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(54) Paper containing fine weakened tear line and method for manufacture of the paper.

(57) A novel paper containing a fine weakened tear line and a method for the manufacture of the paper are disclosed. The fine weakened tear line for facilitating the tearing of the paper along this tear line is formed by causing a paper-weakening liquid which comprises a cellulose-degrading agent and water to be applied in a fine line to the paper surface and allowing the liquid to penetrate the paper in the direction of the thickness of paper thereby causing the liquid to degrade chemically the portion of cellulose of paper underlying the area of the fine line of liquid applied to the paper surface. Effective application of the liquid to the paper and consequent penetration of the liquid through the paper are accomplished advantageously under the pressure applied to the paper by use of a line-printing plate or a paper-incising pen.

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Paper containing fine weakened tear line and method for manufacture of the paper

This invention relates to a paper containing a fine weakened tear line and to a method for the manufacture of the paper.

Among the various conventional papers containing tear lines are counted business forms, tickets such as sheets containing a row of serially printed tickets, postage stamps, and paper containers. In these conventional papers, tear lines of so-called "perforations" are formed by punching or incising linear series of holes by some mechanical method or other through the papers along the lines intended for tearing.

To cite concrete methods available for this purpose, there are the line method which forms perforations on each sheet of printed paper by placing the sheet on a horizontal base having a thin, flexible iron sheet spread on a hard iron plate and then causing a wooden frame containing a so-called perforating comb blade, i.e. an intermittent row of sharp cutting edges arranged in one straight line, to be reciprocated in a vertical direction relative to the horizontal base and therefore allowed to collide with the sheet perpendicularly, the perforation method which forms perforations parallelly on successive sheets of paper by passing the sheets between the concurrently moving surfaces of two

vertically opposed rotary cylinders, one male cylinder containing circumferentially spaced rows of perforating blades and the other female cylinder containing matched rows of blade sockets, and the cross-perforation method which inserts continuous perforations at fixed intervals simultaneously in the lateral and longitudinal directions as in postage stamps by passing each sheet of printed paper between the concurrently moving surfaces of two closely opposed rotary cylinders, and removing the debris of paper resulting from the perforation by a suction device.

All these mechanical methods share a common disadvantage that the operational efficiency is low.

The first reason for the poor operational efficiency is that all the methods form the perforations by use of blades so that, because the filler on the surface of paper contains a material harmful to the cutting edges of such blades, the cutting edges are rapidly worn and, therefore, must be ground or wholly replaced with new supplies at frequent intervals.

The second reason is that since papers are thin, the work of forming straight tear lines having their cut edges completely restrained between the opposite surfaces of papers is too complicated to be practicable by any standard. Thus, the only recourse to be left is forming such tear lines with perforations having perfectly punched holes and complete uncut portions alternately arranged in desired lines. If no precaution is taken in tearing a paper containing such a tear line of perforations, the front of tear while being advanced from one perforation to the immediately adjoining uncut portion tends to run at random. To guide the front of tear correctly along the tear line, it becomes necessary to impart a crease along the tear line by folding the paper, to place

a rule exactly along the tear line of the paper and permit the free side of the paper to be ripped against the edge of the rule, or to cause the front of tear to advance slowly.

The third reason is that the decisive slowness of the perforating work compared with the printing work bottlenecks the whole operation, that the setting of the comb-tooth blade in the perforating device requires fairly advanced skill, and that the quality of perforating work is continuously degraded from the time a new blade is put to use and the time the blade wears out and verges on replacement and this gradual degradation of work quality results in dispersion of the quality of produced perforations.

Heretofore, separation of necessary portions from printed matter, pattern papers, colored papers, etc. has been accomplished manually by use of scissors, knives, and special knives designed exclusively for incising individual sheets of paper.

When a person finds it necessary to take a clipping from a newspaper or a magazine, he does not always happen to have such a cutting tool at hand. Knives designed exclusively for making newspaper clippings are available. They are useless unless a suitable cutting cushion is available for holding newspapers fast in position. Besides, they have no portability.

In the case of such a printed article as a newspapers and magazine which by nature is to be read by a plurality of persons, when one person finds it desirable to clip a portion of the printed article, he is not permitted to do so until all the other persons have read through the printed article. The best he can do is to mark the portion as an aid for

memory. If he is not lucky, the mark may fail to draw his attention as expected.

Blades have directionality. Since the blade cuts the paper in the direction of its cutting edge, it cannot easily cut the paper along a sharply curved line. When the portion to be clipped off has a complicated outline, the blade must be handled with all possible attentions.

This invention relates to a paper containing an entirely novel fine weakened tear line and to a method for the manufacture of the paper.

The paper containing the tear line contemplated by this invention is useful for business forms, tickets, postage stamps, and paper containers which are required to possess tear lines. The fine weakened tear line of this invention takes the place of the conventional perforations formed by the mechanical method using a suitable cutting blade. The fine weakened tear line contained in the paper of this invention is formed by chemically weakening the portion of fibers of the paper falling in the fine line with a liquid containing a cellulose-degrading agent such as sulfuric acid. The paper, therefore, can be readily torn along the fine tear line with slight force.

This invention is aimed at providing a paper containing a fine weakened tear line formed by chemically degrading the portion of cellulose of the paper falling in the fine line by use of a paper-weakening liquid formulated with a cellulose-degrading agent and water so as to seep through the paper in the direction of its thickness. The paper-weakening liquid is desired to contain sulfuric acid as a cellulose-degrading agent in a concentration of 0.1 to 30 weight percent.

The method for the manufacture of this paper comprises causing the paper-weakening liquid to be supplied in the form of a fine line from a liquid supply means onto the paper, thereby allowing the fine line of the liquid to seep through the paper in the direction of its thickness, and consequently chemically weakening the portion of cellulose of the paper in the fine line.

The first embodiment of this method utilizes a line-printing plate which has an elongated liquid feed edge of a hard material thrust out in a straight line from the plate and effects the manufacture of the paper by simultaneously pressing the liquid feed edge of the line-printing plate against the paper along the line and transferring the liquid in a straight line from the liquid feed edge to the paper surface. The second embodiment makes use of a paper-incising pen which has a writing point communicate with the paper-weakening liquid formed of a cellulose-degradation agent and water and contained within a penholder through the medium of an exudation path formed of bubbles, capillaries, grooves, fiber bundles or non-woven fabric and bordering on the liquid and effects the manufacture of the paper by sliding the paper-incising pen on the paper along the line and causing the paper-weakening liquid to be transferred onto the paper surface and penetrated into the paper along the line.

In the paper containing the fine weakened tear line obtained by the aforementioned method using either the line-printing plate or the paper-incising pen, the portion of the paper which falls in the fine line has a weakened fiber structure. By exertion of weak force, therefore, the paper can be torn freely along the line formed by means of the line-printing plate or the paper-incising pen.

FIG. 1 is a graph for illustrating the ease with which the paper is torn.

FIG. 2 and FIG. 3 are cross sections of a paper containing a weakened tear line.

FIG. 4 is an enlarged photograph of a paper containing a fine weakened tear line according to this invention.

FIG. 5 is an enlarged photograph of the cross section of the paper of FIG. 4.

FIG. 6 is an enlarged photograph of a paper containing perforations formed by the conventional mechanical method.

FIG. 7 and FIG. 8 are enlarged photographs of the cross sections of the paper of FIG. 6.

FIG. 9 and FIG. 10 are explanatory diagrams illustrating the torn conditions of papers containing a fine weakened tear line according to the present invention.

FIG. 11 and FIG. 12 are explanatory diagrams illustrating the torn conditions of papers containing perforations formed by the conventional mechanical method.

FIG. 13 and FIG. 14 are cross sections of the line-printing plate.

FIG. 15 is a model diagram illustrating one process for the formation of the fine weakened tear line according to the present invention.

FIG. 16 is an enlarged model diagram taken along the dotted

line indicated in FIG. 15.

FIG. 17 is a model diagram illustrating the other process for the formation of the fine weakened tear line according to the present invention.

FIG. 18 is a longitudinal cross section of a typical paper-incising pen according to the present invention.

FIG. 19 is a partially cut-away longitudinal cross section of another typical paper-incising pen according to the present invention.

FIG. 20 is a longitudinal cross section of yet another typical paper-incising pen of this invention.

This invention relates to a paper containing a fine weakened tear line obtained by causing a paper-weakening liquid formed of a cellulose-degrading agent and water to seep through the paper in the direction of its thickness along the line thereby chemically degrading the portion of cellulose of paper along the fine line, whereby the paper will be easily torn along the fine line and to a method for the manufacture of the paper.

Papers containing fine weakened tear lines which are produced by this invention are useful as business forms, tickets, postage stamps, and paper containers which are required to possess tear lines.

Unlike the conventional papers containing perforations formed by some mechanical method using a suitable cutting blade, the papers of this invention contain fine weakened tear lines obtained by chemically degrading the portions of fibers falling in the fine lines with the liquid containing a

cellulose-degrading agent such as sulfuric acid. When necessary, therefore, these papers can be easily torn along the fine line with weak force.

The expression "fine weakened tear line" as used in the present invention shall mean the fine line formed in a given paper by causing the paper-weakening liquid to seep through the paper along the fine line in the direction of its thickness thereby chemically degrading the portion of cellulose of paper falling in the fine line, whereby the paper will be easily torn along the fine line with weak force.

Generally, paper is a sheet of entangled fibers with a sizing agent and other fillers deposited to fill out interstices between the fibers. The strength of a given paper mainly depends on the strength of fibers, the length of fibers, and the condition of entanglement of fibers. For the paper to be torn neatly along a fine line, the strength of the portion of paper falling in the fine line must be weaker than that of all the other portions of paper. The weakening of the paper along the fine line has heretofore been accomplished by piercing a row of holes (perforations) through the paper along the line by some mechanical method. In contrast, this invention forms a tear line in the paper for facilitating the tearing of paper by chemically degrading the portion of cellulose of paper falling in the fine line with a cellulose-degrading agent.

Generally, when paper is wetted with water or some other liquid, the texture of paper swells and the fibers are released from their entanglement. Thus, in its wet state, the paper is torn with feeble strength. When the wet paper dries, it regains its strength. In connection with this particular property of paper, the time-course change of

strength of the paper treated with a varying cellulose-degrading chemical agent and water will be described with reference to FIG. 1. FIG. 1 is an explanatory diagram illustrating the time-course change of the ease with which the treated paper is torn. The curve A represents the effect of the physical force exerted on the paper by the writing point such as of a pen or the edge such as of a printing plate, the curve B the effect of water caused to seep through the paper, and the curve C the effect of a cellulose-degrading agent similarly caused to seep through the paper.

Now, the ease with which the paper is torn along the fine line weakened with a liquid containing a cellulose-degrading agent and water will be described in detail below. The change of the ease with which the paper wetted with water is torn is represented by the curve B. Immediately after incision of a line, the paper in water is quickly swelled and weakened enough to be easily torn. With elapse of time, the wet paper dries with loss of its moisture content and retains its original strength. After the paper has dried up, the effect of the curve A brought about by the physical force of the pressure of the writing point or the printing plate will remain. The ease with which the paper weakened with the cellulose-degrading agent is torn is represented by the curve C. Although no effect of this agent is discernible immediately after the application of the agent by the writing point, the chemical degradation of cellulose of paper proceeds and the weakening of the paper texture advances with elapse of time. Thus, the ease with which the paper treated with the agent is torn increases with elapse of time, indicating that the effect of the cellulose-degrading agent is manifested slowly.

When a line is inscribed in the paper with a liquid containing

a cellulose-degrading agent and water, the easiness of tearing by the combined effect of the water and the notch (A + B) appears at the point S immediately after the incision, the easiness of tearing by the combined effect of the water, the cellulose-degrading agent, and the notch (A + B + C) appears at the point M after elapse of time, and the easiness of tearing by the cellulose-degrading agent and the notch (C + A) appears at the point L after loss of the moisture. Thus, the tear line formed as described above retains practically constant easiness of tearing along the course of time because the paper-weakening effect is the result of the combination of the quick effect of the water and the slow effect of the cellulose-degrading agent. Particularly, the excellence in its slow manifestation of the effect constitutes one of the salient characteristics of the present invention.

The phenomenon that the texture of paper is generally weakened by water and by chemical substances is widely known to the art. The present invention originated in the effort directed to harnessing this well-known phenomenon for industrial applications, with paper selected as the subject matter of utility. The present invention, therefore, is characterized by providing a paper containing a fine weakened tear line formed as novel means of tearing by chemically degrading the portion of texture of paper falling in the fine line.

Various reactions are available for degrading or embrittling fibers in paper. Examples are hydrolysis, oxidation, esterification, mercerization, etherification, dissolution, irradiation with ultraviolet light, biochemical reaction by use of cellulase and other similar enzymes which are effected on the cellulose of the paper. In the present invention, substances which cause these reactions shall be referred to

collectively as "cellulose-degrading agents."

Concrete examples of cellulose-degrading agents include hydrogen peroxide, potassium permanganate, potassium dichromate, nitric acid, hypochlorous acid, chlorous acid, perchloric acid, salts thereof, nitrogen peroxide, ozone, sulfuric acid, periodic acid, and salts thereof. Preferred examples are sulfuric acid, potassium permanganate, and calcium chlorate.

Examples of hydrolyzing agents include inorganic acids such as sulfuric acid, phosphoric acid, hydrochloric acid, and nitric acid, organic acids such as formic acid and peracetic acid, acidic salts such as potassium hydrogen sulfate, sodium hydrogen sulfate, sodium hydrogen phosphate, and sodium hydrogen carbonate, and alkalis such as caustic soda and caustic potash. Preferred examples are sulfuric acid, phosphoric acid, formic acid, and peracetic acid.

The degradation of paper by the irradiation with ultraviolet light requires preliminary application of a sensitizer such as zinc oxide or titanium oxide to the paper.

When the printing technique is utilized, the degradation of paper is limited to the mere application of an esterifying agent or oxidizing agent. Optionally, the portion of the paper affected by the reaction may be dissolved afterward by use of a solvent.

The cellulose-degrading agents which are advantageously used in the present invention are sulfuric acid, phosphoric acid, formic acid, and peracetic acid which are capable of causing some of the aforementioned reactions in combination. Among other acids, sulfuric acid proves to be particularly

desirable. When the degradation of cellulose is effected by using sulfuric acid, the reactions including hydrolysis, dissolution, esterification, and oxidation concurrently proceed in a complicated manner. Even when the amount of sulfuric acid applied is limited to a very small level, free sulfuric acid disappears before long. After that, the portion of cellulose which has been sulfurized induces the immediately adjoining portion of cellulose to be weakened. In this manner, the degradation of cellulose proceeds in the manner of a chain reaction, though limited locally.

When such a cellulose-degrading agent is applied in a small amount by the inscribing or printing technique, it manifests its effect slowly. Immediately after the application by such technique, the agent has virtually no effect on the paper. With elapse of time, the agent begins to sever chemically the fibers of paper in much the same way as the fibers are incised by a cutting blade, with the result that the affected fibers are divested of their mutual supporting force.

The effective concentration of the cellulose-degrading agent cannot be fixed specifically because it is affected by various factors such as the method of application (inscription or printing), the number of lines, the depth of incision, the quality of paper, and the thickness of paper. Generally, however, this concentration is in the range of about 1 to 30 weight percent.

In all the cellulose-degrading agents available, sulfuric acid is the most desirable. When sulfuric acid is adopted, the effective concentration is in the range of about 0.1 to 30 weight percent, preferably 1 to 10 weight percent. If the concentration is less than 0.1 weight percent, the effect of cellulose degradation is too feeble to permit desired tearing

of paper. If the concentration exceeds 30 weight percent, the corrosion of machine and apparatus by the chemical reaction is so violent as to jeopardize the health of human beings. Particularly when the agent is applied by means of the pen, the concentration is desired to be lower than 10 weight percent to ensure absolute safety.

The paper-weakening liquid may be an aqueous solution which comprises the cellulose-degrading agent mentioned above and water. This liquid is desired to contain additionally at least one member selected from the group consisting of dyestuffs, pigments, tackifiers, and wetting agents. The tackifier serves to retard the infusion of the liquid into the paper texture and, therefore, contributes to the slow manifestation of the cellulose-degrading effect.

Particularly, when the liquid is applied by the conventional printing technique, the liquid is desired to possess viscosity approximating the viscosity of the printing ink adopted for the conventional technique. To acquire the required viscosity, the liquid may incorporate a suitable amount of a tackifier selected from among sodium polyacrylate, CMC, sodium starch glycolate, and methyl cellulose. When the liquid is prepared by using a dilute acid and incorporating a wetting agent such as glycerine or ethylene glycol, the weakening of paper proceeds gradually and the work of paper rewinding is not affected adversely. Optionally, an acid solution may be suspended as a water-in-oil type emulsion in an ordinary stand oil or printing varnish with the aid of a surfactant.

When the paper-weakening liquid is printed in a fine line on the paper, an acidproof coloring matter or pigment incorporated in advance in the liquid enables the printed line to become conspicuous and facilitates the location of the line.

In the paper of this invention containing the fine weakened tear line, the portion of cellulose of paper falling in the fine line has been chemically degraded. Since the degraded fibers of paper still retain the original entangled structure, they are held together in a state of feeble physical bondage.

Now, the cross-sectional structure of the paper containing the fine weakened tear line provided by the present invention will be described with reference to FIG. 2 and FIG. 3. FIG. 2 is an explanatory diagram illustrating a paper 1 on which a fine weakened tear line 6 is applied to one side of the paper under mild pressure not so strong as to impart a notch to the surface. It is noted from the diagram that the paper-weakening liquid has penetrated through the paper surface to produce a portion 2 of heavily degraded cellulose and a portion 3 of feebly degraded cellulose encircling the former portion 2, with a portion 4 of undegraded cellulose remaining on the opposite side of the paper. Generally, the portion 3 of feebly degraded cellulose is distributed in a semicircular region surrounding the portion 2 of strongly degraded cellulose. FIG. 3 is an explanatory diagram illustrating a paper on which a fine weakened tear line 6 is applied to one side of the paper under powerful pressure enough to impart a notch 5 to the surface.

Generally, when the pressure used in the application of the liquid to the paper is high enough to impart notch 5 to the paper, the paper-weakening liquid passes preferentially in the direction of the thickness of paper to the area of paper and produces a weakened tear line having a smaller width and a greater depth than otherwise.

The fine weakened tear line may be formed in a continuous

straight, bent, or curved line. Otherwise, it may be formed in a discontinuous straight, bent, or curved line consisting of dots, dashes, or alternating dots and dashes. The fine weakened tear line in the paper of this invention is desired to be formed with a colored liquid so as to facilitate the location of the produced line. The coloration of the tear line may be accomplished by the method which consists in applying to the paper a paper-weakening liquid containing either a dyestuff or pigment from the beginning therein or the method which consists in having the position of the tear line indicated in color with a suitable mark before or after the paper-weakening liquid is applied to the paper.

Now, the effect of paper tearing by the fine weakened tear line is compared with that of the conventional tear line formed of perforations. FIG. 4 is an enlarged photograph of a paper having a fine weakened tear line 6 formed thereon. When the paper thus containing the fine weakened tear line is torn, the tearing can be made with the torn edges of paper running smoothly along the fine weakened tear line without deviating from this line as illustrated in the enlarged photograph of FIG. 5. The expression "deviation from the tear line" as used in the present invention shall mean the situation that despite an effort to tear the paper along this tear line, the torn edges of paper runs out of the tear line.

FIG. 6 is an enlarged photograph of a paper wherein a weakened tear line is formed by the insertion of perforations by the conventional mechanical technique. The slit at the center represents the position at which the paper is torn. When this paper is torn attentively with a crease imparted to the paper along the line of perforations, the tearing can be made with ridges and grooves occurring

alternately on the torn edges of paper as illustrated in the enlarged photograph of FIG. 7. If the paper is torn without due attention, a deviation from the tear line may start in one unweakened portion between one weakened point (perforation) and the immediately adjacent weakened point (perforation) and spread randomly in a lateral direction relative to the direction of the tear line as illustrated in the enlarged photograph of FIG. 8. Thus, the desired tearing of paper along the tear line cannot be accomplished because the torn edges of paper run at random.

FIG. 9 and FIG. 10 are explanatory diagrams illustrating how the papers respectively containing a straight and a curved fine weakened tear line 6 of this invention appear after they have been manually torn by an ordinary method using feeble force. The sharp torn edges of these papers serve evidence that the papers are both torn neatly along the weakened tear lines.

FIG. 11 and FIG. 12 are explanatory diagrams illustrating how the papers respectively containing a straight and a curved tear line 7 formed of perforations by the conventional mechanical technique appear after they have been torn with ordinary attention without impartment of any crease in the papers along the perforations. It is noted that the fronts of tear deviate from the directions of perforations and run in random directions to involve "deviation 9." For the papers to be torn neatly along the tear lines of perforations, it is necessary that the tearing should be performed with the meticulous care or after impartment of a crease in the papers along the tear lines. Besides, the torn edges of papers are not sharp because they inevitably contain ridges and grooves 8 alternately. Particularly in the case of the paper which contains the curved tear line of perforations as illustrated in FIG. 12, the front of tear tends to run in a random

direction and involve the phenomenon of "deviation 9." Thus, the paper does not suit actual use.

The fine weakened tear line contemplated by the present invention is formed by only weakening the limited portion of the texture of paper exclusively in the direction of thickness. No completely severed portion occurs anywhere in the tear line of this paper. Solely by the method of this invention it is made possible to effect the heretofore unattainable thorough degradation of the limited portion of texture of paper throughout the entire length of the tear line. Consequently, the otherwise possible occurrence of the deviation of the front of tear from the tear line which is ascribable to the interposition of absolutely unweakened portions can be precluded. Optionally, the portions to which the paper-weakening liquid is applied and the portions to which the liquid is not applied may be arranged alternately after the pattern of a dotted line to produce a tear line resembling the conventional tear line formed of perforations.

Even in a paper which is coated with a resin layer, the fine weakened tear line contemplated by the present invention can be formed by first breaking the resin layer under the pressure exerted by the line-printing plate or paper-incising pen and subsequently applying the paper-weakening liquid in the form of a fine line to the paper and allowing the liquid to seep through the portion of fibers of paper falling in the fine line.

When the conventional tear line of perforations is formed in a paper of particularly large thickness or high strength, the portions of paper intervening between the perforations offer high resistance to tear and tend to induce the phenomenon of "deviation of the front of tear from the tear line."

According to the present invention, the fine weakened tear lines, straight or otherwise, to be formed in papers of high strength or large thickness can be adjusted so as to ensure neat tearing and avoid deviation by suitably selecting the concentration of the paper-weakening liquid, the feed volume of the liquid, the magnitude of the pressure applied, etc. The method of this invention, therefore, suits the formation of curved tear lines and the formation of tear lines in papers of high strength better than the conventional method and notably enhances the easiness of paper tearing.

When the paper-weakening liquid has seeped into the water, the cellulose-degrading agent such as, for example, sulfuric acid in the liquid reacts with the cellulose of paper to induce the phenomenon of combination, adsorption, or addition of cellulose, and the water in the liquid passes out through vaporization. Thus, the weakened portion of paper no longer has any sulfuric acid to liberate.

The paper of this invention in which the fine weakened tear line has been formed as described above is a novel paper. Papers containing the fine weakened tear lines produced by this invention can take the place of the conventional papers containing tear lines of mechanically formed perforations such as business forms, postage stamps, tickets, paper containers, and paper patterns.

The present invention has the following effects to offer:

1) By means of the line-printing plate or the paper-incising pen, this invention enables the paper-weakening liquid to be applied to the paper in a fixed shape or in any desired shape. Consequently, tear lines can be formed in portions and in shapes heretofore unattainable by the conventional mechanical method using perforators, knives, and NT

cutters.

2) Unlike the conventional mechanical method, this invention forms the tear lines by a chemical treatment. Even when the paper-weakening liquid passes through the paper and reaches the rear side of the paper, part of the texture of paper wetted by the liquid remains incompletely weakened and retains physical strength owing to the entanglement of fibers in that particular part. Consequently, the fine weakened tear line as a whole possesses moderate strength, although it permits the paper to be neatly torn with feeble strength when necessary.

3) When the paper-weakening liquid is applied to the paper according to this invention, the portion of the paper falling in the fine line manifests the tearing effect of water immediately after the application of the liquid. After the applied liquid has dried, since the cellulose of paper in that portion is degraded chemically by the cellulose-degrading agent contained in the liquid, with elapse of time, therefore, the strength of paper is gradually lowered to permit ready tearing of the paper along the tear line. The paper of this invention, accordingly, has the merit of slow manifestation of the paper-weakening effect.

4) Since this invention effects the degradation of cellulose of paper chemically, the application of the paper-weakening liquid to the paper can be carried out continuously. The formation of tear lines by this invention, therefore, can be effectively incorporated as one step in the conventional continuous printing process. The operation permits easy management and promises high-speed mass treatment. This invention, thus, proves highly advantageous from the economic point of view.

The first method of this invention which produces a paper

containing a fine weakened tear line formed by use of the paper-weakening liquid bears some resemblance to the conventional printing method.

Specifically, this method utilizes a line-printing plate which has an elongated liquid feed edge of a hard material thrust out in a straight line from the plate and effects the manufacture of the paper by simultaneously pressing the liquid feed edge of the line-printing plate against the paper along the line and transferring the liquid in a straight line from the liquid feed edge to the paper surface.

As described above, the formation of the fine weakened tear line on the paper by the present invention is carried out by causing the liquid capable of chemically degrading the paper texture to pass in a fine line into the paper. And this operation is incorporated as one step in the printing process. The objects sought by the ordinary printing technique are widely at variance with those sought by the operation for the formation of fine weakened tear lines according to this invention. Thus, the conventional printing technique cannot be utilized in its unmodified form.

In the first place, in the ordinary printing operation, efforts have been directed to adopting flat, smooth materials for plates and forming the relief faces of printing plates, i.e. tips for supply of printing ink, with soft, smooth materials with a view to avoiding infliction of damage to paper surfaces. In the present invention, the formation of the fine weakened tear line on the paper is accomplished by first depressing the paper surface in the direction of the thickness of paper enough to break the surface and subsequently forcing the paper-weakening liquid to pass into the paper again in the direction of its thickness. For this

reason, the line-printing plate has a liquid feed edge made of a hard material so as to enhance the magnitude of pressure applied to the paper surface. Further, in the ordinary printing operation, the printing ink containing a large proportion of pigment or dyestuff is used in the smallest possible amount to produce a clear printed surface free from smearing and ensure effective shield and clear transfer of ink. In the present invention, even when the pigment or dyestuff is used, it is at most expected to readily locate the fine weakened tear line formed on the paper. What is rather important is that the paper-weakening liquid should be thoroughly seeped through the paper in the direction of its thickness. Thus, the amount of the paper-weakening liquid to be used per unit area of the paper is fairly large by the standard of the conventional printing operation. In the line-printing plate to be used in this invention for the application of the liquid to the paper, therefore, the liquid feed edge has a finely coarsened surface so as to have the liquid amply retained in the recesses of the coarsened surface. During the transfer of the liquid to the paper surface, the protuberances of the coarsened surface inflict a mechanical damage to the paper in the direction of its thickness and the recesses release the liquid into the damaged paper surface. Consequently, the liquid passes into the paper in the direction of its thickness.

The line-printing plate to be used in this invention for the application of the liquid to the paper is so constructed that an elongated liquid feed edge of a hard material thrusts out in a straight line from the plate. To be more specific, this line-printing plate can be formed of any of ordinary plates of rubber, polybutadiene, polyethylene, polypropylene, acryl resin, and vinylidene chloride invariably of conventional use which possess certain degree of resiliency. If

the material to be selected happens to be susceptible to the action of an acid, the plate can be protected with an acid-proof coat. The liquid feed edge of the plate is made of a material harder than the material of the plate such as, for example, metal, ceramic, rigid plastic, or a composite thereof. Optionally, it is made of a mixture of a powder of a hard inorganic or organic substance with a resin. The feed edge is obtained by molding such a material in the shape of a strip and embedding this strip in the aforementioned plate or otherwise attaching the strip fast to the plate. The portion of the liquid feed edge which comes into contact with the paper surface has a width in the range of about 0.1 to 1.0 mm. A linear material having any of various cross sections including circular, triangle, polyangular, starlike, and pseudocircular sections or a linear material formed by stranding a multiplicity of thin wires may be embedded partially in the plate, so that the unburied portion of the linear material will serve as a liquid supply edge. Otherwise, the plate contemplated by this invention may be formed directly by preparing an acidproof metallic roll and causing a powder of hard inorganic substance to be attached fast in a fine line to the surface of the roll with the aid of an adhesive agent.

As the paper-weakening liquid, there is used an aqueous solution consisting of a cellulose-degrading agent and water or the same aqueous solution which additionally incorporates therein at least one member selected from the group consisting of dyestuffs, pigments, tackifiers, and wetting agents. When the liquid contains a tackifier, since the tackifier serves to lower the speed of the passage of the liquid through the paper, it contributes to the slow manifestation of the cellulose-degrading effect of the liquid. Further, it enables the plate to retain a large amount of the paper-

weakening liquid and permits the liquid to be transferred in a large amount to the paper surface.

Now, the method of this invention for the application of the paper-weakening liquid to the paper will be described with reference to the accompanying drawing. FIG. 13 represents a cross section of the plate according to the present invention. Denoted by 10 is a plate made of polypropylene. In the surface of this plate 10, a linear material 12 formed by stranding a multiplicity of fine stainless steel wires 11 is partially embedded so that one lateral side of the linear material 12 will protrude from the plate. The protruding portion of the linear material is used as a liquid feed edge 13. FIG. 14 represents another embodiment of the liquid feed edge 13 which is made of a different material. By 14 is denoted a bundle of cordlike fibers with fine particles of grindstone 15 attached fast to the surface thereof with an adhesive agent. This bundle is partially embedded in the plate so that a lateral side thereof may remain outside the plate and serve as the liquid feed edge 13. Other linear materials usable for this purpose include those made of alumina, glass, mineral materials, and nylon containing particles of grindstone, for example.

FIG. 15 is a model diagram illustrating the operation of the application of the paper-weakening liquid to the paper by use of the line-printing plate of this invention as attached to the plate cylinder. As the paper-weakening liquid 16, a viscous aqueous solution prepared by dissolving 2 weight percent of sulfuric acid and 0.3 weight percent of methyl cellulose in water is used. This liquid is placed in the liquid reservoir 18 which has a scooping roll 17 immersed therein. The application roll 19, the plate cylinder 20

incorporating the plate of this invention, and the impression cylinder 21 are sequentially held in rolling contact. The scooping roll 17, the application roll 19, and the impression cylinder 21 are each coated with a suitable acidproofing material such as Teflon. By 22 is denoted a paper under treatment. FIG. 16 is an enlarged explanatory diagram illustrating the condition in which the linear material is brought into contact with the paper. As the scooping roll 17 is rotated in the direction of the arrow, the viscous paper-weakening liquid 16 adheres to the surface of the roll 17. The amount of the liquid 16 thus entrained on the surface of the scooping roll 17 is determined by the amount of the clearance inserted between the scooping roll 17 and the application roll 19 which are held in rolling contact with each other. Then, the paper-weakening liquid 16 which has adhered to the surface of the application roll 19 is transferred to the liquid feed edge 13 on the surface of the plate cylinder 20 and further transferred onto the paper 22 which is forwarded as held in contact with the surface of the impression cylinder 21. In this case, the pressure of the rolls is fixed at a level such that a slight recess is formed on the surface of the paper 22. Thus, the paper-weakening liquid adhering to the liquid feed edge 13 can be pushed into the paper texture. As illustrated in FIG. 16, the liquid is not spread out on the surface of the paper but is seeped into the paper in the direction of its thickness. When the liquid feed edge has a finely coarsened surface as illustrated in FIG. 16, the paper-weakening liquid is retained in the recesses of the coarsened surface. Consequently, the liquid feed edge can transfer a large amount of the liquid to the paper surface in the direction of the thickness of paper. This method, therefore, proves to be highly convenient when the transfer of the liquid is made to a paper of large thickness, for example.

When an aqueous sulfuric acid solution of low viscosity which contains absolutely no tackifier or only a small amount of tackifier is used as the paper-weakening liquid 16, the method of application illustrated in FIG. 17 is adopted. The blanket roll 24 which contains a liquid impregnation layer 23 is rotated as immersed in the paper-weakening liquid 16 held in the liquid reservoir 18, the paper-weakening liquid 16 wets the liquid impregnation layer 23 and then adheres to the fine line 11 on the plate cylinder 20. Since the liquid feed edge 13 of the fine line 11 contains minute protuberances and recesses on its surface, the paper-weakening liquid 16 is retained in the recesses and then transferred forcibly into the paper 22.

When the application of the paper-weakening liquid described above is carried out on a writing paper of high quality, for example, a slight dent is formed on the surface of the paper. This dent is too slight to be discerned from the rear side of the paper. Since the loss of the strength of paper due to the application of the paper-weakening liquid is slight, the paper can be wound intact in a roll. When the paper is unrolled, cut to sheets of a fixed size and left standing for one month, the sheets of paper can be torn along the tear lines with slight force.

Instead of applying the line-printing plate of this invention fast to the plate cylinder, a powder of solid inorganic substance such as alundum or grindstone may be directly applied with an adhesive agent in a fine line to a plate cylinder such as a chromium-plated metallic roll. Otherwise, a linear material mixed with directly an epoxy type adhesive agent may be formed in a fine line.

The merits and effects of the method of application of the

paper-weakening liquid according to the present invention are enumerated below.

Firstly, unlike the conventional method which mechanically incises cuts in the paper, this method effects the formation of a tear line simply by placing the paper-weakening liquid on the paper. This operation can be incorporated as one step in the printing process. The step in the process is easy to manage. The method, therefore, permits high-speed mass treatment of paper and proves to be highly advantageous from the economic point of view.

Secondly, although immediately after the application of the paper-weakening liquid to the paper, the paper is temporarily weakened because of the wetting, it regains its original strength after the liquid dries up. In the meantime, the degradation of paper by the action of the cellulose-degrading agent proceeds very little in the initial stage. With elapse of time, the degradation gains in momentum with the gradual increase of the concentration of the cellulose-degrading agent due to departure of water. After the degradation proceeds to a certain extent, the progress of the degradation becomes quite moderate. Immediately after the applied paper-weakening liquid dries up, the degradation of paper is limited to the degree as brought about by the pressure exerted mechanically or the infliction of minute damage. So far as the degradation of paper is limited to this degree, the paper can be safely taken up in a roll. In the case of a paper containing a tear line of perforations formed by the conventional mechanical method, since the edges of the individual perforations protrude from the rear side of the paper, stress accumulates in the paper being wound up in a roll even to the extent of causing breakage of paper. Thus, the conventional method finds it difficult

for the paper to be rolled up safely in its longitudinal direction. The paper produced by the method of this invention can be easily wound up in a roll in the longitudinal direction because of the absence of such stress. The winding of the paper in a roll is an indispensable requirement for the high-speed processing of paper by a rotary press.

Thirdly, the paper treated by the method of this invention possesses a very stable, uniform quality. By the conventional mechanical method for producing perforations in the paper, the cutting edges of the blades used for the punching undergo heavy wear. The sharpness of the cut edges of perforations formed by freshly ground blades and that of the cut edges of perforations formed by blades worn out so much as to require replacement are widely at variance. If the roll pressure is increased in proportion as the advance of the wear of cutting edges of blades in an effort to increase the number of cutting cycles of blades, the diameter of the perforations formed proportionally increases and the possibility of deviation of the front of cut from the tear line also increases. It is, therefore, difficult to produce perforations of constant quality. When the line-printing plate of the present invention is used, papers containing fine weakened tear lines of constant quality can be produced by fixing the kind of paper, the concentration of the paper-weakening liquid, and the roll pressure.

Fourthly, the fine weakened tear line can be formed in a continuous line throughout the entire extent of the line along which the paper is expected to be torn. Otherwise, it can be formed in an intermittent pattern, i.e. a pattern wherein portions to which the liquid is applied and portions to which the liquid is not applied are alternately arranged

in much the same way as the perforations formed by the conventional mechanical method. When perforations are formed in a paper of large thickness by the conventional method, the uncut portions intervening between the adjacent perforations offer great resistance to tearing and tend to induce the phenomenon of deviation. By the method of this invention, insofar as the concentration of the paper-weakening liquid, the roll pressure, etc. are properly adjusted, the fine weakened tear line, whether formed in a complicated curved pattern, permits neat tearing without the possibility of deviation. Compared with the conventional mechanical formation of perforations, the method of this invention notably facilitates the formation of a fine weakened tear line, straight or otherwise, in a paper of varying thickness and adds greatly to the easiness of tearing.

Fifthly, the method of this invention for the formation of fine weakened tear lines is one form of printing operation. When the paper-weakening liquid to be used therein additionally incorporates a pigment or coloring matter, the fine weakened tear lines produced on papers become readily discernible and, therefore, requires no additional treatment of the papers for the insertion of marks which aid in the location of tear lines.

Sixthly, where the tear lines are to be formed in papers of particularly large thickness or in cardboard papers, those of perforations formed by the conventional mechanical method and those obtained by the method of this invention may be combined so that the uncut portions intervening between the adjacent perforations will be weakened as aimed at by this invention. Consequently, such thick papers can be neatly torn along the fine weakened tear lines.

The other method of this invention which is available for the manufacture of a paper containing a fine weakened tear line makes use of a paper-incising pen and effects the manufacture of the paper by sliding the paper-incising pen on the paper along the line and causing the paper-weakening liquid to penetrate into the paper along that line.

The paper-incising pen to be used in this manual method has a writing point which communicates with the paper-weakening liquid formed of a cellulose-degrading agent and water and contained within a penholder through the medium of an exudation path formed of bubbles, capillaries, grooves, fiber bundles, or non-woven fabric and bordering on the liquid. When this paper-incising pen is slid in a desired pattern on the paper, the water contained in the paper-weakening liquid swells the paper texture and, at the same time, the relatively hard and sharp writing point of the pen imparts a scratch to the freshly swelled portion of paper, with the result that the paper-weakening liquid will penetrate the paper in the direction of its thickness and give rise to a fine weakened tear line in the paper. The paper containing the fine weakened tear line can be neatly torn with feeble force along this tear line either immediately after the incision of the line or when necessary.

Now, the paper-incising pen will be described in detail below.

By the words "writing point of the paper-incising pen" is meant the very point of the nib of this pen which comes into direct contact with the paper surface at the time of incision. The pen point is required to be in such a construction that it always retains the front of the flow of the paper-weakening liquid from the reservoir within the

penholder and, upon contact of the writing point with the paper surface, readily releases the flow of the liquid to the paper. Any of the pen points generally used in writing utensils of ordinary run such as for example, glass pens, ceramic pens with porous tips, popular iron pen points with slits, and felt points of nylon, polyester and other fibers, non-woven fibers, and spongy substances can be effectively used as the pen point for the paper-incising pen. Since this paper-incising pen is expected to fulfil the part of inflicting a mechanical damage in addition to wetting the paper with the paper-weakening liquid, the pen point is desired to be made of a hard material such as ceramic, rigid plastic, or acidproof metal, for example. The felt pen made of non-woven fabric or fiber bundle may be made useful when it is hardened with a plastic paste or some other hydrophilic paste enough to inflict a scratch upon the freshly wetted paper surface.

The pen point for use in the present invention is required to be provided with an exudation path which is interposed between the reservoir of the paper-weakening liquid and the writing point and is used for delivering the liquid in a suitable amount to the writing point. When this exudation path is formed of a metallic, ceramic, mineral, or plastic material of suitable hardness containing open cells, then the pen point may be formed by extending the exudation path and cutting the extended portion in the shape of a pen. If the pen point is made of a solid material of close texture, grooves may be formed on the periphery as found in a glass pen or a communication path may be formed along the axis. When the pen point is formed of an aggregate of fibrous threads, the interstices between the individual fibrous threads serve advantageously as an exudation path. A bundle of hollow fibers can also be used. Fine tubes of ceramic,

mineral, plastic, or metallic substance are also useful.

The writing point of the pen is desired to be relatively thin. When the writing point is thin, the scratch inflicted upon the freshly wetted paper surface has a small width and the cut line formed in the paper is sharp. The easiness of tearing is enhanced in proportion as the depth of the scratch thus inflicted upon the paper increases. For the fixed pressure of the writing point, the magnitude of pressure applied by the unit area of the writing point increases with the decreasing thickness of the writing point. This means that efficient infliction of a deep scratch is obtained by amply decreasing the thickness of the writing point. When the writing point is extremely thin, however, it fails to slide smoothly on the paper and provides poor results because the point tends to get caught on paper fibers. Generally, the diameter of the writing point is desired to fall in the range of about 0.05 to 1.0 mm, preferably about 0.2 to 0.5 mm.

The paper-incising pen of this invention is desired to provide a larger flow volume of the paper-weakening liquid than the ordinary writing utensils. For the writing utensils, the covering effect matters very much. Efforts are made to vest the writing utensile with an ability to provide continuous flow of the writing fluid in the least possible amount and permit the user to produce clear, even handwriting for a long time. In this invention, however, the pen is rather desired to provide ample flow of the liquid so that the liquid will penetrate the paper throughout the entire thickness of the paper. The flow volume of the liquid should suffice for the purpose of the weakening of the portion of paper texture falling in the fine tear line. In the case of a paper of JIS P-3201 (writing grade A) having a thickness of

0.09 mm, for example, the flow volume of the liquid for continuous scribing is desired to be not less than 0.2 g/100 m and not more than 1.4 g/100 m under the conditions that the scribing speed is 7 cm/sec, the scribing load is 200 g (equivalent to 1960 mN; N for Newtons), and the angle of the pen point with the paper surface is 65°. This flow volume is equivalent to 1.2 to 8.4 times the flow volume per 100 m generally involved in the ordinary commercially available water marking pens. When the flow volume exceeds 1.4 g/100 m, the liquid produces a thick tear line and even oozes from the rear surface of the paper. Consequently, the excess liquid impairs the sharpness of the tear lines and possibly entails the disadvantage that the liquid oozing from the rear surface of the paper will smear other sheets of paper placed underneath. When the flow volume falls short of the lower limit of 0.2 g/100 m, the desired effect of paper tearing cannot be obtained.

Now, the construction of the paper-incising pen of the present invention will be described with reference to the accompanying drawing.

FIG. 18 is a longitudinal cross section of the paper-incising pen according to this invention. Denoted by 25 is a pen point made of a porous aluminum oxide material containing open cells. In this pen point, the open cells constitute an exudation path. The writing point 26 of the pen has as small a radius of carvature as 0.2 mm and is smoothly ground. By 27 is denoted a tube which is filled with an acidproof, swellable material 28 such as acrylic fibers and the paper-weakening liquid. One end of the tube is converged to form a socket for holding the pen point 25. As the paper-weakening liquid, an aqueous solution containing 1 weight percent of CMC, 5 weight percent of sufuric acid, and 0.01 weight

percent of red coloring matter (acid red) is used. By 29 is denoted an air-vent plug for preventing leakage of the aqueous solution from the tube 27. By 30 is denoted a penholder, 31 a cap, and 32 a clip.

The paper-incising pen illustrated in FIG. 18 has the paper-weakening liquid contained in the tube and stowed within the penholder. Optionally, the paper-weakening liquid may be contained directly in the penholder. The pen may be so constructed that the writing point of the pen will be kept retracted within the penholder when the pen is not in use, and thrust out of the penholder when the pen is used. Otherwise, the pen may be in such a construction that the pen point will be kept within the penholder when not in use and removed from the penholder when put to use.

FIG. 19 illustrates another typical paper-incising pen using a different pen point. Denoted by 25 is a pen point made of a plastic material containing finely divided silicon carbide. On the periphery of this pen point are formed grooves which provide communication between the writing point 26 and the base 33. The grooves, thus, constitute an exudation path 34. The base 33 is encircled with a tube 27 and held fast at the leading end of the penholder.

FIG. 20 illustrates a paper-incising pen in which the pen point and the writing point are both made of a felt of bundled fibers, or non-woven fibers.

The pen point and the writing point are rigidified by having their felt points squeezed with a reinforcement of metallic or rigid plastic substance or by having their felt points of non-woven fibers solidified with a resin and tightened with a reinforcement 35 of metallic substance. With a suitable

fitting means 36, the tube 27 and the pen point 25 are combined integrally. The pen point 25 receives the supply of the paper-weakening liquid via the fine pores of fibers which draw the liquid by the phenomenon of capillarity.

As the paper-weakening liquid for use in this paper-incising pen of the present invention, an aqueous solution composed of a cellulose-degrading agent and water or the same aqueous solution additionally containing at least one member selected from the group consisting of dyestuffs, pigments, tackifiers, and wetting agents is available. The wetting agent is useful for the purpose of allowing the liquid to retain the paper in a moistened and swelled state. The tackifier is useful for increasing the viscosity of the liquid.

Now, the merits and effects of the method of this invention as applied to the formation of the fine weakened tear lines in papers by use of the paper-incising pen will be enumerated below.

Firstly, the paper-incising pen resembles the ordinary writing utensil and, provides ready portability. Optionally, this pen may be encased together with an ordinary writing utensil in one penholder. At the time of use, the pen may be drawn out of the penholder to get the writing point ready for use on the paper. Because of the portability, the pen can be used at any time and place to make tear lines in papers.

Secondly, the paper-incising pen has stable sharpness of cutting and retains this sharpness notably longer than the cutting blades. In the case of the conventional blade, the filler contained in the paper forms a cause for wearing the

cutting edge of the blade. In fact, the wear of the cutting edge is so heavy that the blade must be replaced after it has inserted a total of some tens of meters of cuts in papers. The sharpness of cutting widely differs when the cutting edge has worn out to the verge of replacement and when the cutting edge has been freshly replaced. Thus, the produced papers inevitably suffer from dispersion of quality. In the case of the pen of the present invention, since the pen has only to deliver to the paper surface the paper-weakening liquid stored within the penholder, it cannot entail the problem of wear of the point. With 1 g of the paper-weakening liquid, this pen can draw a total of more than 70 meters of tear lines with the same sharpness of cutting.

Thirdly, ordinary cutting blades have directionality so that the fronts of cutting cannot be sharply turned to any desired directions. In the case of the pen of this invention which has the same construction as the ordinary writing utensils, the tear lines can be incised freely in any patterns including curves, small circles, complicated figures. Thus, the pen finds utility in a notably widened range of applications.

Fourthly, the paper-incising pen of the present invention does not suffer from otherwise possible loss of the sharpness of cutting. In papers of one same quality, therefore, the pen can take crippings neatly from individual sheets of paper without fail under a fixed pressure of pen. Further, by simply adjusting the pressure of one and the same pen, there can be formed tear lines with scratches of controlled depths such that the papers containing them may be most effectively torn immediately after, several minutes after, or several days after the insertion of the tear lines.

Fifthly, since the paper-incising pen of the invention can be obtained by simply substituting a rigid, slender pen point of high liquid-flowing property for the cutting blade, it can be mass produced very economically.

Now, the present invention will be described more specifically below with reference to working examples and a comparative experiment.

Example 1:

The relation between the sulfuric acid concentration in the paper-weakening liquid and the degree with which the paper was weakened by the liquid was studied. With a paper-incising pen having a construction of FIG. 18 and holding therein an aqueous solution of sulfuric acid as a cellulose-degrading agent, a straight line was drawn on papers of JIS P-3201 (writing grade A) having a thickness of 0.09 mm under the conditions of 5.0 cm/sec. of writing speed, 250 g of writing load, and 65° of pen point angle with the paper surface. In this case, the flow volume of the liquid was 0.5 g/100 m. The papers containing the drawn tear lines were left standing for about 30 minutes to dry the applied liquid. At the end of the standing, the papers were torn along the tear lines to test for tear strength and easiness of tearing. The results of the test were as shown in Table 1.

Table 1

Concentration of sulfuric acid (wt%)	Tear strength (g)	Easiness of tearing
blank	3000 - 3500	A
0	2000 - 2500	A
0.01	2000 - 2500	A
0.05	1800 - 2000	B
0.1	1000 - 1500	B or C
0.5	800 - 1000	C
1	600 - 700	C
3	500 - 550	C
8	400 - 450	D
10	350 - 400	D
15	300 - 320	D
20	250 - 300	D
30	180 - 200	D

The "blank" in Table 1 indicates the test results obtained on the papers of JIS P3201 without the treatment described above. The methods adopted for these tests were as described below. They apply to the examples and comparative experiment to be cited herein below.

- o Writing load - The paper under test was placed on the platform of a platform balance. On the paper, the pen held at an angle of 65° was depressed and slid to write a line on the paper. During the motion of the pen on the paper, the reading of the scale of the balance was taken accurately to the graduation unit of g.
- o Tear strength - On the paper measuring 10 cm in length and 1 cm in width, a paper-weakening liquid was applied in a straight line along the center line of the paper in the longitudinal direction. One longitudinal edge of this paper was fastened and a spring balance was hung

from the other reinforced longitudinal edge of the paper. An increasing load was applied to the balance until the paper was torn. The load under which the paper was torn was reported accurately to the unit of g. Generally, the feeble force used in tearing papers of this nature corresponds to the load of about 500 to 1500 g.

- Easiness of tearing - The force exerted by hands in tearing papers containing tear lines was measured and reported on the following scale.

  A - During the tearing, the front of tear deviates from the tear line.

  B - During the tearing, the front of tear partially deviates from the tear line.

  C - During the tearing, the front of tear runs smoothly along the tear line without deviation.

  D - The tearing proceeds very smoothly with absolutely no deviation.

Example 2:

The time-course change of the weakening of paper by the application of the paper-weakening liquid was studied. With the paper-incising pen having the construction of FIG. 18 and containing an aqueous 3 weight percent sulfuric acid solution using sulfuric acid as a cellulose-degrading agent and containing a small amount of a red coloring matter, a curved line was drawn on the papers under a writing load of 200 g. In this case, the width of the applied line was 0.2 mm and the flow volume of the liquid was 0.3 g/100 m.

At varying time intervals indicated, the papers were torn along the curved tear lines to test for the time-course change of tear strength. The results of the test were as shown in Table 2. The papers were those of JIS P3201

(writing grade A) having a thickness of 0.09 mm. The tear lines incised on the papers were completely dried about 60 minutes after their application to the papers.

Table 2

Lapse of time	Tear strength (g)	Easiness of tearing
0 minute	550 - 600	C
2 minutes	500 - 600	C
10 "	500 - 600	C
30 "	500 - 600	C
60 "	550 - 600	C
120 "	550 - 600	C
1 day	550 - 600	C
10 days	550 - 600	C
30 "	550 - 600	C

Example 3:

With the paper-incising pen having the construction of FIG. 18 and using, as the paper-weakening liquid, an aqueous solution containing 5 weight percent of sulfuric acid, 1 weight percent of CMC, and 0.01 weight percent of a red coloring matter (acid red), a straight line was drawn on papers of JIS P3201 (writing grade A) having a thickness of 0.09 mm under the conditions of 200 g of writing load (1960 mN) and 65° of pen point angle with the paper surface. In this case, the flow volume of the liquid was 0.45 g/100 m. The depth of the ink penetration in the paper was about 0.06 mm. The papers were torn immediately after and one week after the application of the liquid. The tear strength was 420 g and 400 g respectively. In both cases, the torn edges of papers were sharp.

Example 4:

With the paper-incising pen having the construction of FIG. 18, lines were drawn on the same papers under the same conditions as involved in Example 3 except applying the writing load of 50 g. In this case, the flow volume of the liquid was 0.12 g/100 m. and the depth of the ink penetration in the papers was about 0.03 mm. The tearing of these papers along the tear lines required a strength of 1,430 g. The torn edges of papers were not sharp. The results of this example suggest that tearing of papers along the tear lines can be obtained even when the writing load is small and the notch effect is consequently insufficient.

Example 5:

As the paper-weakening liquids, there were prepared viscous aqueous solutions containing a varying concentration of sulfuric acid (in the range of 0 to 30 weight percent), 0.3 weight percent of CMC, and 0.005 weight percent of benzidine orange as a coloring agent. With these liquids, lines were drawn on papers by the method illustrated in FIG. 15.

The plate was obtained by applying finely divided silicon carbide 120 mesh in particle size in a fine line 0.4 mm in width with an epoxy resin adhesive to the surface of a polyester sheet having a thickness of 0.5 mm, so that the liquid feed edge acquired a finely coarsened surface containing alternating ridges protuberances and recesses. This plate was applied to a plate cylinder. The application of the liquid to papers was carried out under the conditions of printing speed 120 m/min. and liquid feed volume 0.5 g/m. of tear line. The papers containing the applied tear lines were left standing for 30 minutes to dry the applied liquid. Then the papers were torn along the

tear lines to test for tear strength and easiness of tearing. The results were as shown in Table 3.

Table 3

Concentration of sulfuric acid (wt%)	Tear strength (g)	Easiness of tearing
0	2500 - 3000	A
0.1	1500 - 2000	A
0.5	1000 - 1500	A or B
1	900 - 1000	C
5	600 - 750	C
10	500 - 550	C
20	350 - 400	D
30	200 - 250	D

Comparative Experiment:

In papers of JIS P3201 (writing grade A) having a thickness of 0.09 mm, perforations having cut positions 2.2 mm in length and uncut portions 0.8 mm in length alternate in a row were formed. The papers were torn along the perforations to test for tear strength. The results were in the range of 200 to 1100 g.

Claims:

1. A paper containing a fine weakened tear line produced by chemically degrading the portion of cellulose of paper falling in said fine line with a paper-weakening liquid.

2. The paper according to Claim 1, wherein the fine weakened tear line is applied to one surface of the paper.

3. The paper according to Claim 1, wherein the fine weakened tear line comprises the portion of degraded cellulose of paper underlying the area of the fine line and extending over the entire or part of the thickness of the paper.

4. The paper according to Claim 1, wherein the fine weakened tear line is a continuous line.

5. The paper according to Claim 4, wherein the continuous line is a straight line, a bent line, a curved line, or a combination of said lines.

6. The paper according to Claim 1, wherein the fine weakened tear line is a discontinuous line.

7. The paper according to Claim 6, wherein the discontinuous line is a dotted line, a broken line, or a chain line.

8. The paper according to Claim 1, Claim 4, or Claim 6, wherein the fine weakened tear line is a colored line.

9. The paper according to Claim 1, wherein the paper-weakening liquid is a liquid containing a cellulose-degrading agent and water.

10. The paper according to Claim 9, wherein the cellulose-degrading agent is sulfuric acid, phosphoric acid, hydrochloric acid, nitric acid, or peracetic acid.

11. The paper according to Claim 10, wherein the concentration of sulfuric acid in the liquid is in the range of 0.1 to 30 weight percent.

12. The paper according to any of Claim 9 through Claim 11, wherein the paper-degrading liquid contains at least one member selected from the group consisting of dyestuffs, pigments, tackifiers, and wetting agents.

13. The paper according to Claim 12, wherein the tackifier is sodium polyacrylate, CMC, sodium starch glycolate, or methyl cellulose.

14. The paper according to Claim 12, wherein the wetting agent is glycerine or ethylene glycol.

15. A method for the manufacture of a paper containing a readily separable fine weakened tear line, characterized by causing a paper-weakening liquid to be seeped in a fine line into the paper with the aid of liquid supply means thereby chemically degrading the portion of cellulose of paper falling under the area of said fine line with said liquid.

16. The method according to Claim 15, wherein the fine weakened tear line is applied to one surface of the paper.

17. The method according to Claim 15, wherein the fine weakened tear line comprises the portion of degraded cellulose of paper underlying the area of the fine line and

extending over the entire or part of the thickness of the paper.

18. The method according to Claim 15, wherein the fine weakened tear line is a continuous line.

19. The method according to Claim 18, wherein the continuous line is a straight line, a bent line, a curved line, or a combination of said lines.

20. The method according to Claim 15 or Claim 18, wherein the fine weakened tear line is a colored line.

21. The method according to Claim 15, wherein the coloration for indicating the position of the fine weakened tear line is accomplished in a separate step.

22. The method according to Claim 15, wherein the paper-weakening liquid is a liquid containing a cellulose-degrading agent and water.

23. The method according to Claim 22, wherein the cellulose-degrading agent is sulfuric acid, phosphoric acid, hydrochloric acid, nitric acid, or peracetic acid.

24. The method according to Claim 23, wherein the concentration of sulfuric acid in the liquid is in the range of 0.1 to 30 weight percent.

25. The method according to any of Claim 22 through Claim 24, wherein the paper-degrading liquid contains at least one member selected from the group consisting of dyestuffs, pigments, tackifiers, and wetting agents.

26. The method according to Claim 25, wherein the tackifier is sodium polyacrylate, CMC, sodium starch glycolate, or methyl cellulose.

27. The method according to Claim 25, wherein the wetting agent is glycerine or ethylene glycol.

28. The method according to Claim 15, wherein the transfer of the paper-weakening liquid to the paper is effected under application of pressure by a line-printing plate having an elongated liquid feed edge of a hard material thrust out in a straight line from said plate.

29. The method according to Claim 28, wherein the plate has the elongated liquid feed edge of a linear hard material embedded in or fastened to the plate in a straight line.

30. The method according to Claim 28, wherein the plate has the elongated liquid feed edge of a granular hard material embedded in or fastened to the plate in a straight line.

31. The method according to any of Claim 28 through Claim 30, wherein the hard material is formed of at least one member selected from the group consisting of metallic, ceramic, mineral, and hard plastic substances.

32. The method according to Claim 28, wherein the transfer of the paper-weakening liquid to the paper is made in the direction of the thickness of paper.

33. The method according to Claim 28, wherein the liquid feed edge has a finely coarsened surface.

34. The method according to Claim 15, wherein the transfer of the paper-weakening liquid to the paper in a fine line is accomplished by the movement on the paper surface of a paper-incising pen having a writing point communicate with the paper-weakening liquid formed of a cellulose-degrading agent and water and contained within a penholder through the medium of an exudation path formed of bubbles, capillaries, grooves, fiber bundles, or non-woven fabric and bordering on the liquid.

35. The method according to Claim 34, wherein the flow volume of the paper-weakening liquid through the writing point is not less than 0.2 g/100 m. as measured by the method set forth in the specification.

36. The method according to Claim 34, wherein the flow volume of the paper-weakening liquid through the writing point is not more than 1.4 g/100 m. as measured by the method set forth in the specification.

37. The method according to Claim 34, wherein the diameter of the writing point is in the range of 0.05 to 1.0 mm.

38. The method according to Claim 34, wherein the writing point is formed of one member or a mixture of two or more members selected from the group consisting of ceramic, metallic, mineral, hard plastic substances, fiber bundles, and non-woven fabrics.

39. A line-printing plate for the application of a paper-weakening liquid to the paper, having an elongated liquid feed edge of a hard material thrust out in a straight line from said plate.

40. A paper-incising pen for the application of a paper-weakening liquid to the paper, having a writing point communicate with the paper-weakening liquid formed of a cellulose-degrading agent and water and contained within a penholder through the medium of an exudation path formed of bubbles, capillaries, grooves, fiber bundles, or non-woven fabric and bordering on the liquid.

41. A paper-weakening liquid for the production of a fine weakened tear line in a paper for facilitating the tearing of a paper along said tear line, said liquid containing a cellulose-degrading agent and water and used for penetration through the paper in the direction of the thickness of paper.

42. The liquid according to Claim 41, wherein the cellulose-degrading agent is an inorganic acid, organic acid, alkali, oxidizing agent, acidic salt or enzyme.

43. The liquid according to Claim 41, wherein the inorganic acid is sulfuric acid, phosphoric acid, hydrochloric acid or nitric acid.

44. The liquid according to Claim 42, wherein the inorganic acid is sulfric acid.

45. The liquid according to Claim 43 or Claim 44, wherein the concentration of sulfuric acid in the paper-weakening liquid is in the range of 0.1 to 30 weight percent.

46. The liquid according to any of Claim 41 through Claim 45, wherein the paper-weakening liquid additionally contains at least one member selected from the group consisting of dyestuffs, pigments, tackifiers, and wetting agents.

47. The liquid according to Claim 46, wherein the tackifier is sodium polyacrylate, CMC, sodium starch glycolate, or methyl cellulose.

48. The liquid according to Claim 46, wherein the wetting agent is glycerine or ethylene glycol.

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FIG. 1

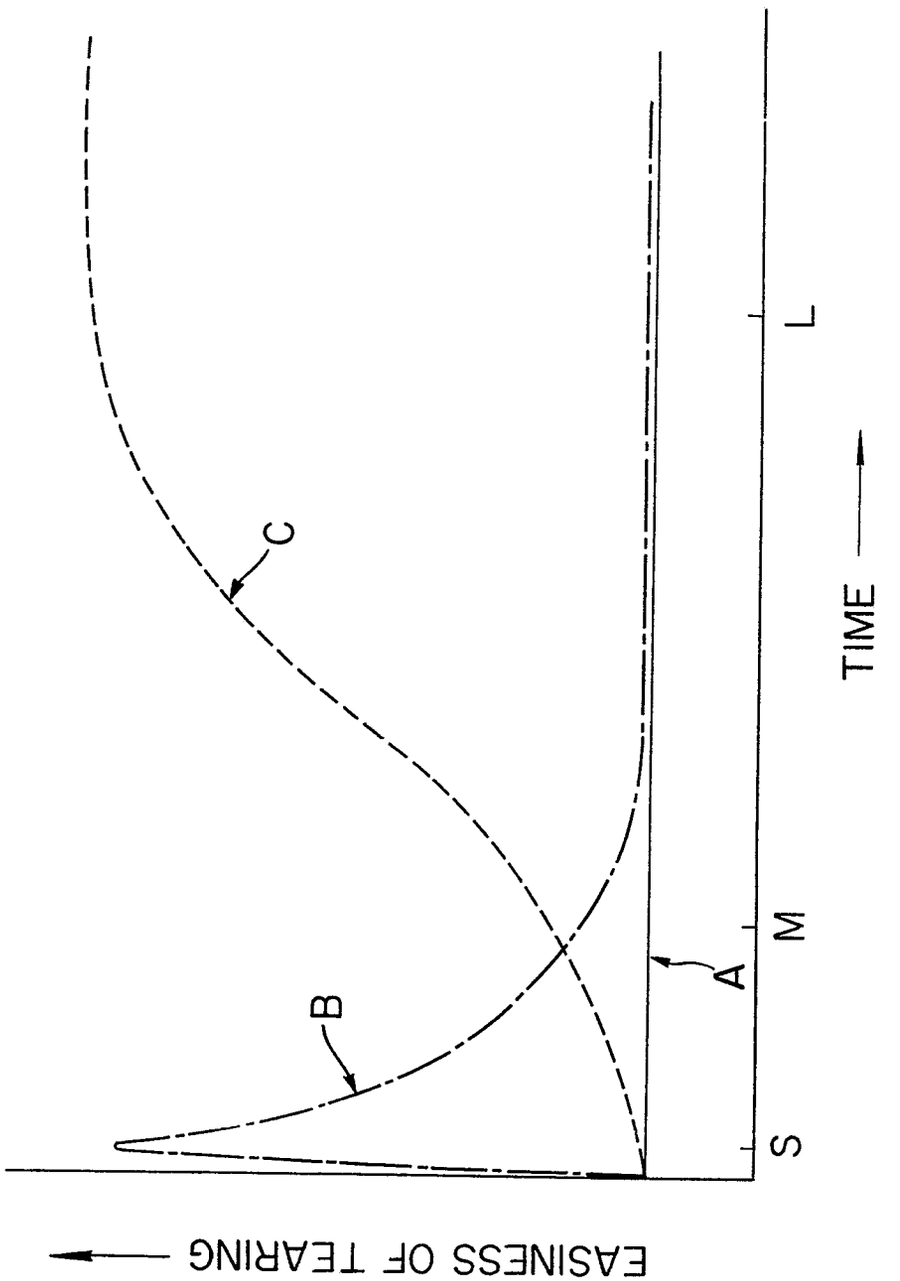

FIG. 2

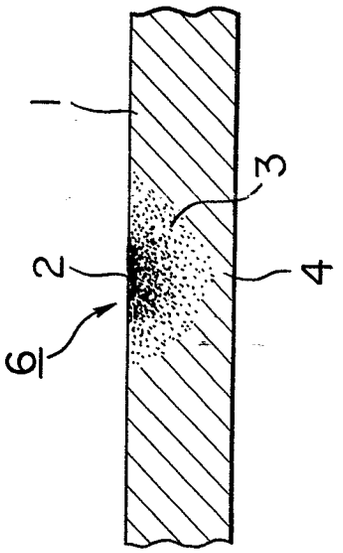

FIG. 3

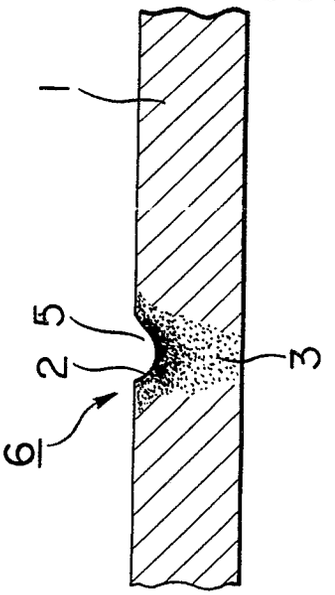

FIG. 4

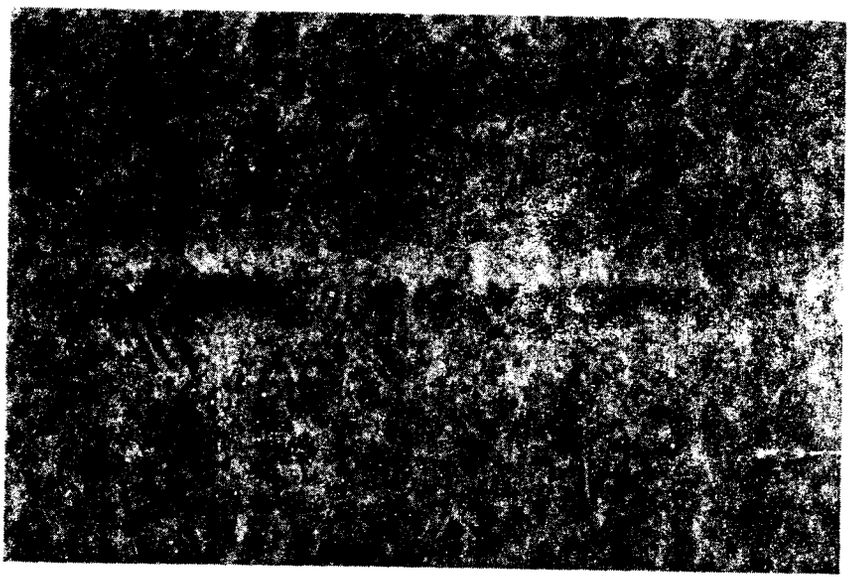

FIG. 5

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FIG. 6

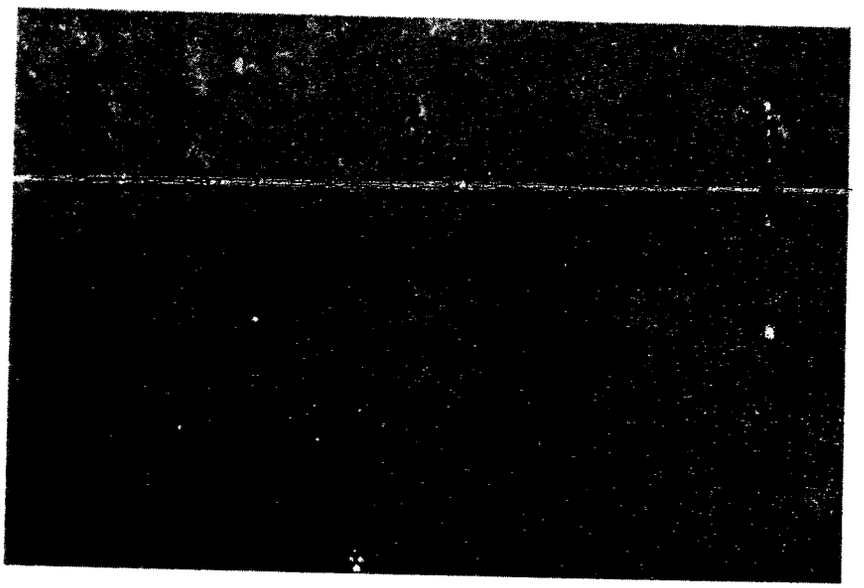

FIG. 7

FIG. 8

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FIG. 9

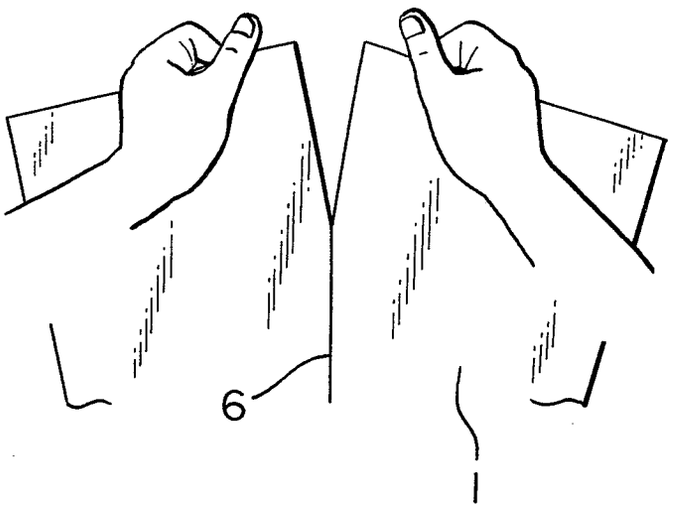

FIG. 10

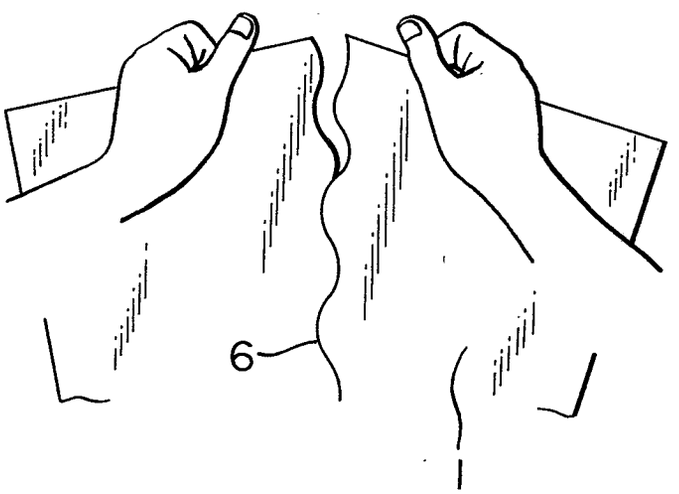

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FIG. 11

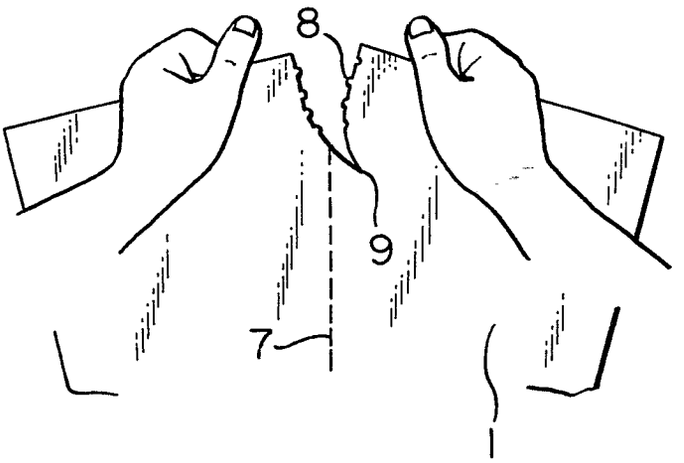

FIG. 12

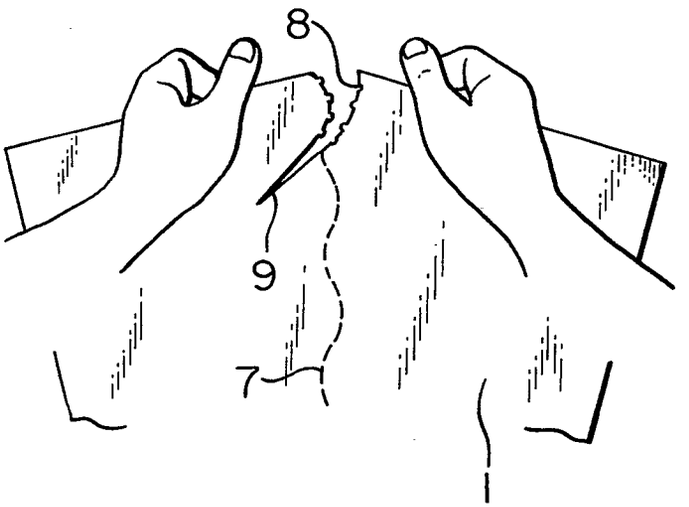

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FIG. 13

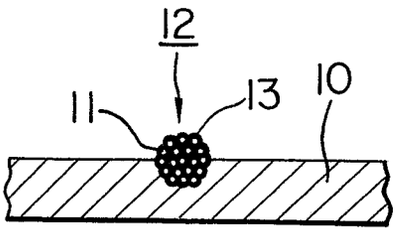

FIG. 14

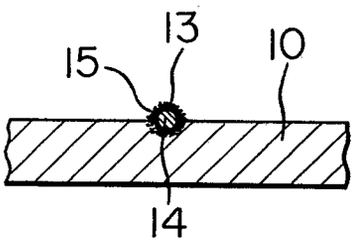

FIG. 15

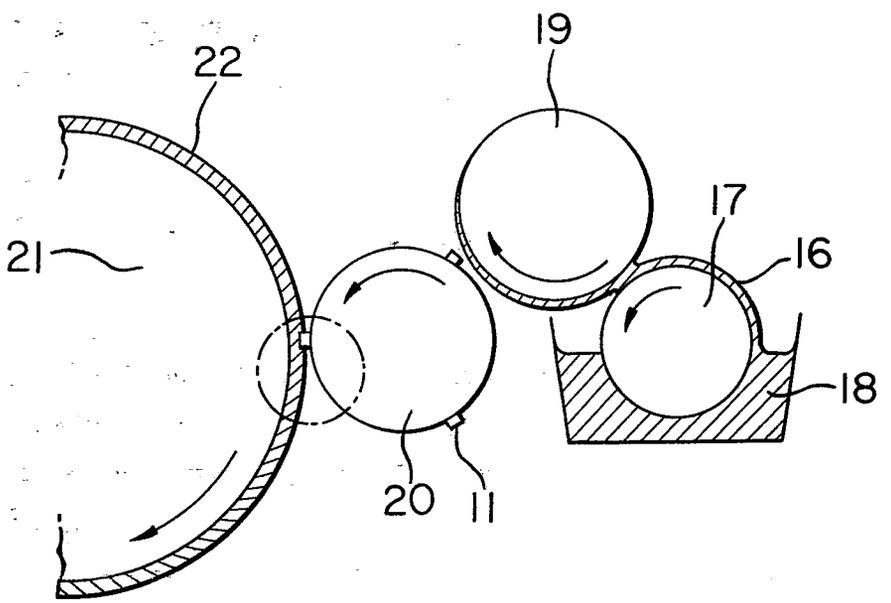

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FIG. 16

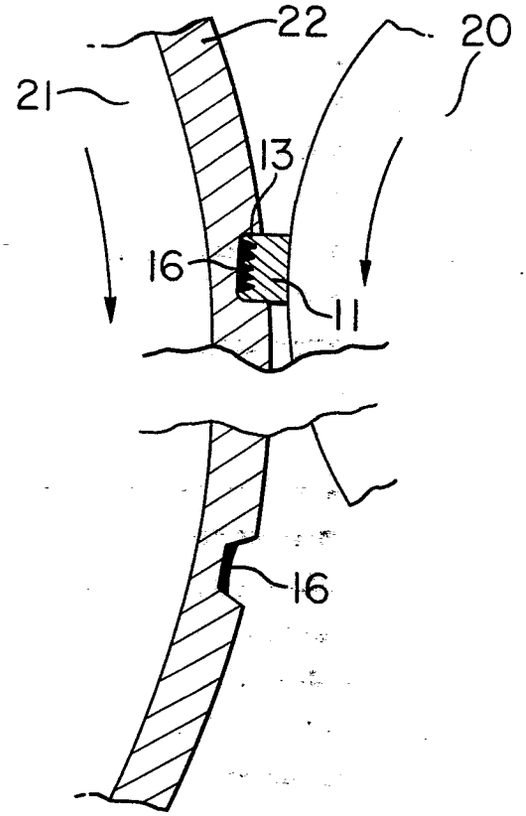
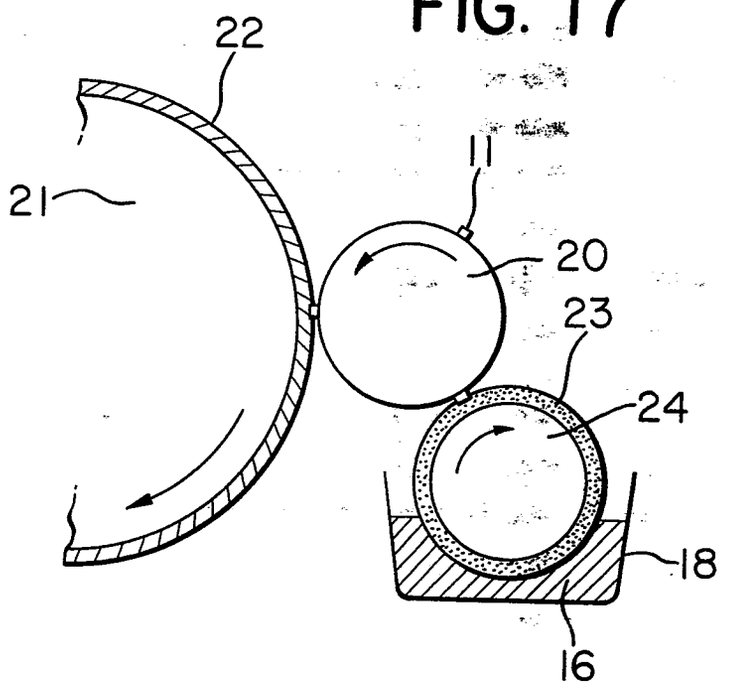


FIG. 17



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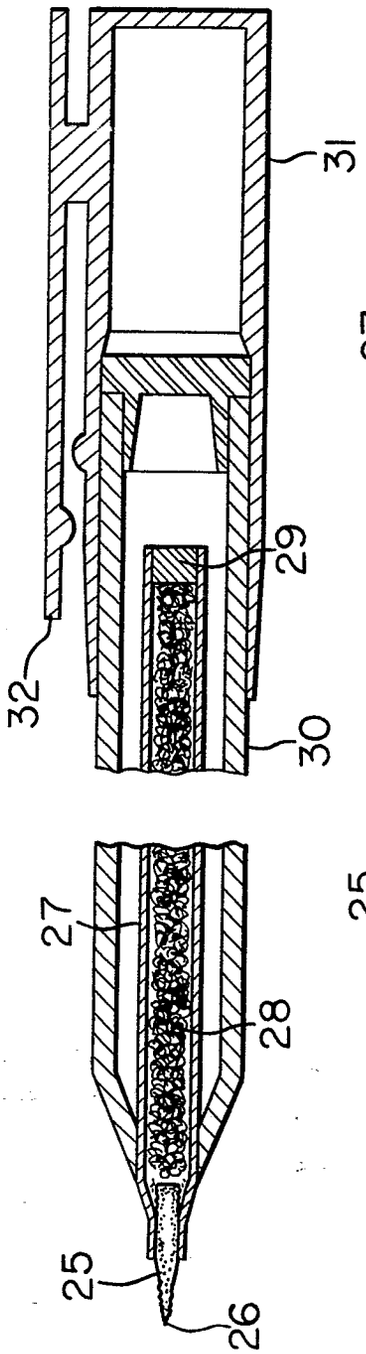

FIG. 18

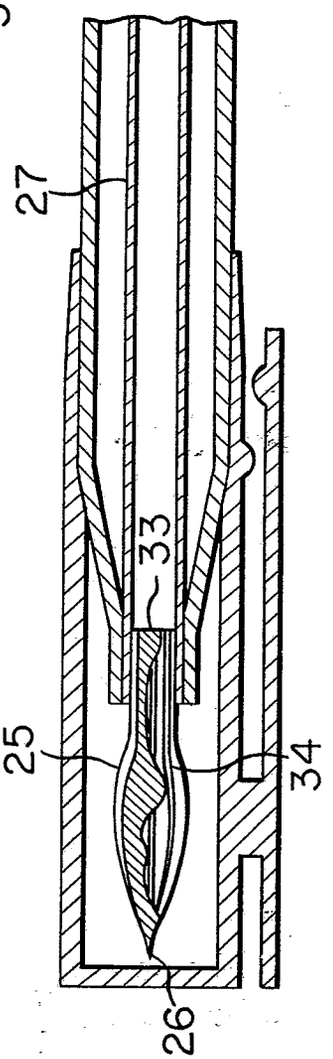

FIG. 19

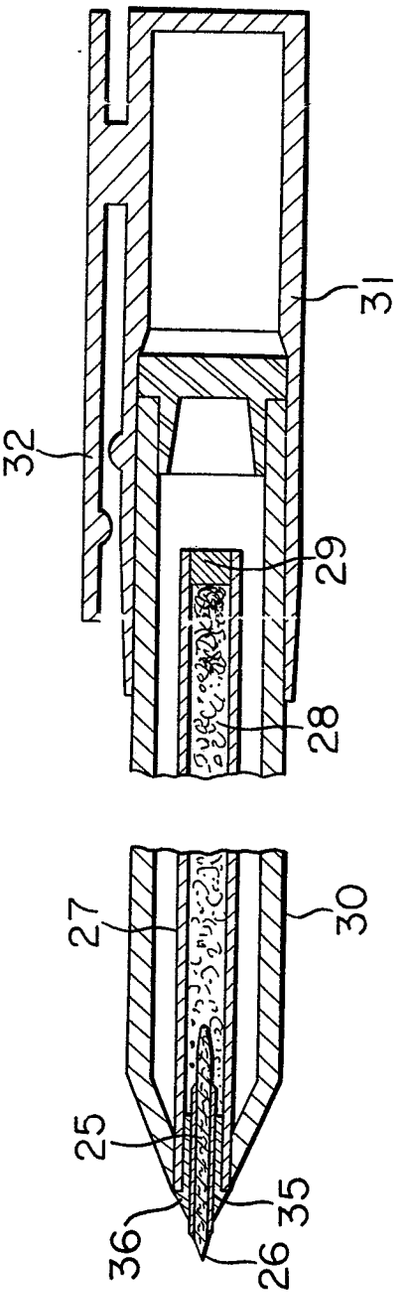

FIG. 20