United States Patent

[11] 3,585,965

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[21] Appl. No. **789,997**
[22] Filed **Jan. 9, 1969**
[45] Patented **June 22, 1971**
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Culver City, Calif.

[54] **DEVELOPMENT CHAMBER**
5 Claims, 11 Drawing Figs.

[52] **U.S. Cl.** **118/9,** 118/48
[51] **Int. Cl.** **B05c 11/00**
[50] **Field of Search** .... 95/89, 93, 94; 355/20, 27; 117/107, 107.1, 106; 118/48—49.5, 9

[56] **References Cited**

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2,439,983 4/1948 Morgan et al. 118/49
2,768,098 10/1956 Hoppe .... 118/49 X
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Primary Examiner—Morris Kaplan
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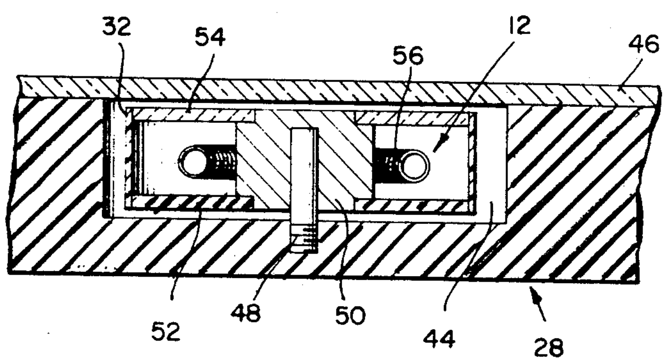
ABSTRACT: The development chamber comprises first and second spaced discs around which a flexible medium to be developed is wrapped around a major portion of the disc circumferences. The medium to be developed has a latent image thereon, which latent image is developed by selective acquisition of metal atoms from a vapor source, in accordance with the latent image character. A vapor source is placed inside the development chamber, between the discs, the discs rotate as the medium proceeds around the circumference exposing the latent images to the metal vapor, and upon completion of the development process moves away from the development chamber.



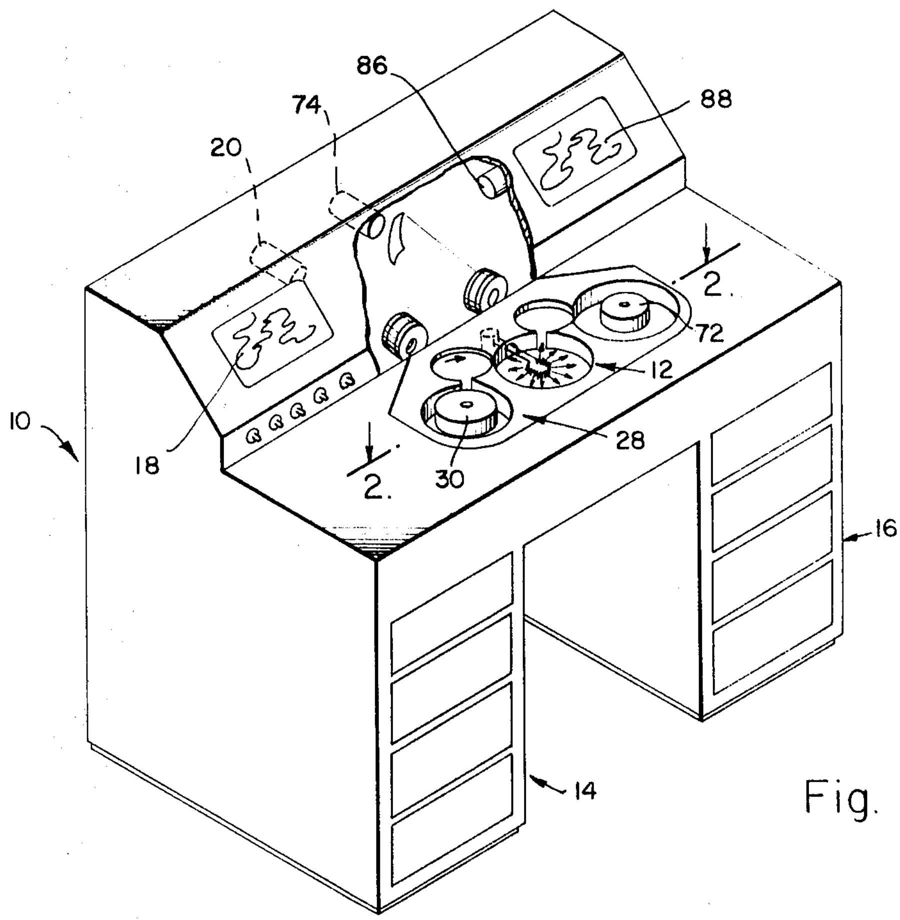


Fig. 1.

Fig. 3

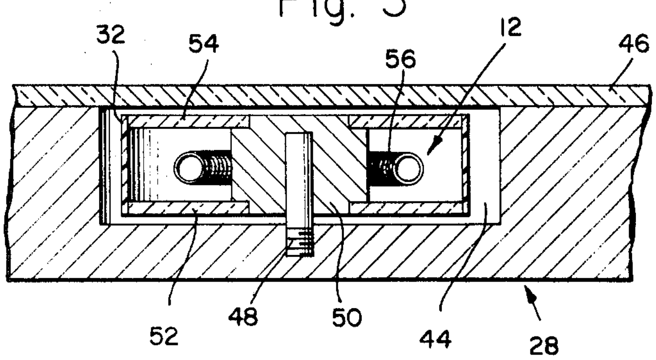


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Fig. 2.

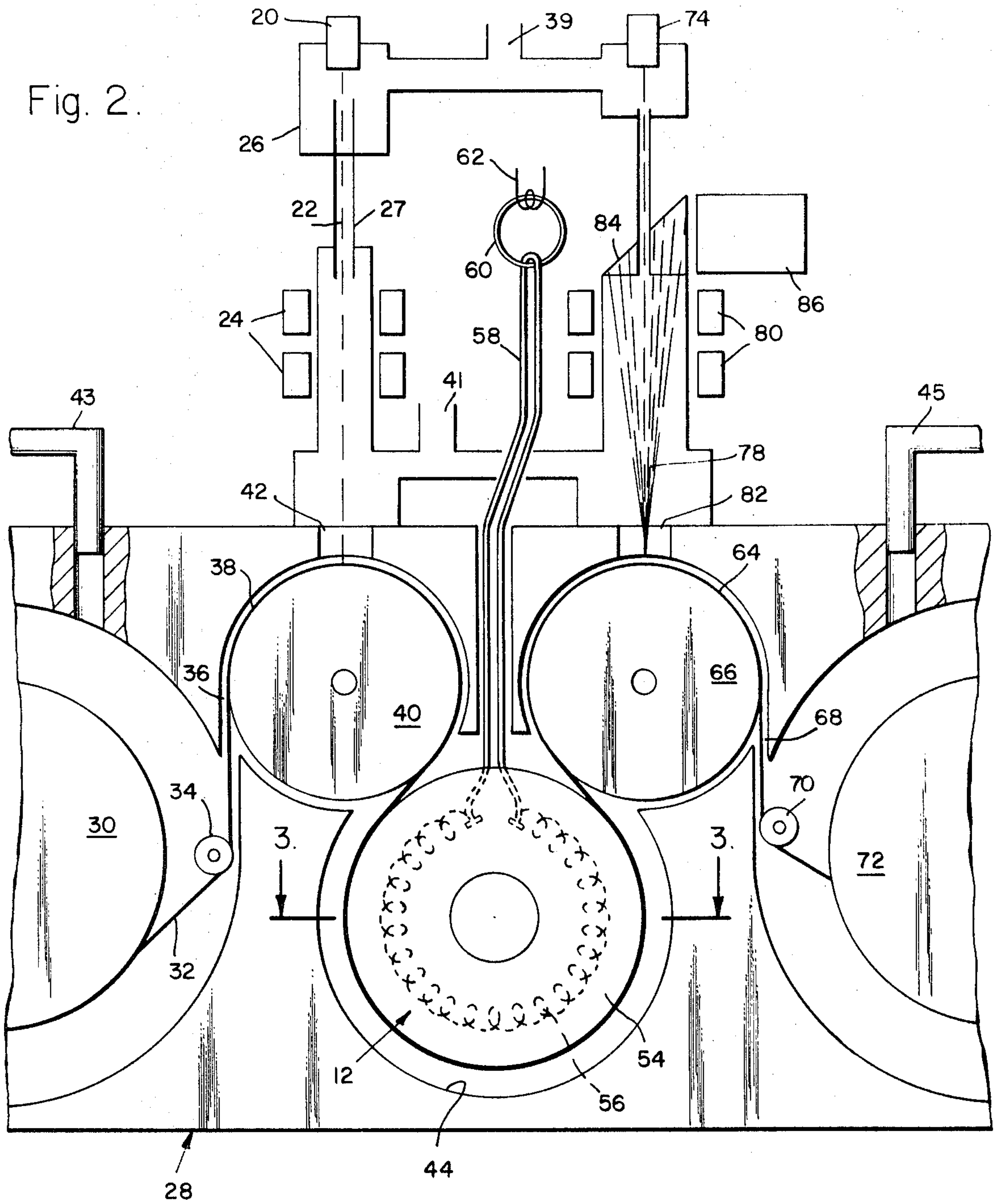

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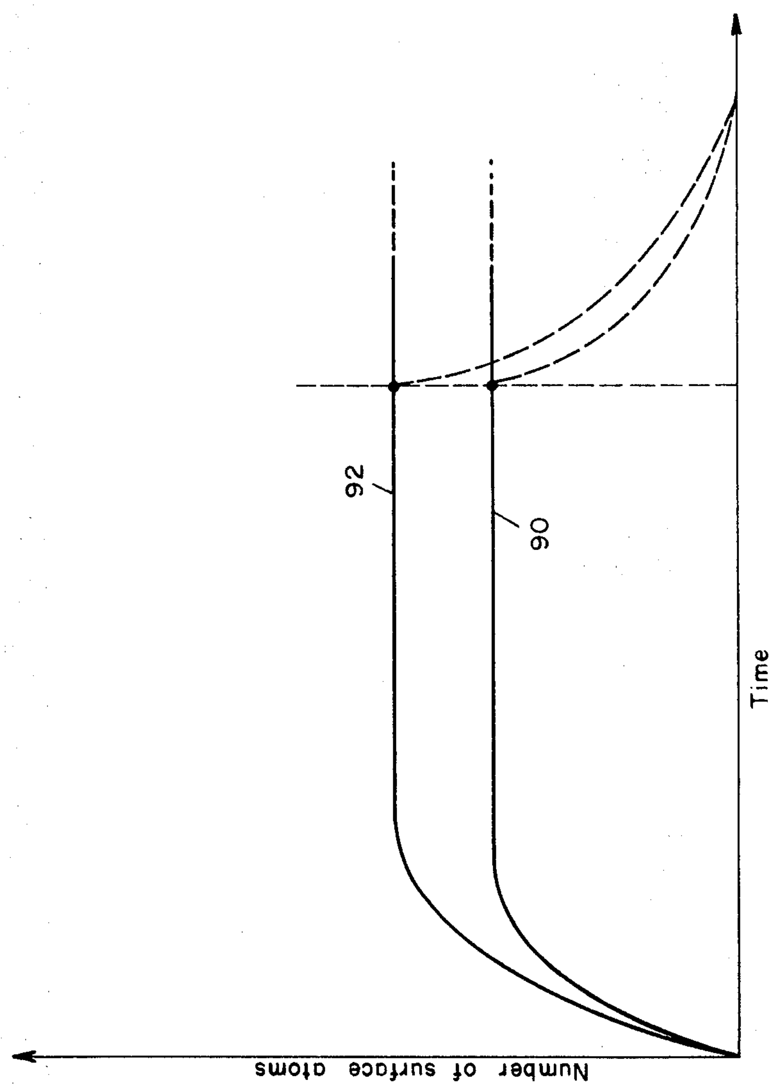
Fig. 4a.



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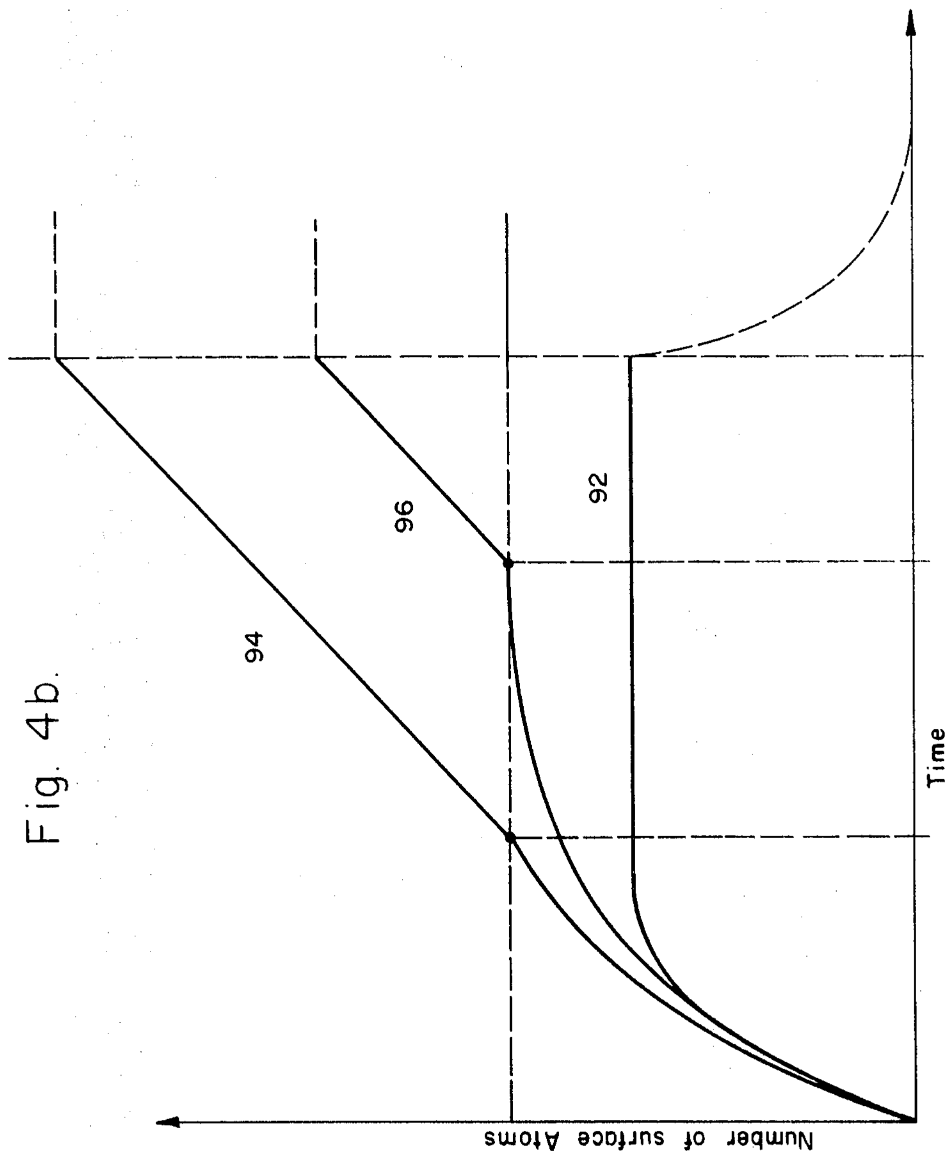

Fig. 4b.

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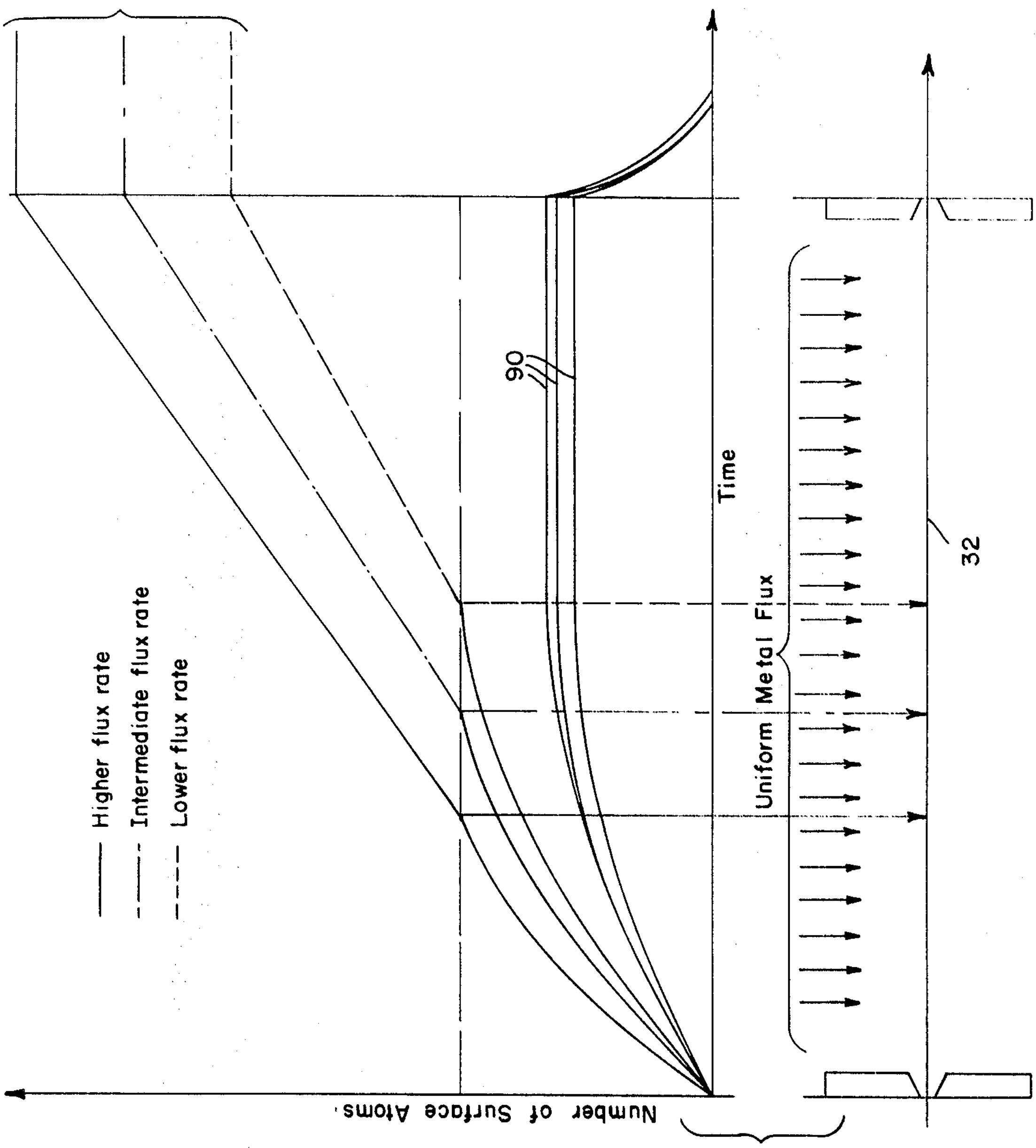

Fig. 4c.

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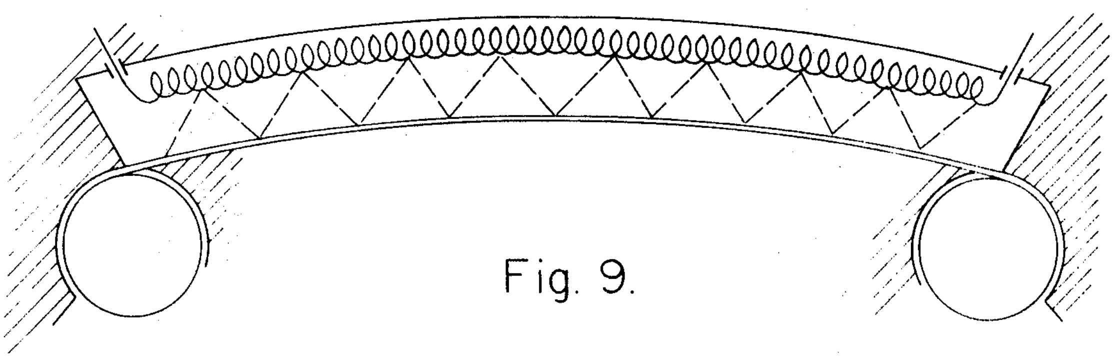
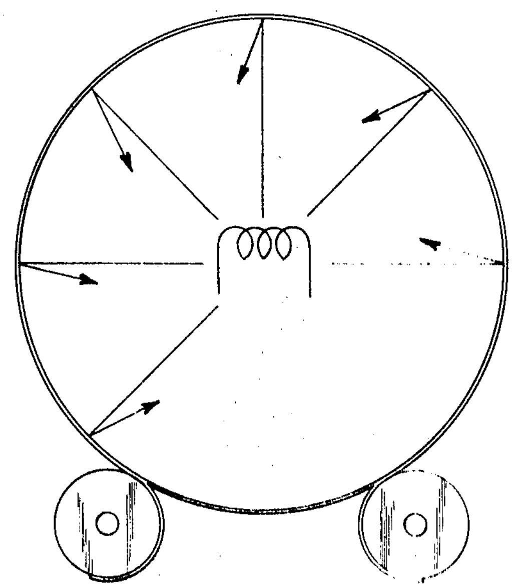


Fig. 9.

Fig. 5.



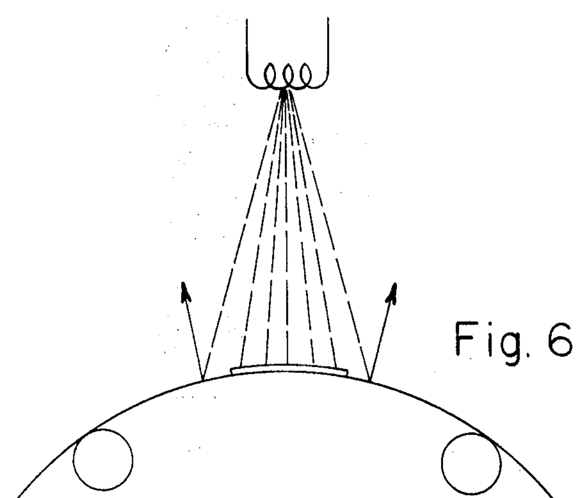


Fig. 6. PRIOR ART

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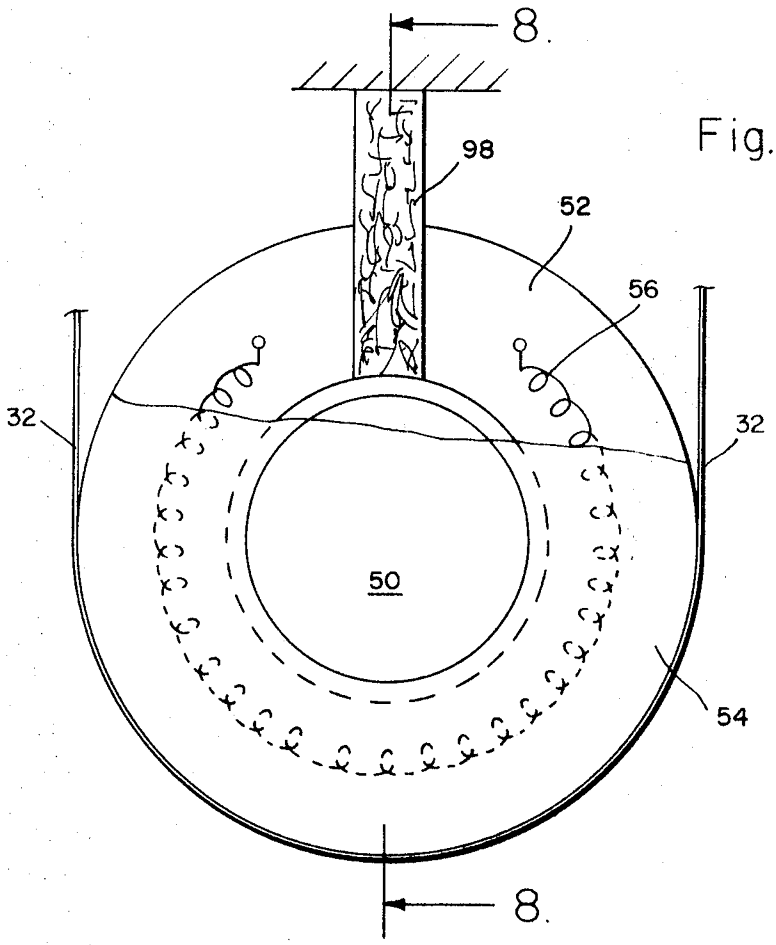

Fig. 7.

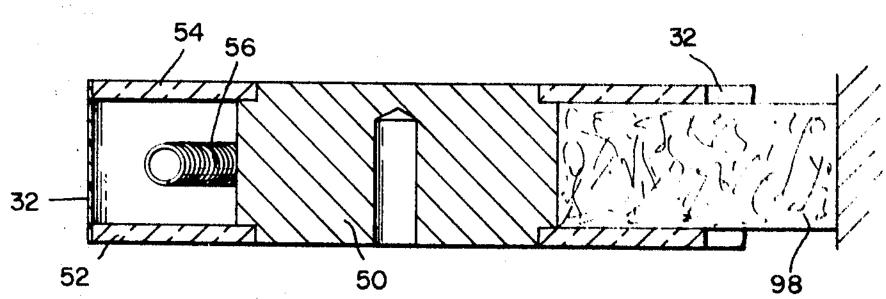

Fig. 8.

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DEVELOPMENT CHAMBER

BACKGROUND

This invention is directed to a rotating development chamber, and particularly to a development chamber for the rapid and continuous development of recording media which have latent images thereon which may be developed into visible images by means of the selective deposition of metal atoms thereon.

A number of prior art processes for the recording of information and subsequent formation of visible images employ the selective deposition of various materials onto latent images. An example of this is found in A. F. Kaspaul, et al. U.S. Pat. No. 3,235,398, granted Feb. 15, 1966. A number of other inventions are directed to the same general type of process. These processes employ the selective deposition of metal atoms to create the visible image. A. F. Kaspaul, et al., U.S. Pat. No. 3,140,143, granted July 7, 1964, describes the use of a metal chosen from Group II–B of the periodic system, as a metal which can be employed with the particular substrate disclosed therein. Selective deposition can be accomplished on suitable substrates by the employment of a variety of other materials as they are discharged from a boiler or any other suitable source. Additionally a metal choosen from Group I–B or magnesium, is suitable and can be employed in the same way. In other cases, the developer material is provided by the dissociation of a metal-containing compound such as silane. Furthermore, cadmium sulfide, lead sulfide, bismuth trioxide may be deposited in imagewise fashion to produce active elements for microcircuitry applications as described in A. F. and E. E. Kaspaul U.S. Pat. No. 3,333,984, granted Aug. 1, 1967. Additionally, while the three cited prior patents describe the selective deposition of metals, metal chalcogenides, etc., for image production, such deposition can be employed for other purposes, such as providing a conductive path, or the like.

The prior art teachings are directed to batch-type processing as well as toward continuous applications. However, they have not resulted in efficient employment of the vaporized materials at high processing speeds. Accordingly, in the prior art applications a sizeable fraction of the "-developer" is deposited within the development chamber rather than onto the substrate. Thus in continuous usage, material is wasted and frequent cleaning is necessary.

SUMMARY

In order to aid in the understanding of this invention, it can be stated in essentially summary form that it is directed to a rotating development chamber, which chamber is formed in part by the medium to be developed. The development chamber is also formed in part by chamber-defining structures. Vapor is present in the chamber and the vapor flux, in combination with the surface condition of the media and the other chamber-defining walls, is such that stable, selective deposition occurs only upon the media.

Accordingly, it is an object of this invention to provide a development chamber which is arranged for the development of various media by the deposition thereon of selected materials to form a visible image faithfully reproducing the information stored in the latent, invisible, images of the media. It is a further object of this invention to provide a development chamber wherein the portion of the chamber which is formed by other than the media is at such conditions, and the developing vapor flux is adjusted to such a rate that stable deposition does not take place on any of the walls of the chamber except the wall formed by the medium. It is still another object of this invention to provide a development chamber which is formed of first and second spaced discs and the medium embraces a large portion of the circumference of the discs to define the development chamber therein. It is still another object to provide a structure wherein media can be continuously developed by passing it circumferentially around a development chamber defined by a pair of spaced discs and by the medium so that media can be continuously moved through a development zone. It is still another object of this invention to provide a development chamber wherein continuous development is accomplished at nearly 100 percent efficient Other objects and advantages of this invention will become apparent from a study of the following portion of the specification, the claims and the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS S

FIG. 1 is an isometric view of a recording and playback console employing the preferred embodiment of the development chamber of this invention.

FIG. 2 is an enlarged partial section taken generally along the line 2–2 of FIG. 1.

FIG. 3 is a partial section taken generally along the line 3–3 of FIG. 2.

FIGS. 4, 4*b* and 4*c* are graphs showing various conditions under which selective deposition of atoms and molecules will occur.

FIG. 5 is a schematic view of the development chamber of this invention showing development vapor paths.

FIG. 6 is a schematic view of a prior art development chamber showing development vapor paths.

FIG. 7 is a schematic view of the development chamber of this invention showing an optional wiper therein.

FIG. 8 is a section on the line 8–8 of FIG. 7.

FIG. 9 is a schematic view of another embodiment of the development chamber of this invention.

DESCRIPTION

A recording and playback console **10** incorporates the development chamber **12** of this invention. Console **10** includes housing spaces **14** and **16** for electronics. It is electrically connected and arranged to receive an electronically defined image which can be visually displayed on the face of cathode-ray tube **18**. In other words, the console receives images and sound in the form of electronic signals resulting from various sources commonly employed in conventional television practice. The purpose of the console is to receive, record and to play back these signals in a desired line frequency.

An electron source **20** produces a modulated beam **22** in accordance with the input signals. Beam **22** is focused and deflected by any conventional electrostatic or electromagnetic means, such as focusing and deflection means **24**. However, rather than producing orthogonal scan, only lateral scan, corresponding to the horizontal scan on the image, is produced by the deflection means. Housing **26** encloses the beam, and is pumped to a suitable low pressure at the pump connections indicated for satisfactory beam performance. Draft tube **27** permits beam passage.

As is seen in FIG. 2, tape deck **28** includes a supply of recording tape on reel **30**. The tape **32** passes around exit guide roll **34** through slot **36** into a very narrow gap of chamber **38**. Capstan **40** rotates simultaneously with capstan **66** within chamber **38**, wrapping the tape **32** around its circumference. The width of slot **36**, and the clearance around recording tape **32** as it moves around the capstan **40** within chamber **38** is minimized to reduce pumping requirements. Opening **42** in tape deck **28** permits beam **22** to impinge upon media **32** as it moves past opening **42** to thus create a latent image on the recording media. Since tape deck **28** and opening **42** are evacuated to different vacuum levels, the narrow spaces in chamber **38** are sufficient to maintain the desired pressures for each area.

Differential pumping of the recording/readout chambers and the respective gun areas is preferably utilized to minimize the size requirements of the vacuum equipment. FIG. 2 shows an arrangement whereby the gun areas may be held at $\leqq 10^{16}$ Torr with a 2 inch diffusion pump by connection **26** to port **39**, whereas the recording/readout chambers are maintained at

10^{14} Torr with a 3 inch booster pump by connection to port 41. Development chamber 44 and tape reel chambers of the tape deck 28 operate at $\leqq 10^{12}$ and $\leqq 10^{1}$ Torr, respectively, by use of forepumps connected to ports 43 and 45.

From chamber 38, the media 32 passes into the stationary development chamber 44 in which the rotating development chamber 12 is located. As seen in FIG. 3, chamber 44 is closed by transparent cover 46 so that the progress of development can be observed. Bearing post 48 is centrally mounted in recess 44 and hub 50 is rotatably mounted thereon. Circular discs 52 and 54 are mounted upon hub 50 so as to rotate therewith. Preferably, upper disc 54 is conveniently removable from the hub and is transparent for visibility purposes. Tape 32 passes around discs 52 and 54, so that the edges of the medium are engaged thereby, and the discs together with the hub, are rotated as the medium passes through the stationary development chamber 44. Tape 32 engages around a substantial part of the circumference of the discs, as shown in FIG. 2, to define the rotating development chamber 12 enclosed by the medium and the discs.

Source 56 is the source of atoms and/or molecules for the development of the latent images contained within the medium 32. Source 56 is conveniently a heated coil or mesh which is connected by leads 58 to the secondary of transformer 60. Energization of leads 62 to the primary of transformer 60 causes high current flow through the coil which forms source 56, thereby heating it to the proper temperature. When the coil or mesh is plated with the metal to be vaporized, such as zinc or cadmium, 10 watts is sufficient to develop a 35 mm. tape at 36 inches/second, and one coil or mesh can have sufficient material to develop more than several thousand feet of tape. Of course, other vapor sources may be employed, e.g., a small boiler could be used to supply the required vapor for many tape reels. Source 56 is preferably positioned so that it is spaced equal distance from all points of the tape as the tape is wrapped around the discs to form the development chamber.

The developer source may be of any type and shape and will successfully operate as long as it is centrally located. Of course an eccentric positioning is possible if one adjusts the efflux pattern accordingly.

After leaving stationary development chamber 44, the now developed tape is transported to chamber 64 where it engages around capstan 66. After leaving capstan 66, tape 32 passes through slot 68 ad around guide roll 70 to be wound on tape reel 72. If reading of the image is required immediately following recording and development it may be accomplished with the readout gun 74 scanning across the tape on 19 capstan 66. Electron gun 74 in housing 76 directs an electron beam 78 onto the image-carrying medium. Focus and deflection means 80 scans the electron beam laterally across the tape as it moves past opening 82. As a result of electron impingement, photons are emitted in accordance with the image content of the medium. These photons are focused by mirror 84 onto photomultiplier 86. The image is thus returned to an electronic signal and can be rebroadcast in a different line frequency and/or cathode-ray tube 88. Housing 76 is suitable evacuated for proper electron beam conditions, and the narrow spaces around the medium in chamber 64 permit the maintenance of a proper vacuum with minimal pumping equipment.

The usefulness of this invention may best be understood by exposing a given surface to a incident flux of atoms and/or molecules from a molecular oven or other vapor sources. Atoms and/or molecules will condense upon the surface, at first moving about it in random fashion. They are eventually captured by active sites to form a stable deposit, or reevaporated from the surface after a certain time has elapsed. At low incident rates, a certain number of atoms will be found upon the surface at any given time so that the equilibrium concentration is reached as soon as the reevaporation rate equals the incident flux. At equilibrium,

$$n_e = i = N_{ad} \cdot A \cdot \exp(-\Phi ad/RT)$$

or $\log n_i/N_{ad} = \log A - (0.434) \cdot \Phi ad/RT$

n_i = Incident flux, [atoms · cm.^{12} · sec.^{11}]

n_e = Re emitted atoms, [atoms · cm.^{12} · sec.^{11}]

N_{ad} = Number of surface adsorbed atoms, [atoms · cm.^{12}]

A = Frequency constant $\approx 10^{14}$ for most metals

Φ_{ad} = Estimated heat of absorption, [Kcal. · mole$^{116\ 1}$]

R = Gas constant [1.987 cal. · deg^{11} · mole^{11}]

T—Temperature in degree Kelvin [°K.] Using zinc for the incident atoms and a glass surface held at 300° K. as the receptor,

$$\log \frac{n_i}{N_{ad}} = 12.3$$

Using this value, surface concentrations of 10^5 or 10^7 atoms/cm.^{2} are obtained with incident rates of 10^{17} or 10^{19} atoms/cm.^{2} · sec. It may be assumed that up to surface coverages of $\theta \leqq 10^{18}$ ($\theta = N_{ad}/N_{pl}$; N_{pl} = number of possible surface sites in an orderly lattice) no stable twins or even triplets will be produced which have a much longer lifetime than single atoms, thus all atoms will eventually leave the surface, especially upon cessation of the incident flux. In FIG. 4*a*, curves 90 and 92 indicate this for the two concentrations of 10^5 and 10^7 atoms/cm.^{2}, respectively, Hence the two glass discs of the development chamber should be free of zinc deposits as long as the surface coverage is kept below 10^{18}, and spurious nucleation centers are avoided. FIG. 7 shows a simple solution for the prevention of random nucleation centers in the rotating development chamber.

As previously indicated, the recording tape containing the latent images forms a substantial portion of the development chamber and is therefore exposed to the incident flux of zinc atoms as long as it surrounds the two glass discs and the developer source. During this time interval, atoms and/or molecules will condense and reevaporate from its surface, which has, with the exception of the latent images, quite similar surface properties as those of the glass discs. Hence no condensation occurs upon the "background" of the medium.

However, electrons previously impinged upon the medium have created latent images characterized by areas of much greater heat of adsorption for zinc. At an incident flux of about 10^{19} atoms/cm.^{2} sec., these invisible images develop into visible images, in less than 1 second, if one assumes that Φ_{ad} is about 12 K. cal./mole for an average portion of the latent image, thus

$$\log n_i/N_{ad} = 5.5$$

The corresponding surface concentration amounts to nearly 10^{14} atoms/cm.^{2} ($\theta = 10^{11}$) which is much too large to maintain equilibrium condition, hence rapid formation of twins, triplets and stable cluster occurs and continuous film growth is only a matter of time.

Because the previous electron beam incidence upon the tape has modulated the number of nucleation sites, their effective energy and distribution, Φ_{ad} varies with the information content and one obtains a time dependence of the onset of permanent condensation. This is illustrated in FIG. 4*b* by curves 94 and 96, assuming a constant incident rate. Curve 94 represents a large exposure to electrons, curve 96 a smaller amount of irradiation, and curve 92 the unexposed background of the tape. The critical surface concentration of about 10^{14} atoms/cm.^{2} was found experimentally; at this point the reevaporation rate drops rapidly to zero and every incoming atom must be captured. By carefully controlling the zinc flux and the development speed, all zinc atoms are eventually deposited upon the recording tape without any loss of material to adjacent areas. Furthermore, by the very nature of the rotating development chamber, any rise of the incident rate does not precipitate the deposition of zinc on unwanted areas, because the process is self-regulating. This is best explained by FIG. 4*c*.

As shown, the tape enters the rotating development chamber on the left and is immediately exposed to a uniform zinc flux. Depending upon the image content it will take a certain time for even the most energetic centers to take full control over the deposition process, faithfully reproducing the desired information.

For all practical purposes, the time interval, from the first exposure of the tape to the zinc vapor to the onset of barely visible images, ranges from about 0.25 to 0.75 of the total time spent in the development chamber.

Normally the onset of visible condensation is chosen to be at about midpoint in the development chamber by adjusting the incident rate accordingly, hence a rise or fall of the number of incident atoms due to various demands of the tape will only shift this point either forward or to the rear without affecting anything else except the final optical density of the images. Curves **90** show the background at the several flux rates while the upper curves show the image deposition at the several flux rates. If unexposed tapes are fed into a development chamber while maintaining a steady efflux from the developer source, the number of available zinc atoms must increase within the volume of the chamber resulting in an excessive incident rate. With the rare exception of the rotating chamber configuration, autonucleation proceeds indiscriminately in the system and suddenly zinc atoms will condense everywhere. At excessive incident rates, the rotating chamber seldom becomes coated and the tape will always pick up the zinc even though it has not been exposed to electrons. This is made possible by the most favorable arrangement whereby the tape circles the developer source.

FIGS. **5** ad **6** show two extremes, in each case utilizing a filament-type zinc source. The FIG. **6** is typical for prior art arrangements and large incident rates are required to produce visible images in the shortest possible time. About 80 percent of the atoms may be lost, at TV-recording rates, whereas by using the rotating development chamber, all reevaporating atoms are collected, eventually, by other portions of the tape. Of course, a modified development system may be constructed whereby a uniform zinc flux is established over a length of tape. However, this is not a simple approach and requires not only a large area source, as is shown in FIG. **9**, but also a sizable backup surface. Since this "zinc reflector" is not renewed it may become coated in time, and adsorbs all the zinc available. In comparison, the "dead area" in the rotating chamber of this invention is quite small and the developer flux incident upon it is far below critical. Furthermore, the two rotating glass discs as well as the hub may be fitted with a stationary wiper as shown in FIGS. **7** and **8**. This felt-type rectangular wiper block **98** may be soaked in a suitable organic liquid of low free surface energy, thus providing continuous protection for the wiped surface from zinc deposition. The kind of recording medium is not critical. As a matter of fact, anything that has a controlled variation of the surface free energy upon it may be developed in this manner. The preferred media for electron beam recording/readout in near-real-time comprise mainly of photoconductive and photoemissive pigments combined with a nucleation inducing compound in a suitable binder. Decomposable compounds yielding nucleation centers of desired configurations upon electron, photon or ion bombardment may also be utilized.

This invention having been described in its preferred embodiment, and an alternative embodiment also described, it is clear that it is susceptible to numerous modifications and embodiments within the ability of those skilled in the art and without the exercise of the inventive faculty. Accordingly, the scope of this invention is defined by the scope of the following claims.

What is claimed is:

1. Means to develop latent images on an indefinite length moving web comprising:
   - a pair of axially aligned rotatable discs;
   - means to feed said web in a path to peripherally engage said discs so as to form a substantially closed chamber with the image areas on said web facing inwardly;
   - said moving web thereby rotating said discs;
   - a source of vaporized developer material disposed within said chamber; and
   - wiper means extending between said discs at an open area thereof with respect to said web whereby said discs are wiped clean of developer material.

2. The development chamber of claim **1** wherein at least one of said discs is transparent so that the development activity within said development chamber can be visually observed from exteriorly of said development chamber.

3. The development chamber of claim **1** wherein said discs are rotatably mounted by being mounted upon a rotatable hub, and said wiper engages said hub to wipe said hub as said hub rotates with said discs.

4. The development chamber of claim **1** wherein said wiper carries an organic liquid thereon having low free surface energy to deposit organic liquid on said discs as said wiper wipes said discs to inhibit deposition of atoms on said discs.

5. The development chamber of claim **1** wherein said first and second closure plates are of such material and are maintained at such a temperature that metal atoms at a suitable metal atom rate for imagewise deposition of metal atoms on the medium do not form a stable film on said first and second closure plates.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,585,965 Dated June 22, 1971

Inventor(s) Alfred F. Kaspaul

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 74, after "connection," delete "26." (Page 6, line 25).

Column 3, line 1, "10^{14}" should be --10^{-4}--. (Page 6, line 27).

Column 3, line 3, "10^{12}" should be --10^{-2}--. (Page 7, line 1).

Column 3, line 48, after "on", delete "19". (Page 8, line 18).

Column 3, line 73, "$n_e = {}_i$" should be --$n_e = n_i$--. (Page 9, line 17).

Column 3, line 75, "$cm^{12} \cdot sec^{11}$" should be --$cm^{-2} \cdot sec^{-1}$--. (Page 9, line 20).

Column 4, line 1, "$cm^{12} \cdot sec^{11}$" should be --$cm^{-2} \cdot sec^{-1}$--. (Page 9, line 21).

Column 4, line 2, "cm^{12}" should be --cm^{-2}--. (Page 9, line 22).

Column 4, line 4, "$mole^{116\ 1}$" should be --$mole^{-1}$--. (Page 9, line 24).

Column 4, line 5, "$deg^{11} \cdot mole^{11}$" should be --$deg^{-1} \cdot mole^{-1}$--. (Page 9, line 25).

Column 4, line 13, "10^{18}" should be --10^{-8}--. (Page 10, line 8).

Column 4, line 21, "10^{18}" should be --10^{-8}--. (Page 10, line 16).

(Continued on Page 2)

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Patent No. 3,585,965 Dated June 22, 1971

Inventor(s) Alfred F. Kaspaul

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 43, "10^{11}" should be --10^{-1}--. (Page 11, line 11).

Signed and sealed this 20th day of June 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents