Nov. 7, 1967 H. HEUER 3,351,740

PUNCHING APPARATUS

Filed July 25, 1963 5 Sheets-Sheet 1

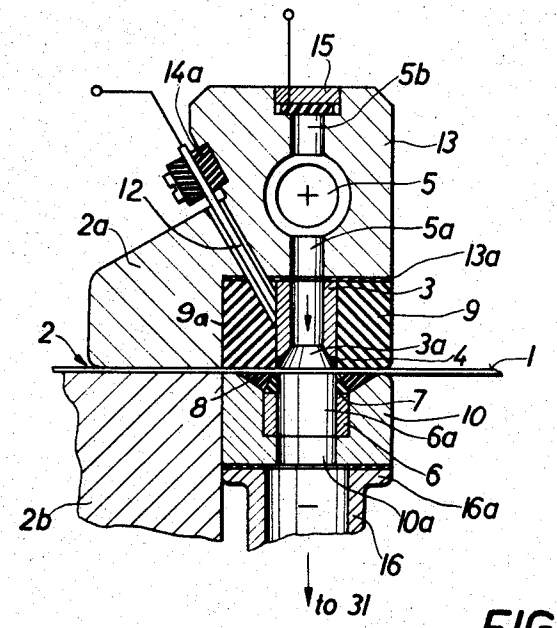

FIG. 1

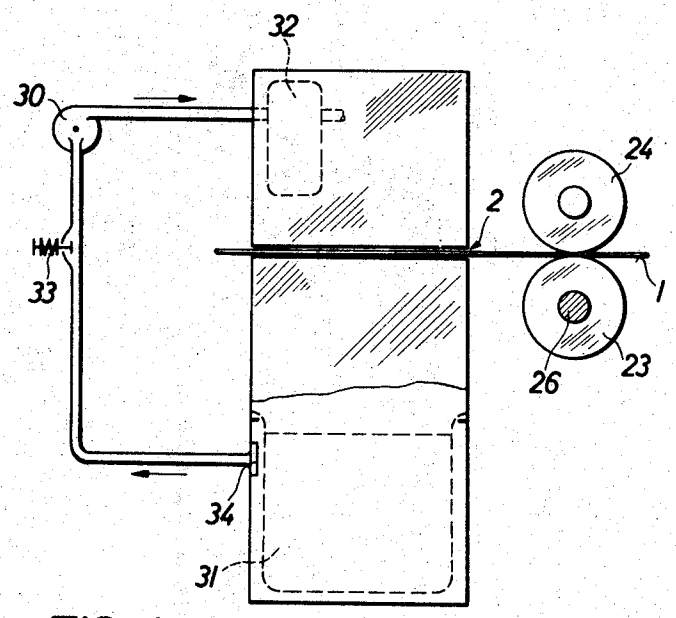

FIG. 4

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Nov. 7, 1967 H. HEUER 3,351,740

PUNCHING APPARATUS

Filed July 25, 1963 5 Sheets-Sheet 2

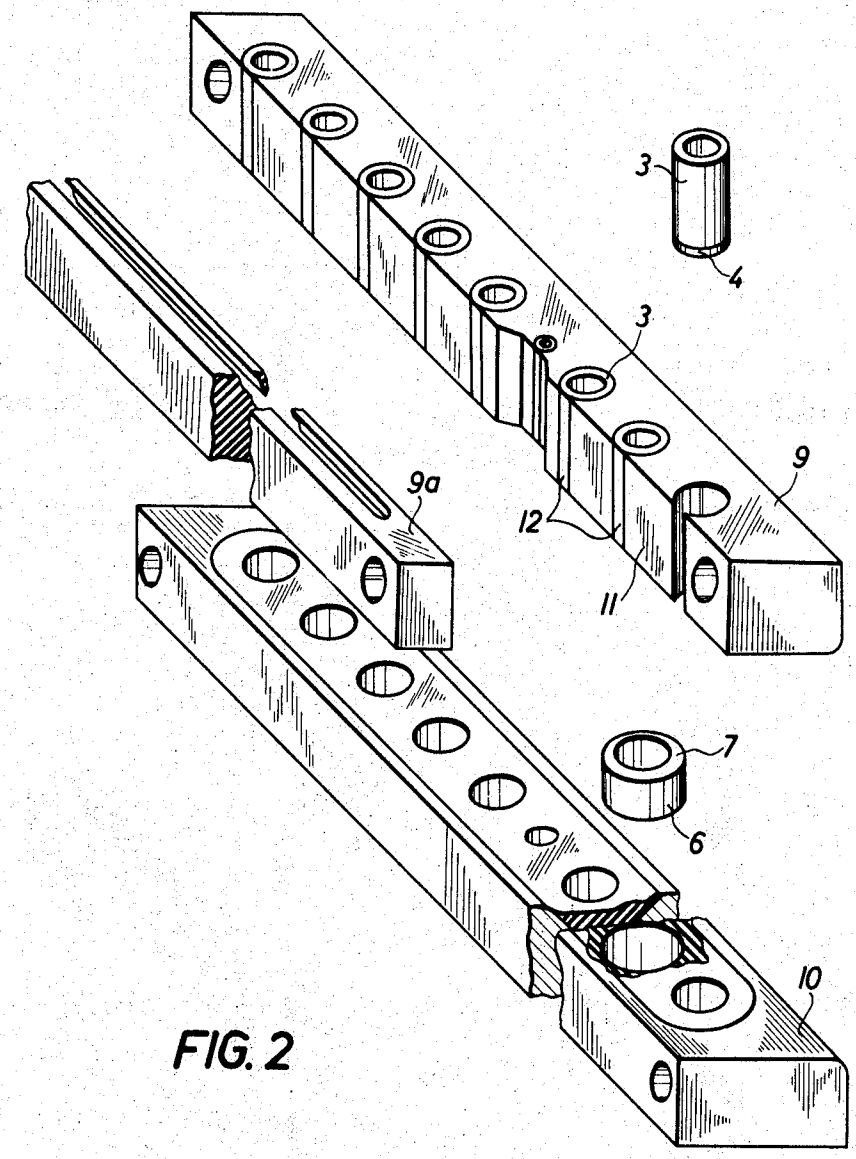

FIG. 2

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Nov. 7, 1967 H. HEUER 3,351,740

PUNCHING APPARATUS

Filed July 25, 1963 5 Sheets-Sheet 3

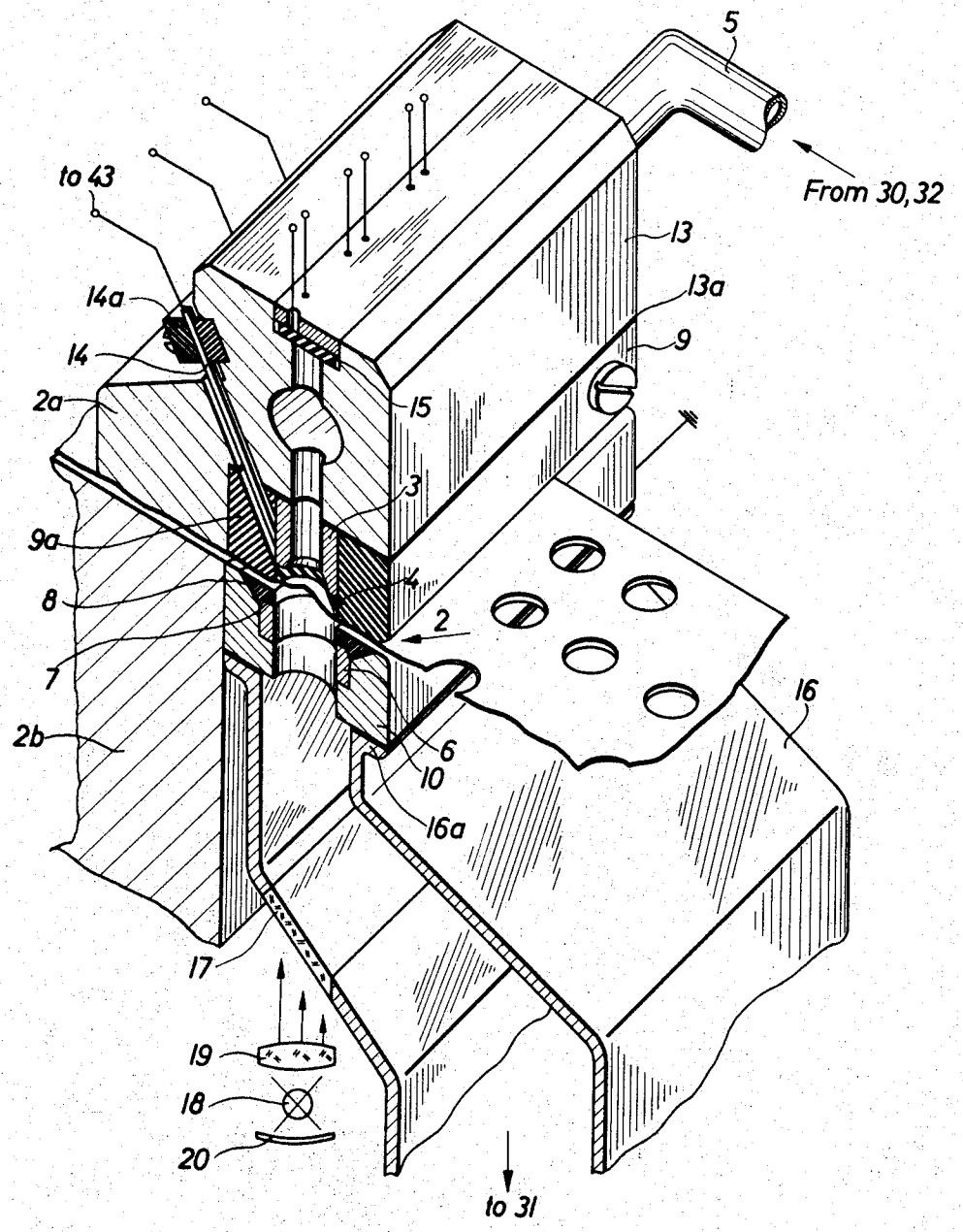

FIG. 3

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PUNCHING APPARATUS

Filed July 25, 1963 5 Sheets-Sheet 4

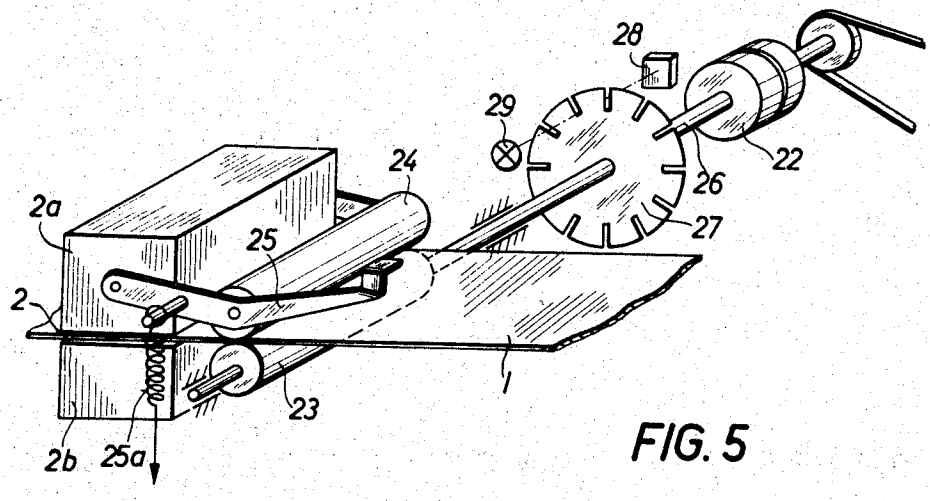

FIG. 5

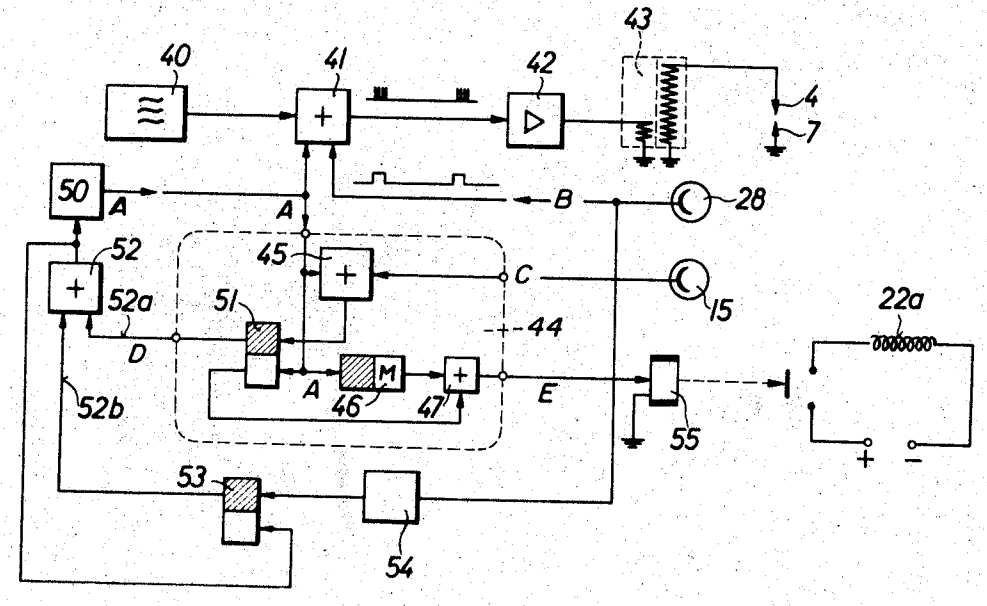

FIG. 6

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PUNCHING APPARATUS

Filed July 25, 1963 5 Sheets-Sheet 5

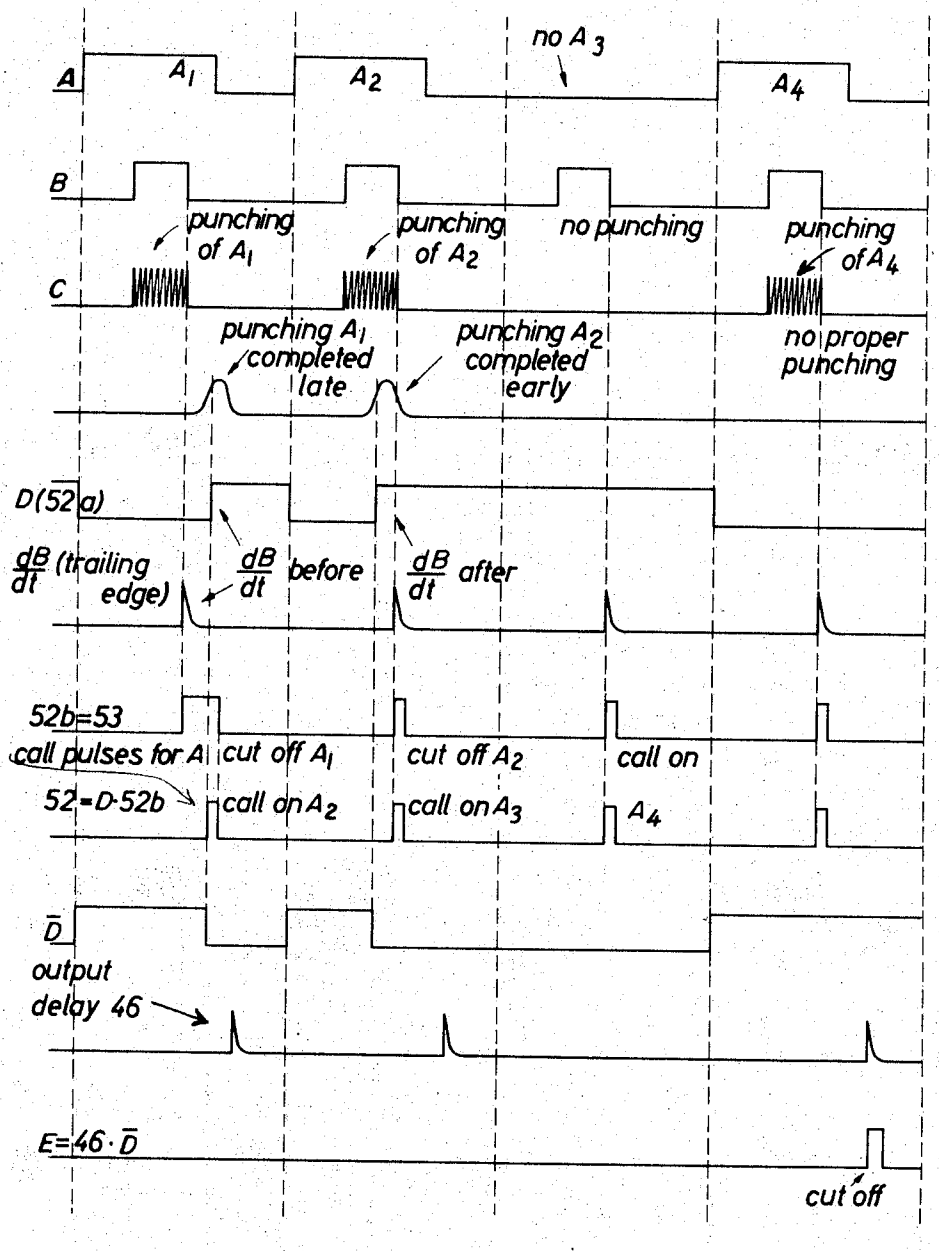

FIG. 7

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United States Patent Office 3,351,740 Patented Nov. 7, 1967

3,351,740

PUNCHING APPARATUS

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Filed July 25, 1963, Ser. No. 299,448
Claims priority, application Germany, Aug. 9, 1962, O 8,919
14 Claims. (Cl. 219—384)

The present invention relates to a new punching apparatus.

Known punching apparatus operate with punching rods usually called punches to be moved up and down to perforate a web, tape, sheet, card etc. Necessarily, the speed of operation of such an apparatus is severely limited by the required physical movement of mechanical parts which have to be accelerated, moved, braked, reversed for retraction, accelerated again, moved, braked and stopped just for punching one hole.

It is an object of the present invention to provide a new punching apparatus using no mechanical and physical parts to be accelerated.

It is another object of the present invention to provide for a new punching apparatus in which the time for punching of one hole is reduced to 40 μsec.

According to one aspect of the present invention in a preferred embodiment thereof it is suggested to provide a spark gap by way of two electrodes preferably having ring-shaped edges of similar diameter and being coaxially disposed. The web or tape traverses the correspondingly ring-shaped spark gap in a direction transversely to the electrode and spark gap axis and punching is carried out in a two-fold manner. First, high frequency, A.C. pulses are applied to the electrodes to produce a series of sparks in alternate directions weakening the web structure in an annulus; second by way of air pressure the rondelle or disc encircled by the weakened annulus is pushed out. The voltage to be applied to the electrodes is, for example, controlled in dependence upon the successful completion of a previous punching step and in synchronism with the web transport.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention, it is believed that the invention, the objects, and features of the invention and further objects, features and advantages thereof will be better understood from the following description taken in connection with the accompanying drawing in which:

FIGURE 1 illustrates a cross-sectional view through a punching station in accordance with the invention, showing a pair of electrodes, the spark gap and a web defining the basic elements of a single punching station unit;

FIGURE 2 illustrates in perspective and exploded view electrodes and electrode carriers for a punching station capable of punching a row of holes or a series of coded holes simultaneously;

FIGURE 3 illustrates in perspective and cross-sectional view a punching station in accordance with the invention;

FIGURE 4 illustrates schematically the air pressure system for removing the punched discs in the aforementioned punching station;

FIGURE 5 illustrates in perspective view web driving means transporting the web through the aforementioned punching station;

FIGURE 6 shows a circuit diagram of a control circuit network for a single unit in the aforementioned punching station; and

FIGURE 7 illustrates a pulse diagram representative of various operating conditions in the above punching station, whereby several logic equations at the left hand margin define the relations among the several pulses.

Proceeding now to the detailed description of the drawing, there is first shown a running web or tape **1** (FIGURES 1, 3, 4, 5) running in and through a flat horizontally extending guiding channel **2** defined between two stationary block type frame or support elements **2***a* and **2***b*. An electrode carrier **13** is integral with block **2***a* carrying a bar assembly composed of bars **9** and **9***a* (see FIGURES 1, 2 and 3) consisting of electrically insulating material but having also a high thermal resistivity such as asbestos. There is a further electrically insulating layer **13***a* interposed between bars **9**, **9***a* and carrier **13**.

The particular shape of bar **9** with supplementing bar **9***a* can best be seen from FIGURE 2. Bar **9** is provided with a plurality of holes or cylindrical bores in axis parallel relationship and being orientated along a line extending across the path of traverse of web **1** through gap or channel **2**. Each hole consequently has an axis extending tranversely to the surface of web **1** when in this flat channel **2**.

Each such hole in bar **9** receives a cylindrical tube **3** constituting a first electrode having an annular sharp cutting edge **4**. The inner space of each tube **3** is denoted as **3***a*. Each tubular electrode **3** when inserted in bar **9** is aligned with a corresponding tubular channel **5***a* in carrier **13** and all such channels communicate with a conduit **5** to be supplied with high pressure air. There is a continuing channel portion **5***b* for each tubular channel **5***a* axially aligned therewith and terminating in a photo-electric receiver **15**.

Beneath bar **9** with tubular electrodes attached to carrier **13** a second electrode carrier **10** is attached to block **2***b*. Carrier **10** is mounted on a flange **16***a* on a waste outlet duct **16** forming part of the stationary frame.

Guiding channel **2** is continued between bars **9**, **9***a* and carrier **10**. On carrier **10** is positioned a filling **8** of insulated material similar to that of bars **9** and **9***a*. Filling **8** and carrier **10** together have a plurality of cylindrical bores **10***a* individually aligned with the cylindrical bores in bar **9** and carrier **13**, but the bores in filling **8** and bores **10***a* in carrier **10** are of larger diameter. The latter bores receive tubular electrodes **6** terminating upwardly in annular inner cutting edges **7**, also called electrode edges. The inner space of each electrode **6** is denoted with reference character **6***a*.

The electrode edges **4** and **7** are of similar diameter but in such a manner that the outer diameter of a tubular electrode **3** is the same as the inner diameter of a tubular electrode **6** (see FIGURE 1). Electrode edges **4** and **7** are made of electric conducting material having a high resistivity against burning, such as platinum, platinum iridium, etc.

Each pair of aligned electrode edges **4**–**7** defines a spark gap traversed by web **1** as stated. The purpose thereof is to have an electrode system to which are applied high frequency voltage pulses capable of producing sparks in alternate directions between electrode edges **4**–**7** and through web **1**.

Upon sparking, the web **1** is structurally weakened in a thin annular zone so that when high air pressure is applied to conduit **5** through the tubular electrodes **3**, the air pushes the severed rondelle into electrode **6** and waste outlet channel **16** feeding and into a waste basket or container **31**. This will be described more fully below.

The web to be perforated or punched is preferably of a type in which any spark between a portion of edge **4** and the adjacent portion of edge **7** prefers to pass through the web **1** at a location not yet having been passed through by a spark. This is important, since normally sparking will not occur uniformly at a ring-shaped spark.

It has to be observed that any electric field between such sharp electrode edges **4** and **7** is very inhomogeneous, and naturally the web **1** when passing through channel **2** will not traverse the ring-shaped spark gap **4**–**7** uni-

formly, nor is it to be expected that the web is exactly coplanar with either electrode edge nor will it be of precisely uniform thickness. Thus, any spark will start to develop at a particular small spot as between a small portion or section of edge 4 and the adjacent portion of edge 7. Such spark traverses a particular spot of web 1. In view of the above stated requirement for the web material, sparking will not continue through that particular spot where sparking occurred initially but adjacent thereto, so that a spark that has once started anywhere will then run around edges 4–7 like a cutting knife. This ensures that with every sparking step only a small spot on the web is attacked initially which is enlarged to an annular portion enveloping a disc or rondelle which is then driven out.

A web meeting such requirements preferably consists of a paper which does not char and which is interspersed with very finely divided metal powder (aluminum or magnesium powder). This metal in fact shortens the nonconductive air gap between a pair of edges 4–7 prior to sparking and thus offers a preferred area for spark penetration.

Any area or spot having been traversed already by a spark is depleted from metal powder particle vaporization thereof. Thus, the effective air gap at such spot is larger as compared with an undisturbed web area. In particular, any web area just being subjected to a spark or a series of sparks and being depleted thereby from metal powder particles becomes less susceptible to further spark penetration than adjacent areas. Thus, upon applying a voltage across a pair of electrode edges 4–7 when traversed by a paper web as aforedescribed, there first will be a particular spot of preferred sparking due to minute inherent inhomogeneity of the edge-paper relationship and due to the great inhomogeneity of the spark producing electric field. Once sparking occurs at such spot, this spot becomes less susceptible to further sparking than adjacent spots, so that the sparks will tend to run in a circle around the ring-shaped gap, weakening the paper in an annular arc thereof outlining a punched out disc.

As will be described more fully below and with particular reference to FIGURE 4, high air pressure is applied to duct 5, effective in the spaces 3*a* of hollow electrodes 3 directly above web 1. Low air pressure is established through outlet channel 16 to bores 10*a* and the individual spaces 6*a* of hollow electrodes 6 to be effective beneath web 1. The web portion traversing the ring-shaped spark gap 4–7 is thus subjected to a downwardly directed pressure differential.

Normally, the pressure difference thus applied across web 1 is insufficient to cause any ripping or perforating thereof. However, when by sparking between electrode edges 4 and 7, the web 1 is weakened in an annular space, the disc enclosed by such weakened annulars can and will be pushed downwardly into outlet duct 16. The weakening of the web in an annular area by sparking has already been described.

Basically, it is unimportant weather the pressure gradient as defined is directed upwardly or downwardly, or whether web 1 runs vertically so that the pressure gradient is orientated horizontally. It is advantageous, however, to have gravity assist the removal of the disc so that the pressure needs only to loosen the disc in the web around its weakened circumference. Thus, the device as shown with high pressure being applied from above is the preferred structural arrangement.

Proceeding now with the detailed description of the inventive construction one can best see from FIGURE 2 that electrodes 3 and 6 are standardized or standardizable elements. Tubular electrodes 3 are embedded in bar 9 having one side abraded so that there are longitudinal slots exposing a small metallic surface portion 12 of any tubular electrode 3 inserted therein. These surface portions 12 serve as electric connecting surfaces respectively engaging contact springs 14 which are inserted into channels of body 2*a* and positioned centrally therein by insulators 14*a*. Springs 14 furthermore traverse a slanted, elongated slot in the supplementing bar 9*a* suitably attached to bar 9. Electric connection is made with each individual tubular electrode 3, 4 by means of these contact springs 14 insulatedly introduced into block 2*a* to individually engage the exposed contact surfaces 12 of electrodes 3. It is thus apparent that tubular electrodes 3 with their sharp electrode edges 4 are, in fact, completely insulated from each other and from block 2*a*, and there is further provided the insulating layer 13*a* to insulate electrodes 3 from metallic carrier 13.

Electrodes 6 are inserted directly into metallic bar 10, thus these electrodes are all kept at equal potential, which may be ground or mass potential. However, each electrode edge 7 is surrounded by the insulating material of filler 8 so that, in fact, each electrode edge 7 appears in channel 2 as insulated from the other electrode edges thus enabling individual sparking with the respectively adjacent electrode edge 4 without influencing neighboring electrode pairs.

Bar 10 has its cylindrical bores 10*a* communicating with a space defined by frame structure portions 16 constituting a common outlet channel for the removed discs. The flange 16*a* on frame structure 16 is provided to support bar 10 as stated. A glass window 17 in frame structure 16 permits light from light source 18 to enter each individual bore 10*a* of bar 10, and the space 6*a* in each tubular electrode 6.

Whenever a disc is being removed from web 1 the light can pass on into the space 3*a* of the individually aligned tubular electrode 3, and the bores 5*a* and 5*b* thereabove in carrier 13. Aligned bores 5*a* and 5*b* serve as light channels for the individual photoelectric receivers 15, the purpose of which will be explained below. It is apparent that light from source 18 will reach a photoelectric receiver 15 whenever a perforation below it in web 1 has been completed. Whenever web material covers the ring-shaped electrode edge 7, either because no perforation was initiated or the perforation was faulty and the disc adheres to the web, no light will be received by photocell 15.

A lens 19, preferably a cylindrical lens and a mirror 20, preferably a cylindrical mirror serve to equalize the light for each light channel 10*a*–6*a*–3*a*–5*a*–5*b*. Lamp 2*c* is preferably of elongated form.

Web 1 is transported by a motor (not shown) connected to a clutch 22 having on its driving side a shaft 26 on which is mounted a transport roller 23. Shaft 26 is suitably journaled in the stationary framework of the device. Roller 23 cooperates with a pressure roller 24 to positively advance web 1 without slippage. Pressure roller 24 is mounted on a lever 25 which is engaged by a spring 25*a* urging lever 25 in such a direction that roller 24 is urged toward roller 23. Clutch 22 is preferably of the controlled, electromagnetic type so that upon de-energization shaft 26 with roller 23 can be stopped thus stopping transport of web 1.

A slotted disc 27 is mounted on shaft 26 rotating therewith. There is provided a light source 29 and a photoelectric receiver 28 defining a light path. The disc 27 is positioned so that upon rotation thereof the slits temporarily open this light path and thus light pulses are received by photoelectric receiver 28 and converted therein into electric pulses of limited duration and frequency as compared with the light pulses. It is apparent, that the frequency of these light pulses is directly proportional to the speed of web 1 and these pulses thus constitute clock pulses used for control purposes in a manner described more fully below.

The motor also drives a pump 30 pumping high pressure air into a pressure chamber 32 (see FIGURE 4) feeding conduit 5. This pump also reduces the pressure in the container 31 collecting the punched out discs. In particular, the low pressure is to be effective in the

tubular electrodes **6** below the passing web **1** as aforedescribed. A sieve **34** prevents the pump from sucking up punched out discs. A basket of wire mesh **31** to serve as a waste collecting container could also be used so that no paper will enter the pump and air circulation. Since some air will escape from between the open electrodes **6** and web **9**, a valve **33** serves to replenish the amount of air pumped into pressure chamber **32**.

The slots of disc **27** are dimensioned so that the web moves by 0.1 mm. during the punching of one hole. The slits are spaced apart to correspond to a web transport distance of $\frac{1}{10}$" between two successive punchings. The diameter of the punched hole is about half that size.

The diameter of transport roller **23** may for example be about 16 mm. and rotating with a speed of 3000 revolutions per minute thus advancing the web by 2.54 m. per second. The distance from punch hole to punch hole is to be about $\frac{1}{10}$" so that there are a thousand punching steps carried out per second.

The punching time of one hole measured as the time of sparking to "cut" the disc to be punched out is about 40 μsec. so that the web advances 0.1 mm. during the "cutting."

Assuming further that the punching of one hole is performed by about 100 sparks (per 40 μsec.), the necessary frequency for the production of sparking will be: 2.5 megacycles per second. Since sparking is carried out by A.C. using voltages between electrodes **4** and **7** in both directions, a high frequency generator of 1.25 megacycles per second produces this rate of sparking.

Having thus developed the conditions for the electric control device as being set by desired operating conditions as well as the mechanical provisions outlined above, I now shall proceed to describe the electric control circuit.

In FIGURE 6, there is shown a pulse generator **40** producing output pulses at the rate of 1.25 megacycles per second. These pulses are preferably unidirectional and are fed to the main input side of an electronic gate **41**. Assuming gate **41** is open, the pulses are then passed on to an amplifier **42** and from there to a step-up transformer **43** converting each pulse into a high voltage A.C. oscillation. One side of the secondary winding of step-up transformer **43** is connected to one electrode edge **4**. The opposite side of this secondary transformer winding is grounded, so is the corresponding electrode edge **7**.

It will be remembered that the device illustrated in the figures described above shows a series of punching arrangements (pairs of electrodes **3**, **4–6**, **7**) arranged transversely to the direction of web movement to punch holes across the entire web width at desired locations. For each pair of electrodes there is an individual gate **41**, an amplifier **42**, and a transformer **43**. However, for the entire device only a single generator **40** is needed.

The gate **41** is controlled by two independently produced signals A and B, but the presence of both such signals is necessary to open the gate **41**.

Signal A is the main input signal representing a bit information drawn from a data processing device **50**. Signal A basically consists of a voltage (or current) level to be applied to one control input terminal of gate **41** as one gate opening voltage and representing a "punch hole" command signal for one hole, thus being in fact a bit of information. Absence of such signal A means "pause" or "no hole."

The second gate opening signal B is drawn from photoelectric receiver **28** (see also FIGURE 5). As was described above this photoelectric receiver **28** produces electric clock pulses at a rate determined by the web speed. In fact, these clock pulses determine (at a given web speed) the distance (and time intervals) between successive punchings.

Whenever both pulses A and B are present, a train of H.F. pulses from generator **40** is permitted to pass through gate **41** and ultimately cause sparkings between the associated pair of electrode edges **4** and **7**.

The pulses B however are more than merely synchronized clock pulses. Returning briefly to FIGURE 5 it will be observed thta the photoelectric receiver **28** is energized as between two levels—bright and dark. "Bright" occurs when light is permitted to pass through a slot of disc **27**. Moreover, "bright" will occur as long as this slot determines the time of light energization of receiver **28** which in turn means that this determines the length of pulse B. It is thus apparent that by properly selecting the slot width of the slots in disc **27** the pulse duration for each pulse B is determined. This holds true of course only for a given speed of disc **27**, but constant speed thereof and constant web speed can readily be assumed during normal operation.

The duration of each pulse B thus determines the number of HF pulses permitted to pass through gate **41** as well as the duration of sparking to produce one punched hole. The number of slots in disc **27** determines the B-pulse frequency. Thus, ultimately the disc **27** and its specific design alone determines the duration and frequency of the punching process. In case it is desired to change the punch hole distance on the web, or to adapt to a different brand of paper for web it is only necessary to exchange disc **27**. This facilitates and simplifies greatly the electric circuitry.

It should be mentioned further that the frequency of the H.F. generator **40** and the frequency of punching are of course different and to some extent unrelated. The only requirement is that each punching step is to be carried out by a large number of individual sparking pulses, here by one hundred. Thus, as a general rule, the frequency of generator **40** and frequency or rate of occurrence of the B pulses should be apart by several orders of magnitude. In this connection it is also assumed that pulses A is of relatively long duration. Appearance of pulses A can be controlled as follows:

In FIG. 6 there is further provided a coincidence type network **44** to which is also applied the command pulse or bit information A. Network **44** in its simplest form is primarily comprised of a logic "and" circuit **45** and a delay element **46** both having one input each connected to a delivery line for pulses A.

The "and" circuit **45** of network **44** has a second input terminal to which is connected photoelectric receiver **15** feeding pulses C to this second input terminal. It will be recalled that photoelectric receiver **15** (see FIG. 3) produces a pulse C whenever a single punching step had been completed successfully. The output of "and" circuit **45** is connected to one side, called the "on"-side, of a flip flop **51** having the output of its on-side serving as an output for network **44**. The pulse drawn from this output is called D.

Network **44**, particularly "and" gate **45** thereof responds to pulses A and C in a twofold manner, but presence of a pulse A is the first prerequisite for network **44** to produce any output at all.

Assuming now, a short pulse C arrives at the said second input terminal of "and" gate **45** indicating that for that bit information pulse A still standing at the first input terminal of gate **45** punching has been completed successfully; an output pulse D is now being produced at the output side of flip flop **51** since upon concurrent occurrence of pulses C and A the output of gate **45** turns flip flop **51** on. This output pulse D is, in fact, a signal indicating that the punching station has properly evaluated the command pulse A. Pulse C is of short duration because pulse C is produced in receiver **15** after a punched out disc has dropped out, and pulse C remains on only until the advancing web interrupts again the light path **18–15** (see FIG. 3). The output of "and" circuit **45** is correspondingly short but sufficient to trigger flip flop **51**. Pulse D remains on after pulse C has disappeared. Thus, pulse D can be used (1) to turn off the particular pulse which was the punching command signal and (2) to call on the next pulse A. There are now two possibilities.

First, there now is another bit representing a new pulse A appearing again at gate **41**, then the next pulse B will

open gate **41** as aforedescribed, and another hole is being punched. The other possibility is that no new pulse A is present which means that upon occurrence of the next pulse B no punching is carried out leaving a particular spot on web **1** unimpaired.

Complete utilization of pulse D thus is as follows: Flip flop **51** has its output side connected to a first control terminal **52***a* of an "and" gate **52**. Thus, this first control terminal **52***a* is activated upon occurrence of a pulse D which particular activation stays on until flip flop **51** is turned off.

"And" gate **52** has a second input terminal **52***b* which is connected to the output "on"-side of another flip flop **53** which is being turned on by the output of a differentiating stage **54** which in turn is fed with the pulses B from receiver **28**. Differentiating stage **54** is coupled to flip flop **53** in such a manner that only the differentiated trailing edge of each pulse B performs the switching action effectively turning on flip flop **53** to activate input terminal **52***b*.

The output of "and" gate **52** is being used to call on station **50** in synchronism with the occurrence of pulses B. Flip flop **53** is being reset by feeding back the output of gate **52** as turning-off pulse for flip flop **53**.

Input terminal **52** remains activated after production and continuation of a pulse D until a bit pulse A is being produced next, which next pulse A turns off flip flop **51**. Preferably, the "off"-side input of flip flop **51** for pulse A and for turning flip flop **51** off is a differentiating one, responding only to appearance of an A bit pulse, but not to disappearance thereof. A next following pulse A can be called upon only after occurrence of a new following pulse D, that is to say, that any particular pulse A having turned off the flip flop **51** must be properly evaluated in the punching station before another pulse A can be called on. Also, the differentiated respective trailing edges of the B pulses provide the necessary synchronism between calling on the next A pulse and the desired rate of punching.

In case a punching step has not been carried out properly, no pulse C will appear and flip flop **51** remains turned off, thus no pulse D is being produced by network **44**. Correspondingly, no new activation occurs at input terminal **52***a* so that in fact no new A bit will and can be called upon from station **50** regardless of further occurrence of B pulses. However, non-occurrence of pulse C results in the production of a pulse E which in effect is a delayed pulse A. As can be seen from the drawing, delay element **46** is also connected to the A pulse delivery line and feeds its delayed output to an "and" gate **47**. Delay line **46** may be constituted by a monostable flip flop which produces output pulse E upon reversing to its stable state after having been placed into the unstable state by a pulse A. The second input for "and" gate **47** is the output of the off-side of the flip flop **51**. Thus, whenever flip flop **51** has been turned on, "and" gate **47** is blocked (pulse D).

The output of "and" gate **47** is the pulse E produced (1) when flip flop **51** is being turned off and (2) when a delayed A pulse has been transmitted through delaying element **46**. "And" gate **47** is a necessary element because element **46** delays every A pulse regardless of evaluation, but pulse E is to be produced only when no C and thus D pulse was being produced so that production of a pulse E is to be made dependent upon non-occurrence of C and/or D.

Pulse E activates a relay **55** turning off the current supply to a coil **22***a* normally energizing clutch or coupling **22** so that clutch **22** is being de-activated upon occurrence of pulse E. Such de-activation in fact stops the transport of web **1**, and now the necessary steps can be taken to remedy the reason why the last hole was not properly punched.

The circuit network as described uses circuit elements of conventional design such as flip flops, bistable multivibrators, gates, "and" circuits, monostable multivibrators, differentiating stage.

Elements of this type are described for example in Ledley-Digital Computer and Control Engineering, McGraw-Hill; Richards Digital Computer, Components and Circuits, Van Nostrand; Henney Radio Engineering Hand Book; U.S. Letters Patent, Hense, 3,048,330 and others.

Considering the above definitions of the various pulses, the following equations in Boolean terminology will facilitate the orientation: The call pulses for A are $=C\cdot 52b$. The cut-off control pulses $E=46\cdot\overline{D}$, with **46** and **52***b* here denoting the output pulses of the correspondingly denoted elements.

The entire arrangement as described thus far operates in a manner best to be described with reference to FIG. 7.

Assuming for the sake of brevity that web **1** is already running, i.e. that by way of a manually operated push button switch it was assured that clutch or coupling **22** is energized and that terminal **52***a* is activated. It is thus simulated that a previous punching was carried out successfully. There are already produced a train of pulses B and generator **40** produces H.F. pulses at desired rate, but gate **41** is still closed.

The next pulse B is transmitted through elements **54**, **53** and **52***b*, **52** as aforedescribed, to call on the first pulse A, called A_1 and to turn flip flop **53** off. Occurrence of this pulse A_1 turns off flip flop **51** so that the input line **52***a* reverts to the nonenergized state. In order to allow sufficient time for this pulse A_1 to appear, the trailing edge of the previous pulse B was used to control this calling, and only the succeeding pulse B undifferentiated is used as a whole to open the gate **41** for the duration of a B pulse. When gate **41** opens, a train of H.F. pulses passes through elements **41–42–43** to produce a series of sparks at the corresponding electrode pair **4–7**. Sparking occurs at a rate as determined by the frequency of generator **40** and for a duration determined by the length of the pulse B.

With the occurrence of pulse A_1 and the resulting turning off of flip flop **51**, the pulse $\overline{D}$ (non-D) as derived from the off-side of flip flop **51** potentially enables gate **47** to function.

The sparking occurs between electrode edges **4** and **7** and first traverses a minute spot in web **1** and then weakens an annular area thereof for "cutting" out a disc in paper **1**; the air pressure difference between the corresponding cavities **3***a* and **6***a* (see FIG. 1) causes the disc to drop into basket **31**. Upon removal of this disc, light is permitted to pass from lamp **18** (see FIG. 3) onto and into the photoelectric receiver **15** producing a pulse C indicating that punching was duly carried out. The occurrence of C pulse activates network **44** to produce coincidence pulse A.

It is presumed that completion of punching of bit pulse A_1 occurs slightly after termination of the H.F. sparking, so that the differentiated trailing edge of pulse B appears slightly before pulses C and D.

Pulse D energizes terminal line **52***a* of gate **52**, also "and" gate **47** is blocked again. Monostable flip flop **46** still produces a delayed A which however remains ineffective.

The trailing edge of that pulse B which caused the punching just completed, turned on flip flop **53** slightly before occurrence of pulse D. Thus, gate terminal **52***b* is already activated when flip flop **51** is turned on and now an output is produced at the output side of gate **52** to call on the next bit pulse which is A_2. Flip flop **53** is reset by this call pulse as derived from the output side of gate **52**. When A_2 appears, flip flop **51** is turned off again and gate **47** is potentially enabled.

In the pulse diagram of FIG. 7 it is assumed that upon occurrence of the next pulse B this pulse A_2 is also being properly evaluated, and in fact the situation is shown in which the punching (cutting of a disc and removal thereof) is completed even prior to the termination of

this particular B pulse. This means, that now C and correspondingly D will appear prior to the differentiated trailing edge of B. There now will only be a short output at flip flop **53**, because D (output of flip flop **51**) appeared first and immediately upon occurrence of the output of flip flop **53**, "and" gate **52** responds, turning off again flip flop **53** and calling on the next pulse A, which may be called A_3. In the meantime a delayed pulse A appeared at the output side of monostable vibrator **46** but this remains ineffective since gate **47** was blocked immediately upon occurrence of C and D.

Assuming that this last mentioned call pulse from flip flop **52** results in no pulse A ($A_3=0$), then the next pulse B (photocell **28**–disc **27**) still prepares gate **41**, but the A input thereof remains de-activated, gate **41** remains open but no punching occurs. There will now be no pulse C since no paper was removed obstructing the light path from lamp **18**. However, since there was no A bit pulse, flip flop **51** still remains in the on-state continuing to produce D. This is indeed correct, because pulses C and D are to indicate that the respectively last punching step has been carried out properly, and this particular result remains true regardless for how long no new A will appear. Thus, the effect of a C must remain as a continuous D until another A to be punched appears. "And" gate **47** remains blocked as long as D stays on and as long as no $\overline{D}$ appears, no E pulse will result even though there is no new C pulse.

Coupling **22** thus remains activated. The pulse B which caused opening of gate **41** without initiating H.F. transmission because there was no A pulse, still has its trailing edge differentiated. This differentiated trailing edge of B causes flip flop **53** to be turned on so that input terminal **52***b* is newly activated. Since **52***a* did remain activated, the output of "and" gate **52** can call on the next pulse A, if any.

Assuming there is a next pulse A_4, both flip flops **51** and **53** will then be reset (closed) as aforedescribed, and the A terminal of gate **41** will be activated, and the "and" gate **47** opened. The next B pulse opens gate **41** and sparking occurs again at edges **4**–**7**.

Assuming now, that for some reason the disc thus cut in the web is not removed, or not properly being cut or the like, no pulse C will occur.

Absence of pulse C has a twofold effect, first, is the resulting absence of a pulse D which in turn means that terminal **52***a* remains de-activated. Since there did appear the pulse A_4 flip flop **51** is turned off so that no output leaves gate **52** and no new A bit pulse is being called on. Since this cutting step was actually initiated, the trailing edge of the B pulse prepares terminal **52***b*, but terminal **52***a* remains unactivated because no C and no D appeared. Thus, pulse $\overline{D}$ stays on at gate **47**. "And" gate **47** is still open because absence of D means presence of $\overline{D}$. Second, since gate **47** is open, a delayed pulse A will pass on through element **46**. A pulse E is produced by the output of flip flop **46** which was activated upon occurrence of A_4. E turns off the drive for the web **1** by de-activating the coupling **22**.

The invention is not limited to the embodiments described above but all changes and modifications thereof not constituting departures from the spirit and scope of the invention are intended to be covered by the following claims:

What is claimed is:

1. An apparatus for perforating coded holes in a tape comprising means for advancing the tape, first electrodes disposed on one side of the tape and second electrodes disposed on the opposite side of the tape for perforating the tape with an electric spark, the improvement comprising said first electrodes having first ring-shaped edges and said second electrodes having second ring-shaped edges of substantially the same diameter of said first ring-shaped edges; said first ring-shaped edges disposed coaxial to said second ring-shaped edges defining a gap whereby a spark which forms at one point between a pair of said edges moves around the peripheries of said edges in a closed path severing a rondelle from the tape by burning away the periphery of the rondelle, in combination with pneumatic means for removing rondelles and waste material from said edges and photoelectric means responsive to optical conditions in said gap actuating said electrodes and said means for advancing whereby the tape is advanced when the rondelle is removed and the advancement of the tape is stopped when the rondelle is not removed.

2. The apparatus of claim **1**, wherein said electrode have hollow passages connecting said edges and said pneumatic means.

3. The apparatus of claim **1**, wherein said edges are metal having high resistance to oxidation under sparking conditions.

4. The apparatus of claim **2**, wherein said pneumatic means comprises a closed conduit for air circulation.

5. The apparatus of claim **4**, wherein said closed conduit includes a blower **30** for maintaining a positive air pressure on one side of the tape and a reduced pressure on the other side.

6. The apparatus of claim **5**, wherein said closed conduit includes an air inlet valve **33** connected to the low pressure side of said blower for replacing air lost from the high pressure side.

7. The apparatus of claim **2**, wherein said photoelectric means comprises a first light source **18** adapted to project a light beam through said hollow passages of a pair of first and second electrodes to a first photoelectric cell **15** whereby an impulse C is produced after each perforation.

8. The apparatus of claim **7**, wherein said means for advancing includes a transport roller **23** mounted on a drive shaft **26** and said photoelectric means further comprises a disc **27** having slots therein mounted on said drive shaft, a second light source **29** disposed on one side of said slotted disc adapted to project a light beam, and a second photoelectric cell **28** disposed on the other side of said slotted disc whereby an impulse B is initiated by said light beam passing through said slots and said electrodes are actuated in synchronism with the forward movement of said tape.

9. The apparatus of claim **8**, wherein said electrodes are cylindrical tubes connected to an impulse transformer **43**, said impulse transformer is connected to an electronic gate **41**, said electronic gate is connected to a high frequency generator **40** and said electronic gate is connected to a source of perforation command pulses A and said second photoelectric cell.

10. The apparatus of claim **9**, wherein said source of perforation command pulses A is connected to a coincidence network **44** and said coincidence network is connected to said first photoelectric cell **15** whereby upon coincidence of said command pulses A and said impulse C said network produces an output pulse D initiating the next perforation command pulse A for the next punching operation, and upon failure of coincidence of said command pulses A and said impulse C, an impulse E is generated and the forward movement of the tape is stopped.

11. The apparatus of claim **1**, wherein said first electrodes **3** are cylindrical tubes seated in a first heat stable electric insulating body **9** having a slot **11** for exposing a portion **12** of said first electrodes.

12. The apparatus of claim **11**, wherein a second heat stable electric insulating body **9***a* abutting said first insulating body supports contact springs **14** in contact with said portion **12** of said first electrodes.

13. The apparatus of claim **12**, further comprising an electrode carrier **13** having a conduit for air therein, said carrier adapted to be connected to and readily detachable from said first and second insulating bodies, said contact springs and said first electrodes.

14. The apparatus of claim **13**, wherein said second electrodes **6** are cylindrical tubes seated in a recessed

metallic body **10** connecting a carrier member **16** adapted to remove rondelles and waste material.

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