Aug. 23, 1966 D. J. ROTH 3,267,780

ELECTROHYDRAULIC IMPULSE SCORING AND/OR WEAKENING OF THIN MATERIALS

Filed March 25, 1965 3 Sheets-Sheet 1

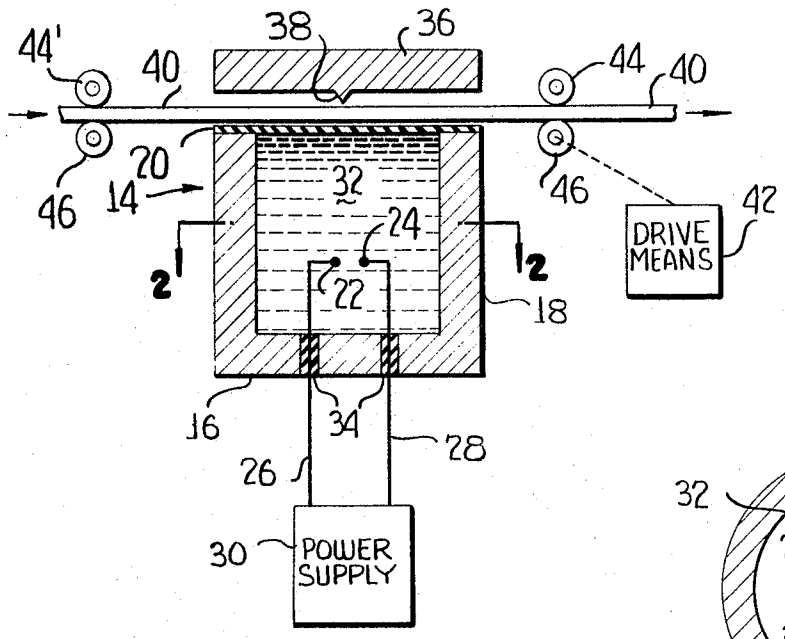


FIG. 1

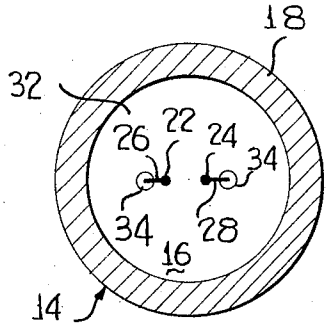


FIG. 2

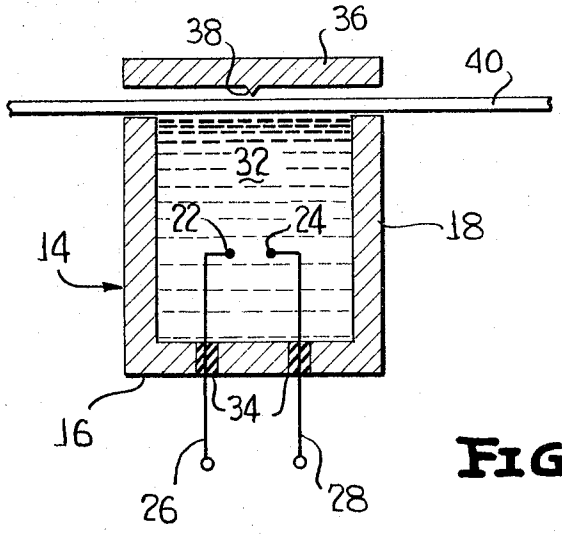


FIG. 3

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FIG. 4

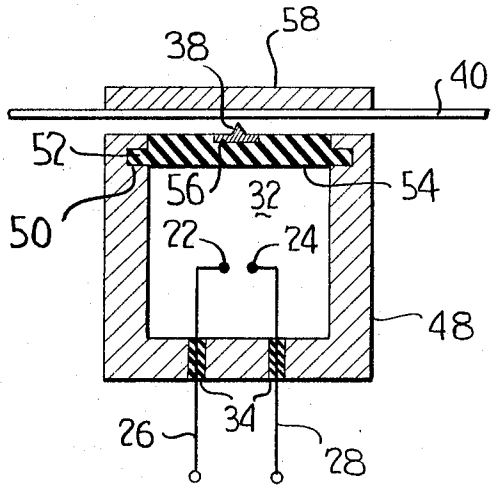
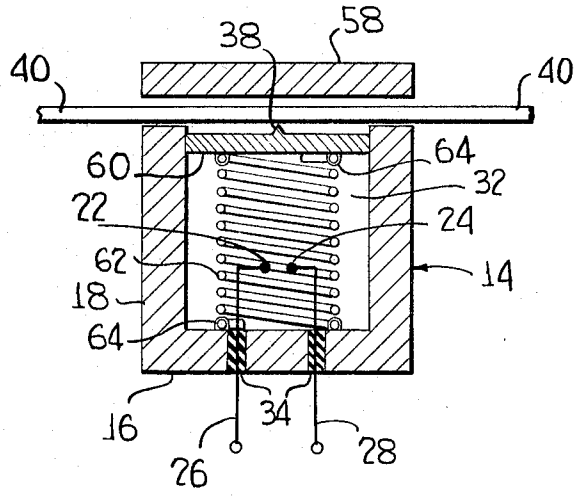


FIG. 5



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FIG. 6

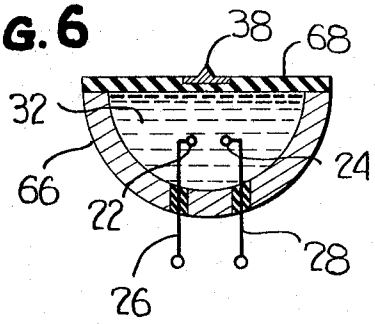


FIG. 7

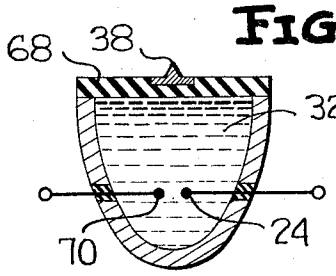


FIG. 8

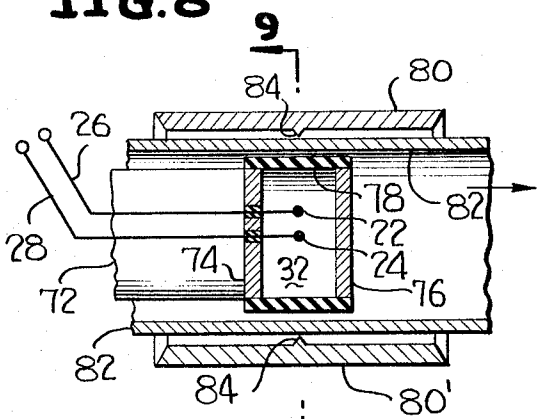


FIG. 9

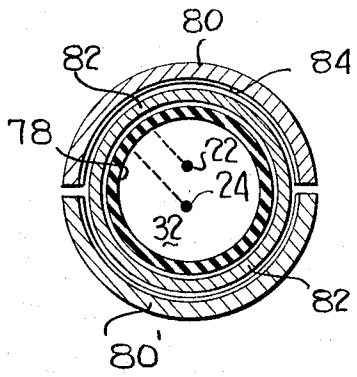
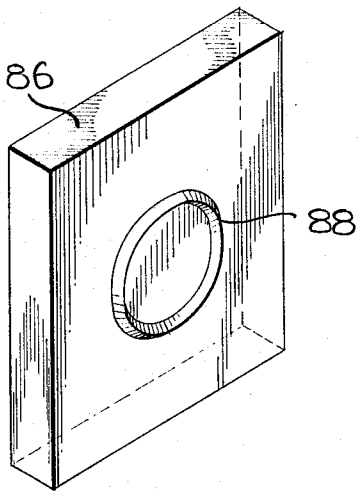


FIG. 10



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3,267,780

ELECTROHYDRAULIC IMPULSE SCORING AND/OR WEAKENING OF THIN MATERIALS

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Filed Mar. 25, 1965, Ser. No. 442,733
37 Claims. (Cl. 83—7)

This invention relates to material working and more specifically to a method and apparatus for scoring and/or weakening of thin materials by the energy created in an electrical discharge.

The process of scoring relates to a material working step wherein the material is severed about a line perpendicular to the length of the material. In other words, the effective thickness of the material is reduced in the area of the score. Scored material and articles have had many uses in the past; however, in recent times, the popularity of the "easy open beverage container" has increased the need for scored lids or tops for the containers many fold. Many beverages must be stored under pressure. The type of materials selected for the container of beverages under these conditions is usually of metal. Prior to the securing of the end of the container, the end may be scored or weakened so that a pressure, either above or below atomspheric pressure, may be maintained within the container and the container still lend itself to "easy opening" by the subsequent removal of the scored strip after attachment of a small tab to the scored strip so that the scored strip may be initially broken and severed from the container end. Since the score has weakened the material in the area of the scored impression, but not to an extent that the container is opened to the atmosphere under usual conditions of pressure, the container is readily opened by the tearing of the metal below the scored line and without the aid of any further opening means.

Although the foregoing discussion relates primarily to the scoring of metal objects, scoring is also practiced wherein the material may be of plastic, paper, etc.

Since the scoring of material results in a weakening of the material in the area of the score line, the terms "score or scoring" and "weakening" will be used synonymously throughout the specification.

It is the usual practice in forming scored sheets or tops, to advance the material to a scoring machine wherein the machine in a reciprocating motion drives a die into the material to be scored and while the die is moving away from the scored article, the scored material or article is removed and another article positioned to receive the impact of the scoring die during the next cycle of operation of the scoring machine. This serial process is time consuming and requires a great deal of attention on the part of the operator to its adjustment. In addition, caution must be exercised to prevent the feeding of two or more objects simultaneously to the machine to be scored. Under these conditions, the thickness of the material would be doubled or more in thickness which would result in damage to the die and/or the machine since the reciprocating movement of the machine would be downward to its maximum displacement, a distance now in excess to satisfactorily score the first object to be scored.

Thus, it is highly desirable that means be found for scoring objects in a highly rapid and efficient manner wherein the means is capable of accommodating objects of multiple thicknesses without damage to the means. Further, it is highly desirable that the means be capable of accurately scoring a continuous strip if such be the requirements.

Accordingly, it is the principal object of the present invention to improve material scoring techniques.

It is a further object of the present invention to improve material scoring techniques by employing the force exerted by an electrical discharge.

It is a further object of the present invention to improve material scoring techniques by providing a method and apparatus for quickly and efficiently scoring materials whose composition may be of metal, plastic, paper, combinations of the foregoing, etc.

It is a further object of the present invention to provide a method and apparatus for efficiently scoring materials having a flat configuration as well as various other geometric configurations.

It is a further object of the present invention to provide a scoring apparatus and method wherein the force exerted by an electrohydraulic discharge within a chamber is directed to cause an abrupt engagement of a scoring knife and the material to be scored.

It is a further object of the present invention to provide an arrangement wherein a flexible membrane is actuated through the force exerted by an electrical discharge within a chamber, which membrane drives the material to be scored into engagement with a scoring knife.

It is a further object of the present invention to provide an arrangement wherein a scoring knife is supported by a flexible membrane which is actuated through the force exerted by an electrical discharge within a chamber to drive the knife into the material, the transverse motion of the material being halted by a backing member.

It is a still further object of the present invention to provide an arrangement wherein a scoring knife is supported by a piston in a chamber and is actuated by the force created by an electrical discharge below the piston to thereby drive the scoring knife into engagement with the material whose transverse motion is halted by a backing member.

In accordance with the principles and objects of the present invention a chamber having an open end is positioned so as to permit the passage of material to be scored over the open end. The chamber may contain a fluid, such as water, and a flexible membrane, such as one of the many elastomers, retains the fluid within the chamber. Positioned within the chamber is a pair of electrodes whose connecting leads are coupled to a power supply, located externally of the chamber. Positioned above the flexible membrane but at a distance to permit passage of the material to be scored, is a backing member which bears the scoring knife or edge. When it is desired to score the material positioned between the flexible membrane of elastomeric material and the backing member bearing the scoring knife, electrical energy is supplied to the spaced electrodes by the power supply. The force which performs the mechanical work of scoring the material is created by the discharging of a high power spark across the spark gap within the chamber. A plasma bubble is formed in the spark gap and continues to grow as continued power flows into the spark gap from the power supply. This displacement of the fluid by the bubble forces the flexible membrane outwardly very rapidly against the work piece or material and causes the work piece to impact against the scoring knife. Since the operation is extremely rapid, it may not be necessary to halt the forward motion of the work piece or material during the scoring operation. Precise amounts of power can be supplied to the spark gap by the power supply and since the amount of material left at the score is the critical parameter which controls the desirable score performance, the strength of the score, the ease of tearing and removing the scored piece, etc. may be effectively controlled.

In further embodiments envisioned in the practice of the invention, the work piece serves to partially enclose the open end of the chamber so that the flexible membrane may not be necessary. It will be intuitively clear

that the loss of certain fluids, such as air and water, by the chamber about its edges where it joins with the work piece is not undesirable. The invention has other ramifications such as a reversal of the position of the score knife so that the score knife is now supported by the flexible membrane. In addition, a piston may be positioned within the chamber which bears the score knife and the piston may be actuated by the electrohydraulic discharge across the gap within the chamber. Also, circular, parabolic, conical, hyperbolic, exponential, etc., chambers are envisioned in the practice of the invention and that chamber would be selected which is most efficient for the operation to be performed. Lastly, the scoring of circular objects and objects of other geometric configurations may be practiced along with the scoring of substantially flat work pieces. The actual score line itself may be straight, circular, oblong, triangular, etc. according to the particular requirements.

The invention both as to its organization and method of operation together with further objects and advantages thereof will best be understood by reference to the following specification taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a sectional elevation view of one embodiment of the invention wherein the electrical discharge across the electrode gap causes a flexible membrane to drive the work piece into engagement with a scoring die;

FIGURE 2 is a cross sectional view taken along the line 2—2 of the FIGURE 1;

FIGURE 3 is similar to the FIGURE 1 except that the flexible membrane covering the opened end of the chamber has been eliminated.

FIGURE 4 is another embodiment of the invention wherein the scoring knife is carried by the flexible membrane over the open end of the chamber so that the scoring knife is driven into a work piece passing below a backing plate having no transverse motion;

FIGURE 5 is another embodiment of the invention wherein the flexible membrane of the FIGURE 4 has been replaced by a piston which bears the scoring knife and when driven outwardly by the electrical discharge causes a score in the work piece; the piston being confined to predetermined positions through the use of a helical spring;

FIGURE 6 is another embodiment of a chamber and illustrating the positioning of the score knife bearing flexible membrane over a chamber of circular cross section;

FIGURE 7 is similar to the FIGURE 6 except that the figure illustrates an exponential chamber;

FIGURE 8 illustrates an embodiment of the apparatus wherein a tube of circular cross-section may be scored;

FIGURE 9 is a cross sectional view taken along the line 9—9 of the FIGURE 8; and,

FIGURE 10 is a perspective view of a circular scoring die which may be employed in the practice of the invention.

With reference to the FIGURE 1 and the FIGURE 2, which is a cross sectional view taken along the line 2—2 of the FIGURE 1, a chamber **14** is of substantially circular cross section and has a bottom wall **16** and a side wall **18**. The upper end of the chamber **14** is discontinuous and enclosed by a flexible membrane **20** of an elastomeric material. Positioned within the chamber and in spatial relationship is a pair of electrodes **22** and **24** whose electrical energy is supplied via a pair of conductors **26** and **28**, respectively, from a power supply **30**. The power supply **30** is of such magnitude as to supply sufficient electrical energy across the gap formed by the electrodes **22** and **24** to drive the flexible membrane **20** abruptly upward and into engagement with a work piece and scoring knife, to be hereinafter described.

A fluid **32** such as air, water, oil or the like is contained within the chamber **14** and serves to transfer the energy produced by the power supply **30** to the electrodes **22** and **24** and to the flexible membrane **20**. The conductors **26** and **28** pass through the bottom wall **16** of the chamber **14** and are electrically insulated therefrom by the insulating material **34**, as shown.

The flexible membrane **20** is positioned over the chamber **14** in any suitable manner such as by an adhesive, screws, or by extending the flexible membrane **20** over the edges of the side wall **18** and securing in position by a circular clamp, not shown.

Immediately above the flexible membrane **20** and coextensive therewith but spaced apart therefrom is a die **36** which bears a score knife **38** on its undersurface. Positioned between the tip of the score knife **38** and the flexible membrane **20**, is a work piece **40** which may be advanced through the work carrier below the score knife **38** by a drive means **42** which is mechanically coupled to a pair of rollers **44** and **46** positioned above and below, respectively, of the work piece **40**. As the rollers **44** and **46** are positioned on the downstream side of the moving work piece **40**, a similar pair of rollers **44'** and **46'** are positioned on the upstream side of the work piece **40**. The rollers **44'** and **46'** may be driven by the work piece **40** or may be driven by any other means, as desired.

When it is desired to score the work piece **40**, the power supply **30** is actuated so that a large amount of energy is delivered to the electrodes **22** and **24**. The resulting arc created between the electrodes **22** and **24** form a plasma bubble within the fluid **32** through vaporization of the fluid which quickly grows in magnitude sufficient to drive the flexible membrane **20** upwardly, as shown in the FIGURE 1. As the flexible membrane **20** moves upwardly, it carries with it the work piece **40** and thereby forces the work piece **40** into engagement with the score knife **38** supported on the die **36**. The penetration of the score knife **38** into the upper surface of the work piece **40** results and the degree of penetration may be regulated by the length of the score knife **38** (the distance of its protrusion from the die **36**) or by the amount of electrical energy supplied to the electrodes **22** and **24** by the power supply **30**. Since the action of the flexible membrane **20** is produced in a time range of milliseconds, it is not necessary to halt the forward motion of the work piece **40** as long as the forward motion of the work piece is not excessive. In the event that it is desired that the work piece **40** be halted, the drive means **42** will so accommodate.

In the embodiment shown in the FIGURE 3, the flexible membrane **20** has been removed and the work piece **40** serves to enclose the chamber **14**. In the chamber **14** of the FIGURE 3, the fluid **32** may be of air or water since a certain amount of loss of the fluid would occur at the junction between the side wall **18** and the work piece **40**; however, due to the availability of these two fluids, their loss would not be an economic loss to avoid but would be compensated for due to the simpler construction of the chamber as compared to the chamber of the FIGURE 1.

The apparatus of the FIGURE 3 operates in the manner similar to the FIGURE 1 and similar rollers **44** and **46**, not shown in the FIGURE 3, may be employed to transport and position the work piece **40** through the work area which is under the score knife **38**. When it is desired to score the work piece **40**, sufficient electrical energy would be supplied by a power supply, similar to the power supply **30** of the FIGURE 1, to the conductors **26** and **28** so that the resulting arc between the electrodes **22** and **24** would be sufficient due to bubble displacement of the fluid, to drive the work piece **40** upwardly and into engagement with the score knife **38**. Any loss in fluid **32** from the chamber **14**, could be replaced by any suitable means, such as the provision of a valve, not shown, in the side wall **18** or by the return of the fluid about the junction formed between the work piece **40** and the side wall **18**.

With reference to the FIGURE 4, a chamber similar to the chamber of the FIGURE 1, with certain exceptions, is identified as **48**. The chamber **48** is substantially U-shaped in sectional elevation view and substantially circular in plan view. Formed about the inside and near the open end of the chamber **48** is a peripheral notch **50** which is adapted to receive a projecting ear **52** of a flexible membrane **54**. By the cooperation of the peripheral notch **50** and the projecting ear **52** of the flexible membrane **54**, the flexible membrane **54** is restrained within the position as shown, i.e., enclosing the upper portion of the chamber. Affixed to and flush with the upper surface of the flexible membrane **54** is a metal element **56** which bears the score knife **38**. The score knife **38** borne by the metal element **56** may be secured to the flexible membrane **54** in any suitable manner and most expeditiously, in a manner to permit its quick removal in order to facilitate the replacement of the score knife **38** in the event of breakage or dullness to the knife.

Positioned above and coextensive with the chamber **48** is a backing member **58** which is solidly positioned so as to permit the score knife **38** to enter the work piece **40** and thereby perform a scoring operation upon the occurrence of an electrical discharge across the electrodes **22** and **24**.

Another embodiment of the invention is shown in the FIGURE 5. In this embodiment, the flexible membrane of the FIGURES 1 and 4 has been replaced by a piston **60**. The piston **60** bears upon its upper surface the score knife **38** and the piston **60** is loosely retrained within the side wall **18** by a coil spring **62** which may be secured to the upper surface of the bottom wall **16** and the lower surface of the piston **60** in any suitable manner such as by the small U clamps **64**.

In a manner similar to the FIGURE 4, a backing member **58** is rigidly positioned above the chamber **14** but in spatial relationship so as to define a work area between the lower surface of the backing member **58** and the upper surface of the piston **60**. Actuation of the piston **60** to drive the score knife **38** into the work piece **40** which, in turn, abuts the backing member **58**, is accomplished by the application of sufficient electrical energy across the electrodes **22** and **24** to result in a rapid bubble displacement of the fluid **32** to thereby produce the desired actuation of the piston **60**. The coil spring **62**, which may be of other configurations, such as helical, returns the piston **60** to its position as shown in the FIGURE 5, after the scoring operation has been completed.

The FIGURES 6 and 7 illustrate other shapes of chambers which may be employed in the practice of the invention. For example, a circular chamber **66** is fitted with a flexible membrane **68** which encloses the chamber and supports on its upper surface the score knife **38**. Within the chamber **66** is the pair of electrodes **22** and **24**, similar to the earlier figures.

In the FIGURE 7, a parabolic chamber **70** supports over its open end the flexible membrane **68** bearing the score knife **38** and the electrodes **22** and **24** form a spark gap by which energy may be transferred from the electrodes **22** and **24** through the fluid **32** and to the flexible membrane **68** and score knife **38**. In many applications, the parabolic chamber **70** of the FIGURE 7 will be found to be more efficient than any other geometric configuration of chamber.

The FIGURES 8 and 9 illustrate the form of the apparatus for scoring work pieces of a circular nature. A horn **72** supports a pair of spaced, circular, parallel plates **74** and **76**. The plate **74** is secured to the horn **72** and the plate **76** is secured to the plate **74** by a circular flexible membrane **78** which surrounds the plates **74** and **76** and effectively forms a chamber within. The electrodes **22** and **24** are positioned within the chamber formed between the elements **74**, **76** and **78** and are supplied high voltage via the conductors **26** and **28**. A circular die **80** is spaced away from but surrounds the horn **72** and the flexible membrane **78** and at a distance to permit the passage of a work piece **82** therebetween. As shown in the FIGURE 9, the circular die comprises an upper section **80** and a lower mating section **80'**. Any suitable means, not shown, may be employed to advance the sections of the circular die **80** into engagement at the appropriate time so that the scoring operation may be accomplished.

As shown in the FIGURES 8 and 9, the circular dies **80** and **80'** bear a circular score knife **84** upon their inner circumference. When it is desired to score the tubular work piece **82** of the FIGURES 8 and 9, simultaneously, sufficient electrical energy is supplied via the conductors **26** and **28** to the electrodes **22** and **24** to produce an abrupt force which causes the flexible membrane **78** to be driven outwardly while the circular dies **80** and **80'** are driven inwardly and into mating engagement. In this manner, the work piece **82** is effectively scored but not deformed as would be the case if the flexible membrane **78** were not actuated to assist in driving the score knife **84** into the periphery of the tubular work piece **82**.

The invention may also be practiced wherein circular, oblong, triangular, etc. scores are produced as well as the substantially straight line scores illustrated throughout the figures. With reference to the FIGURE 10, a die **86** supports a circular score knife **88**. It will be readily understood that the score knife **88** could be of any desired geometrical configuration. Further, if the score knife **88** borne by the die **86** of the FIGURE 10, is to be employed in the practice of the invention, then it would be supported above, for example, the apparatus of the FIGURE 1 and would replace the die **36** in that figure. Actuation of the power supply **30** would result in a circular score upon the upper surface of the work piece **40**.

Thus, there has been shown and described an apparatus and method for efficiently and rapidly scoring a work piece. Since the amount of material remaining at the score is the critical parameter which controls the desired score performance, the apparatus as set forth produces a product having the desired strength, ease of displacing the scored portion, etc. It is noted that the use of the electrohydraulic impulse permits the work piece to be scored which is of practically any geometric shape as long as the score knife and the electrohydraulic chamber fit the desired shape. The invention is applicable to scoring metals having any electrical conductivity, as well as polymers, paper, etc. In a preferred embodiment of the invention, a fluid chamber is provided which is enclosed by a flexible membrane of elastomeric material. The fluid chamber may be filled with any suitable fluid such as air, water, or oil. The force which performs the mechanical work of scoring is created by discharging a high power spark across the spark gap positioned within the chamber. A plasma bubble is formed in the spark gap and continues to grow as continued power flows into the spark gap. This displacement of the fluid by the bubble forces the elastomeric material out very rapidly against the work piece causing the work piece to impact against the score knife. A number of ramifications are envisioned wherein the elastomeric material is eliminated, the positions of the die and the elastomeric material are reversed, wherein a piston is substituted for the flexible membrane or elastomeric material, and where various chambers of differing geometric configuration may be employed to produce substantially straight in-line scores, circular scores, triangular scores, etc. In addition, a thin ignitor wire could replace the spark gap. The ignitor wire would be replaced automatically after each electric discharge and would provide a means for allowing a shaped pressure wave which could fit the shape of the score knife, the chamber, etc. As an alternative, a mercury jet could be employed as the electrodes.

Thus, the present invention may be embodied in other specific forms without departing from the spirit and the essential characteristics of the invention. The present embodiment is, therefore, to be considered in all respects as illustrative and the scope of the invention being indicated by the appended claims rather than the foregoing description, and all changes which come within the meaning and the range of the equivalency of the claims are, therefore, intended to be embraced therein.

What is claimed is:

1. Material scoring apparatus comprising a fluid filled chamber having an open end, a scoring die positioned over said chamber and coextensive with the open end, said die being in spatial relationship to said chamber and defining a work area therebetween, and means for displacing the fluid in said chamber to exert a force on said scoring die.

2. Scoring apparatus comprising means for scoring material and having a material passageway therethrough said means including a scoring knife projecting partially into the material passageway, and electrical means positioned within said means for scoring for causing a flow of pressure in the direction of said scoring knife to thereby cause an engagement of material in the material passageway with said scoring knife.

3. Scoring apparatus comprising means for scoring material and having a material passageway therethrough, said means including a scoring knife projecting partially into the material passageway, a power supply, and a pair of electrodes positioned within said means and coupled to said power supply for causing, upon the occurrence of a discharge between said electrodes, a flow of pressure in the direction of said scoring knife to thereby cause an engagement of material in the passageway with said scoring knife.

4. Material scoring apparatus comprising a fluid filled chamber having an open end, a scoring die positioned over said chamber and coextensive with the open end, said die being in spatial relationship to said chamber and defining a work area therebetween, a power supply, and a pair of electrodes positioned within said fluid-filled chamber and coupled to said power supply for causing, upon the occurrence of a discharge therebetween, the fluid in said chamber to exert a force on said scoring die.

5. Material scoring apparatus comprising a fluid-filled chamber having an open end, a flexible membrane positioned over said chamber and enclosing the open end, a scoring die positioned over said chamber and coextensive with said flexible membrane, said die being in spatial relationship to said flexible membrane and defining a work area therebetween, and means for displacing the fluid in said chamber to thereby direct said flexible membrane into the work area and toward said scoring die.

6. The combination as defined in claim 5 wherein said chamber is cylindrical.

7. The combination as defined in claim 5 wherein said chamber is hemispherical.

8. The combination as defined in claim 5 wherein said chamber is hemi-ellipsoidal.

9. Material scoring apparatus comprising a fluid-filled chamber having an open end, a flexible membrane positioned over said chamber and enclosing the open end, a scoring die positioned over said chamber and coextensive with said flexible membrane, said die being in spatial relationship to said flexible membrane and defining a work area therebetween, a power supply, and a pair of electrodes positioned within said fluid-filled chamber and capable, when actuated, to cause a displacement of the fluid in said chamber to thereby force said flexible membrane into the work area and toward said scoring die.

10. Material scoring apparatus comprising a fluid-filled chamber having an open end, a flexible membrane positioned over said chamber and enclosing the open end, a scoring die positioned over said chamber and coextensive with said flexible membrane, said die being in spatial relationship to said flexible membrane and defining a work area therebetween, means for advancing material through the work area, a power supply, and a pair of electrodes positioned within said fluid-filled chamber and coupled to said power supply for causing, when actuated, an increase in the fluid pressure in said chamber to thereby expand said flexible membrane and to force the material being advanced by said means for advancing material into engagement with said scoring die.

11. Material scoring apparatus comprising a fluid-filled chamber having an open end, a scoring die positioned over said chamber and coextensive with the open end, said die being in spatial relationship to said chamber and defining a work area therebetween, means for advancing material along the work area between said die and said chamber, and means to abruptly cause a displacement of the fluid in said chamber to thereby direct the fluid to force the material being advanced by said means for advancing material through the work area against said scoring die.

12. Material scoring apparatus comprising a fluid-filled chamber having an open end, a flexible membrane positioned over said chamber and enclosing the open end, a scoring die positioned over said chamber and coextensive with said flexible membrane, said die being in spatial relationship to said flexible membrane and defining a work area therebetween, means for advancing material through the work area, and electrical means for increasing the fluid pressure in said chamber to thereby cause said flexible membrane to drive the material in the work area into engagement with said scoring die.

13. Scoring apparatus comprising means for scoring material and having a material passageway therethrough, said means including a scoring knife projecting partially into the material passageway and an actuable membrane positioned on said means and cooperating with said scoring knife for defining the material passageway, and electrical means positioned within said means for scoring for causing a flow of pressure in the direction of said scoring knife to actuate said membrane and thereby cause an engagement of material in the material passageway with said scoring knife.

14. Scoring apparatus comprising means for scoring material and having a material passageway therethrough, said means including a scoring knife projecting partially into the material passageway and an actuable flexible membrane positioned adjacent said scoring knife, means for advancing material through the material passageway formed by said scoring knife and said flexible membrane, a power supply, and electrical means coupled to said power supply and positioned within said means for scoring for causing a flow of pressure in the direction of said scoring knife to thereby cause an engagement of material in the material passageway with said scoring knife through the force created by the flow of pressure against said actuable flexible membrane.

15. The combination as defined in claim 14 wherein said means for scoring material is a chamber over which said actuable flexible membrane is positioned and said electrical means is a pair of electrodes in spatial relationship within said chamber.

16. Material scoring apparatus comprising a fluid-filled chamber having an open end, a flexible membrane secured to and positioned within the open end of said chamber, a scoring knife supported by said flexible membrane, a backing member positioned adjacent and in spatial relationship and coextensive with said flexible membrane and defining a material passageway therebetween, and means to abruptly displace the fluid in said chamber to thereby cause actuation of said flexible membrane and said scoring knife into the material passageway adjacent said backing member.

17. Material scoring apparatus comprising a fluid-filled chamber having an open end, a flexible membrane secured to and positioned within the open end of said chamber, a scoring knife supported by said flexible membrane,

a backing member positioned above and in spatial relationship and coextensive with said flexible membrane and defining a material passageway therebetween, a power supply, and a pair of electrodes coupled to said power supply and positioned within said chamber for causing, when power is supplied thereto, a displacement of the fluid in said fluid-filled chamber to thereby drive said scoring knife into the material passageway and toward said backing member.

18. Material scoring apparatus comprising a fluid-filled chamber having an open end, a flexible membrane secured to and positioned within the open end of said chamber, a scoring knife supported by said flexible membrane, a backing member positioned above and in spatial relationship and coextensive with said flexible membrane and defining a material passageway therebetween, means for advancing material through the material passageway, a power supply, and a pair of electrodes coupled to said power supply and positioned within said chamber and capable of, when actuated, causing a displacement of the fluid to drive said flexible membrane and said scoring knife supported thereon against the material being advanced by said means to advance material, said material having any transverse motion halted by said backing member.

19. Material scoring apparatus comprising a fluid-filled cylinder having an open end, a piston positioned within said cylinder, a scoring knife carried by said piston, a backing member in spatial relationship to and coextensive with said piston and defining a material passageway therebetween, and means within said cylinder for advancing said piston toward said backing member so that said scoring knife extends into the material passageway.

20. Material scoring apparatus comprising a fluid-filled cylinder having an open end, a piston positioned within said cylinder, a scoring knife carried by said piston, a backing member in spatial relationship to and coextensive with said piston and defining a material passageway therebetween, a power supply, and a pair of electrodes coupled to said power supply and positioned within said cylinder for increasing the fluid pressure to thereby drive said piston supported scoring knife into the material passageway between said piston and said backing member.

21. The combination as defined in claim 20 including means for advancing material through the material passageway and upon actuation of said piston, said scoring knife engaging the material and driving the material against said backing chamber.

22. The combination as defined in claim 20 including means for limiting the reciprocatory motion of said piston.

23. Scoring apparatus for scoring tubular material comprising a horn, a fluid-filled chamber supported by said horn, said chamber formed of a pair of parallel circular plates joined by a circular flexible membrane, a circular scoring die positioned about and in spatial relationship to said chamber, the area between said scoring die and said flexible membrane forming a tube passageway, a scoring knife positioned upon the inside circumference of said circular scoring die and in the area about said flexible membrane, and means positioned within said chamber for causing an increase of the fluid pressure in said chamber and a resultant outward movement of said flexible membrane to thereby drive a tube into engagement with said scoring knife supported by said scoring die.

24. The combination as defined in claim 23 wherein said means positioned within said chamber includes a pair of electrodes in spatial relationship, and a power supply coupled to said electrodes.

25. A process for scoring material comprising the steps of positioning a flexible membrane over a fluid-filled chamber, supporting a scoring die above the flexible membrane, and increasing the fluid pressure in the chamber to thereby force the flexible membrane toward the scoring die.

26. The method as defined in claim 25 wherein the step of increasing the fluid pressure is by supplying energy to a pair of electrodes within the chamber.

27. A process for scoring material comprising the steps of positioning a flexible membrane over a fluid-filled chamber, supporting a scoring die above the flexible membrane, advancing material to be scored between the flexible membrane and the scoring die, and displacing the fluid in the chamber to thereby force the material to be scored into engagement with the scoring die by the actuation of the flexible membrane.

28. A process for scoring material comprising the steps of positioning a flexible membrane over a fluid-filled chamber, supporting a scoring die above the flexible membrane, advancing material to be scored between the flexible membrane and the scoring die, and heating the fluid in the chamber by an electrical discharge to thereby force the material to be scored into engagement with the scoring die through actuation of the flexible membrane.

29. A process for scoring material comprising the steps of positioning a fluid-filled chamber having an open end, supporting a scoring die above the open end of the chamber, passing material to be scored over the open end of the chamber and below the scoring die, and displacing the fluid in the chamber to increase the pressure and thereby force the material to be scored into engagement with the scoring die.

30. The method as defined in claim 29 wherein the step of displacing the fluid in the chamber is by supplying energy to a pair of electrodes within the chamber.

31. A process for scoring material comprising the steps of positioning a flexible membrane over a fluid-filled chamber, supporting a scoring die upon the flexible membrane, positioning a stationary backing member adjacent the scoring die, advancing material to be scored between the scoring die and the backing member, and causing an abrupt displacement of the fluid in the chamber to thereby displace the flexible membrane and drive the scoring die into the material to be scored, the transverse motion of the material being inhibited by the backing member.

32. The method as defined in claim 31 wherein the step of causing a displacement of the fluid in the chamber is by supplying energy to a pair of electrodes within the chamber.

33. A process for scoring material comprising the steps of supporting a fluid-filled chamber, positioning a scoring die piston within the chamber, positioning a backing member above the piston, advancing material to be scored between the piston and the backing member, and increasing the fluid pressure in the chamber to thereby force the scoring die into the material to be scored and against the backing member.

34. The method as defined in claim 33 wherein the step of increasing the fluid pressure in the chamber to actuate the piston is by supplying energy to a pair of electrodes within the chamber.

35. The method as defined in claim 33 including the step of restraining the travel of the piston to a predetermined path.

36. The method as defined in claim 34 wherein the step of increasing the fluid pressure is by heating which is supplied through a pair of electrodes within the chamber.

37. A process for scoring tubular material comprising the steps of positioning a flexible membrane about a fluid-filled cavity, supporting a scoring die circumferentially about the flexible membrane, advancing tubular material over the flexible membrane and within the scoring die, and abruptly increasing the fluid pressure in the chamber to thereby engage the flexible membrane with the tubular material to force the tubular material into engagement with the scoring die.

No references cited.

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