair of electrodes.

15. Printing apparatus in accordance with claim 14 in which said means comprises a cylinder embedded in said first plate in a manner to be capable of rotation and axial motion, said cylinder being in a position presenting a portion of its surface between a pair of said electrodes, the said portion of said surface being substantially all the surface appearing between said pair of electrodes.

16. Printing apparatus in accordance with claim 14 in which said means comprises a rotatable cylinder embedded in said first plate and having its axis substantially perpendicular to the plane in which a given pair of said electrodes lies, said rotatable cylinder presenting a portion of its surface between a pair of said electrodes, the said portion of the surface being substantially spaced the space distance from said second plate as said first plate is spaced from said second plate, the axis of said rotatable cylinder being substantially parallel to the smooth surface of said first plate, and the said rotatable cylinder being movable axially during its rotation.

17. A method of perforating a record medium including the steps of positioning the record medium in a partially confined space containing heat expansible gases, positioning a pair of spaced electrode terminals within said space and on one side of said record medium, and heating and expanding the gases in said space by discharging an arc across said electrode terminals in said confined space to accelerate said record medium against one of the walls forming the boundaries of said confining space to form perforations in said record medium in accordance with perforations in said wall.

18. A method of embossing a record medium comprising the steps of positioning the record medium in a partially confined space containing heat expansible gases, positioning a pair of spaced electrode terminals within said space and on one side of said record medium, and suddenly heating and expanding the gases within said space by discharging an arc across said electrode terminals in said confined space to accelerate said record medium against one of the walls forming the boundaries of said confining space to form embossments in said record medium in accordance with indentations in said wall.

19. A method of removing selected areas of an opaque coating from a transparent record medium comprising

the steps of positioning the record medium in a partially confined space containing heat expansible gases, and suddenly heating and expanding the gases within said space by discharging an arc in said confined space on one side of said record medium to accelerate the coated side of said record medium against one of the walls forming the boundaries of said partially confined space to cause a predetermined portion of the coating on said recording means to be removed from said record medium.

20. Method of making a predetermined formation in a formable member comprising the steps of producing an electrical discharge to heat and expand gases exposed to the discharge, placing a member to be formed adjacent said discharge, confining the gases to apply the force of the heated and expanded gases resulting from the electrical discharge to the member, and restraining displacement of that portion of the member that surrounds an area having an outline corresponding to the outline of the formation desired and which is subjected to the force from the electrical discharge to a greater extent than the portion of the member confined within the outline of the formation desired.

21. Method of making predetermined formations in a formable member which comprises producing, through a volume of fluid confined closely adjacent one face of the formable member, an electrical jump spark to create, by heating and expansion of said fluid by said spark, an explosive increase of pressure of said fluid against said formable member to thereby drive said formable member with forming force against a forming member.

22. Method of forming a predetermined configuration in a formable member comprising the steps of supporting against substantial displacement that portion of the member to be formed which immediately surrounds the area within the desired configuration and leaving the portion of the member within this area at least partially unsupported so as to permit greater displacement thereof than at the surrounding portion of the member, placing a formable member in juxtaposed relation with the support, producing an electrical discharge to heat and expand surrounding gases, and confining and applying the explosive force resulting from the expanded gases against the at least partially unsupported portion of said member thereby permanently displacing it.

23. Method of forming an aperture of a predetermined configuration in a puncturable member comprising the steps of supporting against substantial displacement that portion of the member to be punctured which immediately surrounds the area within the desired configurations leaving said area unsupported, placing a puncturable member in juxtaposed relation with respect to the support, producing an electrical discharge to heat and expand surrounding gases, and confining, and applying the explosive force resulting from the expanded gases against said portion of said member immediately surrounding said unsupported area thereby removing said unsupported portion from said member.

24. Method of forming an embossment of a predetermined configuration in an embossable member comprising the steps of supporting against substantial displacement that portion of the member which immediately surrounds the area within the desired configuration, limiting displacements of elementary areas within the configuration by extents to form the embossment desired, positioning the member in juxtaposed relationship with respect to the support, producing an electrical discharge to heat and expand surrounding gases, confining and applying the explosive force resulting from the expanded gases against said portion of said member immediately surrounding said area, and limiting displacements of elementary areas of the member within the configuration by extents to form the embossment desired.

25. Apparatus for puncturing material comprising in combination, a body having an internal chamber formed between two surfaces arranged in juxtaposed substantially

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parallel relation to one another, said chamber containing heat expansible gases, electrode means for creating an electric discharge adjacent to one of said surfaces and substantially parallel thereto, the remaining one of said two surfaces being provided with a recess opposite to said electrode means and having an outline which defines a desired configuration, means for positioning a puncturable member between said electrode means and said recessed surface, and circuit means including a source of electrical energy connected to said electrode means and operable to create a controlled electrical discharge on one side of a puncturable member disposed between said electrode means and said recessed surface to heat and expand the gases in said chamber to produce a sufficient force to impel said member against the recessed surface and cause that portion of the member overlying the recess to be punctured with the desired configuration.

26. Apparatus for forming predetermined configurations in a formable material comprising a body having an internal chamber formed between a pair of spaced, juxtaposed surfaces, said chamber containing heat expansible gases, a pair of spaced electrodes communicating with said space through one of said surfaces, the other of said surfaces being provided with forming means disposed substantially opposite the surface between said electrodes, said forming means determining permissible displacement of a portion of a material overlying it, means providing for the interposition of a member to be formed between said pair of spaced electrodes in said one surface and the forming means in the other of said surfaces, and circuit means including a source of power connected to said electrodes for producing a controlled electrical discharge thereacross for expanding the surrounding gases and thereby impelling a member to be formed thus interposed between said surfaces against said forming means.

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27. Apparatus for forming predetermined configurations in a formable member, a member having a surface for limiting displacement of a member to be formed, said surface having an opening therein, means for creating an electrical discharge through heat expansible gases to expand the latter, said discharge being spaced from said surface and opposite said opening therein and means for substantially confining said gases in the immediate vicinity of said opening in said limiting member including means for directing the force created by the expanding gases resulting from the discharge toward said opening, whereby a formable member disposed adjacent said limiting surface between said opening therein and said electrical discharge will have that portion thereof overlying said opening permanently displaced by an amount depending on the character of said opening.

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