March 22, 1966 N. S. KAPANY ETAL 3,242,328

ILLUMINATION DEVICE

Filed March 12, 1962 3 Sheets-Sheet 1

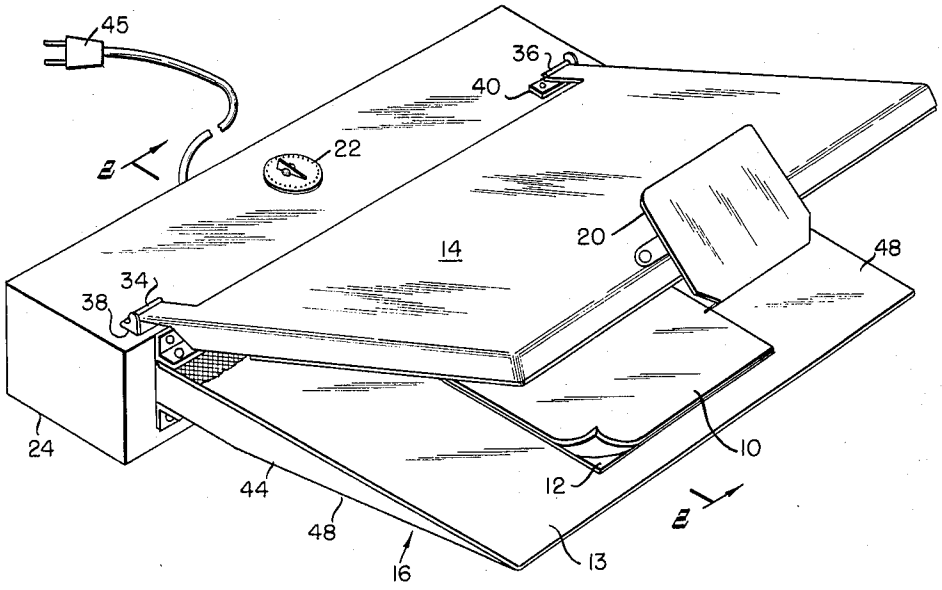

Fig. 1

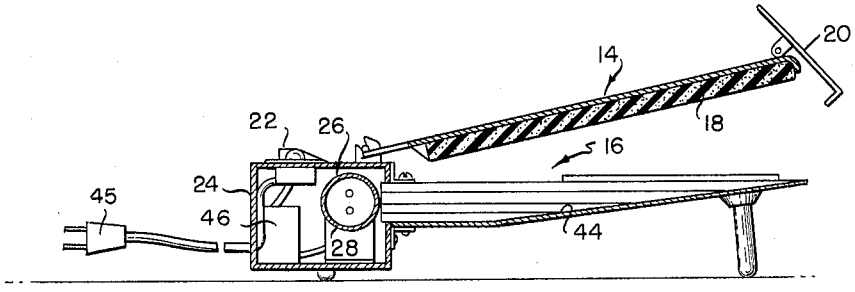

Fig. 2

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ILLUMINATION DEVICE

Filed March 12, 1962 3 Sheets-Sheet 2

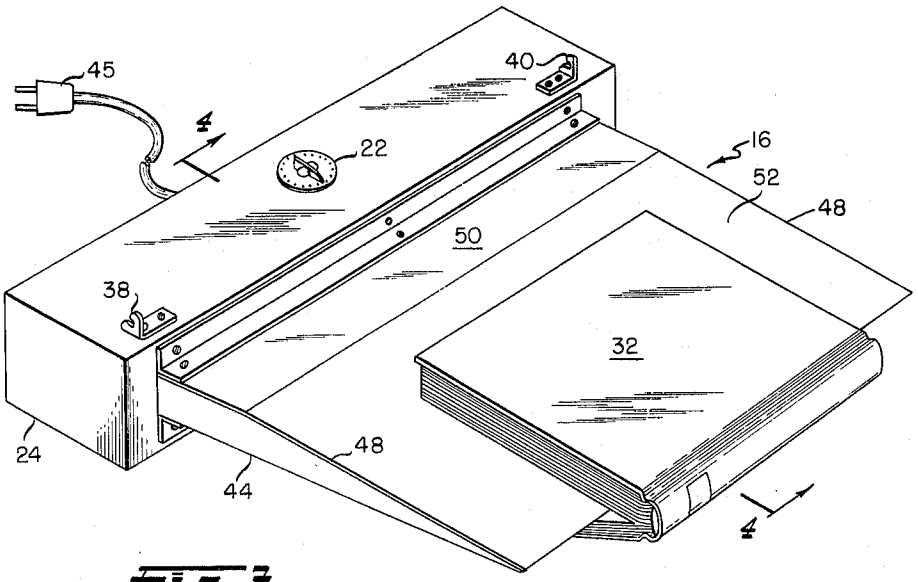
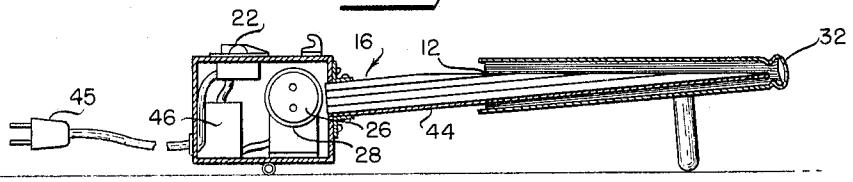


Fig. 3

Fig. 4



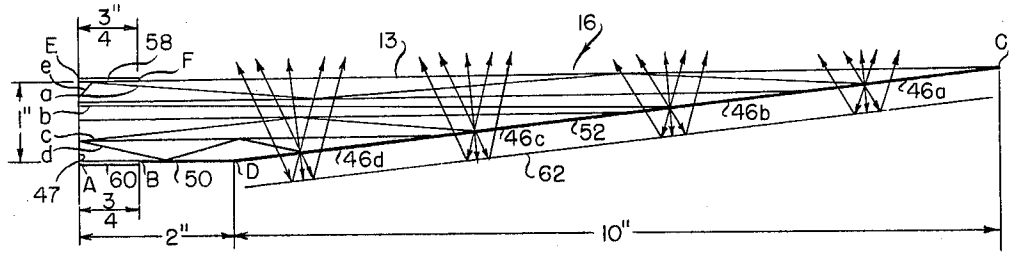


Fig. 6

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ILLUMINATION DEVICE

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Fig. 5

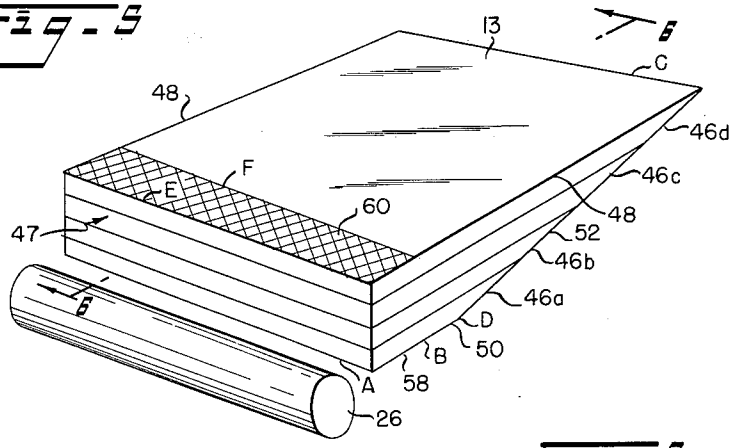
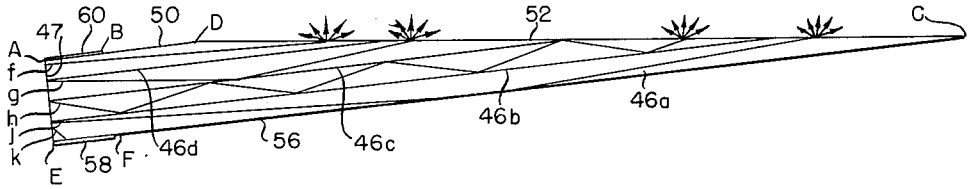


Fig. 6



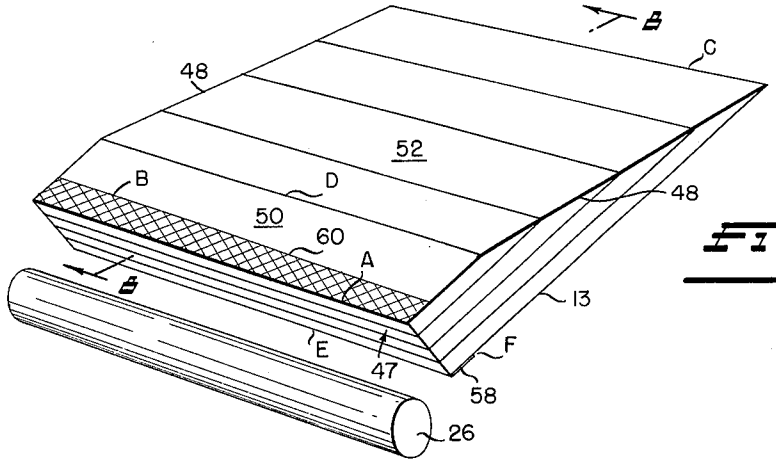


Fig. 7

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United States Patent Office 3,242,328
Patented Mar. 22, 1966

3,242,328

ILLUMINATION DEVICE

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Filed Mar. 12, 1962, Ser. No. 179,025
1 Claim. (Cl. 240—1)

This invention relates to illumination devices and, in particular, to illumination devices for use in making photographic exposures of image bearing sheets, such as typed or printed pages, on photosensitive paper. Specifically, this invention relates to illumination devices of the type described above incorporating edge-lighted illuminated panels composed of a plurality of light transmitting laminae.

Many types of photocopying exposure devices can be found on the market today but most are too cumbersome to be easily moved from one place to another and many include liquid developing baths which make moving the device a rather hazardous operation. A great number of these machines are equipped with inferior light distributing elements and, as a result, faded out areas and hot spots frequently appear on the copies, making good reproduction difficult. The large size of their light distributing elements makes it awkward and, occasionally, entirely impossible, to obtain an exposure of a page of a book without permanent injury to the backing of the book.

Edge-lighted prisms have heretofore been employed in photocopying devices in attempts to overcome the problems appurtenant to conventional photocopiers. One type of edge-lighted prism was formed from a single rectangular block of Lucite or optically similar material. One face of the block was roughened, and was oriented in a horizontal plane and constituted a light emitting and diffusing surface. A light source was positioned adjacent a highly polished end face of the block which acted as a light receiving surface. To insure a more uniform distribution of light, a number of horizontal, vertically spaced apart slots were provided in the block parallel to the light emitting surface, the block, therefore, consisting of a number of relatively thin, vertically spaced apart elements connected to each other adjacent the light receiving edge. The upper surfaces of these elements adjacent the light receiving face were highly polished to act as reflectors and the remainder of these surfaces were roughened to act as diffusers. The length of the reflecting portion of the lowermost surface was relatively short with this distance being increased for each successive element.

In theory, light rays emitted from the source would enter the light receiving edge of the block and be distributed among and travel through the several elements until the roughened surface portion was reached. As they impinged on the roughened surfaces, the light rays would be broken up and directed upwardly to the light emitting surface where they would be further broken up and emitted in a uniformly dispersed pattern. A typical edge-lighted prism of this type is illustrated in FIGURES 12–14 of United States Patent 2,347,665 issued May 2, 1944, to G. B. Christensen et al. for Internal Reflection Lighting Means.

The number of defects inhering in this type of prism rendered it impracticable. The comparatively thin, cantilevered, light transmitting elements were structurally weak, thus necessitating a complicated support structure. The prism was difficult and expensive to fabricate, especially the polishing and roughening of the surfaces of the light transmitting elements. It was impossible to obtain an exposure close to the binding of a heavily bound volume without injuring its backing. The uniformity of light distribution across the light emitting face was not satisfactory. Light rays entering the prism at an angle to the normal less than the critical angle were emitted directly from the light emitting face, and, as the number of such rays was large, hot spots (areas of high intensity) were produced on the emitting face adjacent the light receiving edge. This type of prism was inefficient, since a significant portion of each of the light rays broken up on the roughened surface of the elements would be directed downwardly rather than upwardly and would be lost.

Laminated edge-lighted prisms in accordance with the present invention, in contradistinction to devices of the type described above, are extremely strong structurally, being formed of a plurality of bonded together light transmitting laminae. They are easily and inexpensively manufactured as the necessary polishing and roughening operations may be performed before the laminae are assembled and the forming steps are comparatively simple. The novel wedge-like configuration makes it a simple operation to obtain an exposure of the page of a book without injuring its backing. An improved arrangement of light absorbing and reflecting elements together with the superior light conducting properties of the novel laminated structure eliminates hot spots and otherwise vastly increases the uniformity of light distribution. Novel reflection means may be employed to recapture downwardly directed rays, which would otherwise be lost, to increase the efficiency of the prism.

The primary object of this invention is, therefore, the provision of an improved light distributing element which will eliminate all faded out areas and hot spots on photosensitive copy paper when employed in a photocopying exposure device.

Another object of this invention is the provision of a relatively simple photocopying exposure device which is light in weight and comparatively inexpensive to manufacture.

Still another object of this invention is the provision of a photocopying exposure device which may be used to copy the pages of a bound volume without injury to the backing of the volume.

These and other objects of the present invention will become more fully apparent from the appended claim and the descriptive text that follows.

Basically, the apparatus consists of a rectangular, wedge-shaped, prismatic element composed of a plurality of superposed, preferably uniformly thick, internally reflective, light transmitting laminae together with a support cover, a light box, and a timer. The material to be copied or exposed is inserted between a lateral light emitting face of the prismatic element and the cover with a sheet of photosensitive paper. The cover is then closed and a timer control turned on. After a predetermined exposure time interval, the timer automatically turns the exposure device off and the original and copy may be removed and the copy developed in any convenient manner.

The same procedure is used when copying the pages of a book except that the cover of the device is removed and the book is held down upon the light emitting face of the light conductive element with the photosensitive paper between the page of the book and the element.

The invention will be more easily understood by referring to the following drawings wherein:

FIGURE 1 is a perspective view of a photocopy device embodying the principles of the present invention, showing it in the condition in which it is used to copy a single sheet;

FIGURE 2 is a sectional view of the photocopy device taken substantially along line 2—2 in FIGURE 1;

FIGURE 3 is a perspective view of a modified photocopy device embodying the principles of the present invention, showing it in the condition in which it is used to copy a page from a book;

FIGURE 4 is a sectional view of the modified photocopy device taken substantially along line 4—4 in FIGURE 3;

FIGURE 5 is a perspective view of the light conductive element as seen from above and in the orientation in which it is employed in the photocopy device illustrated in FIGURE 1;

FIGURE 6 is a sectional view of the light conductive element, taken substantially along line 6—6 of FIGURE 5;

FIGURE 7 is a perspective view of the light conductive element as seen from above and in the orientation in which it is employed in the modified photocopying device illustrated in FIGURE 3; and,

FIGURE 8 is a sectional view of the light conductive element taken substantially along line 8—8 of FIGURE 7.

FIRST EMBODIMENT

FIGURES 1 and 2 show a first complete physical embodiment of the invention. An original **10** to be copied and a sheet of photosensitive copy paper **12** are inserted as a two-ply laminar assembly between a pivoted cover **14** and an upwardly facing light emitting surface **13** of a laminated light conductive element **16**. Element **16** is a wedge-like prismatic body composed of a plurality of superposed, preferably but not necessarily uniformly thick laminae of light transmitting material which, in the specific illustrated and preferred embodiment, is methyl methacrylate (or as it is commercially known, Lucite). Element **16** will hereinafter be referred to as a laminated wedge for simplicity. The invention is not restricted to Lucite. Any similar rigid light conductive material, such as glass, fused quartz or any of the transparent plastic compositions which in themselves or which when coated with a material whose index of refraction is significantly different than that of the light conductive material exhibits the phenomenon of total internal reflection, may be used.

Lucite is particularly advantageous to use because its index of refraction is significantly different from the index of refraction of air to produce the phenomenon of total internal reflection. However, if other light transmitting material is used for the laminae of the wedge, the binder material used to bond the laminae together must be of a significantly different refractive index than that of the light transmitting material.

With the original **10** and the photosensitive paper **12** in place, the top cover **14** is lowered until a compression pad **18** (see also FIGURE 2) of plastic foam or sponge rubber compresses sheets **10** and **12** against light emitting planar surface **13** of wedge **16**. Top cover **14** is then locked in place by latch **20** and a timer **22**, located in light box **24**, is turned on.

Located inside of light box **24** (FIGURE 2) is a tubular fluorescent lamp **26** which is covered by a vinyl sleeve **28**, circumferentially lined with numerous graduated fine black circles (not shown) at predetermined, axially spaced intervals. Sleeve **28** is of a conventional construction which is frequently used on tubular fluorescent lamps to insure that even light distribution is attained the full length of the tube. Any type light source may be used in place of the fluorescent lamp.

When timer **22** is turned on, the fluorescent lamp **26** is instantly lighted. After the proper length of time necessary to expose the photosensitive paper **12** has elapsed, timer **22** automatically shuts off the machine and the exposed copy paper may be removed.

Generally, the structure of the apparatus is simple. Light box **24** may be constructed of sheet or die cast metal or of wood, metal being preferred for a more sturdy construction. Top cover **14** and support **42** for laminated wedge **16** may be constructed of similar materials. The

wiring of the apparatus is very simple and follows standard methods. Electric power is supplied from an A.C. outlet through a plug **45**, a switch (not shown) controlled by timer **22**, and a transformer **46** to the input terminals of lamp **26**.

Fluorescent lamp **26**, vinyl sleeve **28**, transformer **46**, and timer **22** are all standard items and can be of any commercially available construction.

An important item to note at this point in relation to fluorescent lamp **26** is that the length of the light emitting portion should be longer than light receiving edge **47** of laminated wedge **16** and its diameter should be greater than the width of this edge to assure uniformity of light concentration over the entire surface of edge **47** and thereby prevent faded out areas on the copy paper overlying the light emitting surface **14** of wedge **16** adjacent its lateral outside edges **48**.

The most important part of this invention is the novel formation of the laminated wedge **16** (see FIGURE 5) which embodies a very special geometry and arrangement of light absorbing, reflecting, and diffusing surfaces which, it has been discovered, gives a more uniform lighting over the entire copying surface **13** than any other design known to applicant. Referring to FIGURES 5 and 6, laminated wedge **16** is constructed of a plurality of superposed laminae of substantially uniform thickness bonded together by a suitable binding material. In FIGURES 5 and 6 four such laminae **46***a–d* are shown though it is to be understood that this particular number was selected for purposes of illustration and the particular number employed is not critical but will depend upon the particular application of the invention. Laminated wedge **16** has four lateral planar faces **13**, **47**, **50** and **52**. Faces **13** and **50** are parallel and are normal to the light receiving edge face **47** which they intersect at lines E and A respectively. Surface **13** is the light emitting face of laminated wedge **16**. Surface **52** intersects surface **50** at line D at a large obtuse angle and intersects surface **13** at line C a small acute angle. The acute angle is sufficiently small to permit insertion of the laminated wedge **16** between the pages of a book with line C closely adjacent its binding without injury to the backing and sufficiently large for structural strength and rigidity. Lines A, C, D and E are all parallel. Faces **13**, **47**, **48** and **50**, and the internally disposed surfaces of laminae **46***a–d* are all polished. Face **52** is uniformly roughened, as by sand blasting, and functions as a light diffuser. Equal width portions **58** and **60** (bounded by lines E and F and by lines A and B, respectively) of polished surfaces **13** and **50** are covered with a light absorbing material such as black paint.

FIGURE 6 illustrates the progress of four typical light rays *a*, *b*, *c*, and *d* through laminated wedge **16**. Ray *a* impinges on wedge edge face **47** intermediate the upper and lower surfaces of lamina **46***a* which it enters. It next impinges upon the lower surface of lamina **46***a* at an angle to the normal greater than the critical angle and is reflected upwardly to the upper surface of lamina **46***a*. Ray *a* proceeds, in this manner, through lamina **46***a* until it reaches edge face **52** intermediate the upper and lower surfaces of lamina **46***a*. Since surface **52** is roughened, ray *a* is broken up, half being emitted from roughened face **52** and half being reflected through lamina **46***a* and impinging on surface **13** at an angle to the normal less than the critical angle thus leaving the laminated wedge **16**. Ray *b* impinges on edge face **47** intermediate the upper and lower surfaces of lamina **46***b* at such an angle that it travels directly to edge **52** where it is broken up in the same manner as ray *a*. Ray *c* exhibits the same characteristics as ray *a* except that it enters edge face **47** intermediate the upper and lower surfaces of lamina **46***c* and is reflected between its upper and lower faces until it reaches edge **52**. Upon reaching edge **52**, it is broken up, half of it being reflected through laminated wedge **16** and impinging on surface **13** at an

angle to the normal less than the critical angle and thus leaving the wedge **16**. Rays *a*, *b*, and *c* are typical of the rays necessary for light to emerge from surface **56** in a uniform pattern.

To correct for hot spots (which are caused by greater levels of light intensity usually found adjacent the light source in the prior designs of edge lighted panels), means for intercepting the undesirable rays and means for increasing the probability of internal reflection within laminae **46***a–d* before a ray impinges on light scattering surface **52** are provided.

Ray *d* strikes surface **50** between lines A and D at an angle to the normal greater than the critical angle, is reflected to the upper surface of **46***d* and is then reflected downward to a light scattering point on surface **52** at a distance further along laminated wedge **16** than would have been found the case if this ray had hit surface **52** immediately after entering the wedge. Because there are many rays that will follow similar paths, the present invention purposely provides the reflective area between lines B and D on lamina **46***d* and on the contacting surfaces of laminae **46***a–d* so as to cause many of those rays to be reflected further down the laminated wedge **16** before impinging on face **52** and thereby eliminates the hot spots close to edge **47**.

Ray *e* enters edge **47** of laminated wedge **16** intermediate the upper and lower surfaces of lamina **46***a* and is immediately absorbed by black painted area **58**. This degree of downgrading is necessary to prevent the large number of random rays entering edge from also causing greater levels of light intensity or hot spots along this edge. Black painted area **60** serves the same purpose.

As noted in FIGURE 6, light emanating from surface **52** would normally be lost because it it is not coated with a bonding. To recapture this "lost" light, a sheet of white paper **62** may, in accordance with the teachings of copending application No. 103,355 filed April 17, 1961, now Patent No. 3,132,810, and assigned to the same assignee as this invention, be provided adjacent, but not in full surface-to-surface optical contact with, roughened surface **52**. The actual relation between surface **52** and sheet **62** is shown in FIGURE 6. The "lost" light is reflected and caused to re-enter laminated wedge **16**, augmenting the light emanating from printing surface **13**. Thus, it will be seen that maximum use has been made of light source **26**. It is, of course, to be understood that instead of using white paper **62** as a reflector, the same effect can be achieved by painting the inside surface **42** of wedge support **44** (FIGURE 2) white.

With respect to laminated wedge **16**, it is important to note that the bonded superposed laminae are optically independent. Thus, light entering edge **47** is trapped in the individual lamina and is transported without material loss to the light emitting face **52** of the wedge. As may be seen from FIGURE 6, the light is, because it does not leak from one lamina to another, distributed to and emitted from face **13** in a highly uniform pattern. The uniformity of distribution achieved by a laminated Lucite wedge in accordance with the principles of the present invention is, in fact, of an order heretofore unapproachable in edge-lighted illuminating panels.

The specific dimensions of one practical embodiment of laminated wedge **16** when made of Lucite are given in FIGURE 6. The relative proportions of these dimensions should preferably be kept substantially the same for optimum results.

SECOND EMBODIMENT

FIGURES 3 and 4 show a somewhat modified embodiment of photocopying device in accordance with the present invention set up to copy a page of a book. As in the first embodiment, the apparatus includes a rectangular, wedge-shaped, light conductive, laminated, bonded prismatic element **16** together with a support **44**, a light box **24**, a timer **22**, and a cover **14** (which has, in this instance, been removed for a purpose which will be explained presently). All of these components are identical to the corresponding components in the first embodiment with the exception of light box **24** and wedge support **44** which have been slightly modified to support laminated wedge **16** with face **52** (which in this embodiment is employed as the light emitting face) oriented in an upwardly facing horizontal position.

FIGURE 4 shows the machine set up to copy a page of a book **32**. The top cover (see FIGURE 1) is removed by lifting hinge pins **34** and **36** (FIGURES 2 and 4) out of slotted brackets **38** and **40**. The photosensitive paper **12** is then placed on light emitting face **52** of laminated wedge **16** and the page to be copied is placed thereon. Timer **22** is turned on and, as in the single copy reproduction, the proper exposure and subsequent development of the photosensitive paper will result in a perfect copy. It may be helpful to press down firmly on the book by hand to insure that the photosensitive paper is absolutely flat, which it must be to avoid blurred edges and distortion in reproduction of the printed matter closest to the page edge nearest the binding of the book. The laminated wedge **16**, due to its relatively sharp edge, fits easily between the pages of the book **32** closely adjacent the binding without injury to its backing.

In conjunction with the foregoing description, it will, of course, be understood that the second embodiment of the photocopying device may be employed in the same manner as the first embodiment to copy a single sheet of material and that the first embodiment may be utilized to copy the pages of a bound volume by proceeding in the manner described in conjunction with the second embodiment.

FIGURE 8 illustrates the progress of five typical light rays *f*, *g*, *h*, *j*, and *k* through laminated wedge **16**. Ray *f*, after impinging on edge **47** intermediate the upper and lower surfaces of lamina **46***d*, strikes the light scattering, roughened surface of light emitting face **52** where it is broken up, emerging from the face in a scattered pattern as shown in FIGURE 8.

Ray *g*, after entering edge **47** intermediate the upper and lower surfaces of lamina **46***c*, strikes the lower surface of lamina **46***c* at an angle to the normal greater than the critical angle and is reflected upwardly to surface **52** where it is broken up in the same manner as ray *f*. Ray *h* enters edge **47** intermediate the upper and lower surfaces of lamina **46***b* and is reflected alternately between these surfaces until it strikes, breaks up on, and emerges from surface **52**. Ray *j* follows a path through lamina **46***a* similar to that which ray *g* follows through lamina **46***c*. Rays *f*, *g*, *h*, and *j* are typical of the rays necessary for light to emerge from surface **52** in a uniform pattern.

Finally, ray *k* enters edge **47** intermediate the upper and lower surfaces of lamina **46***a* at an angle to the normal less than the critical angle and is immediately absorbed by the light-absorbing material **58**. As we explained above in conjunction with the description of laminated wedge **16**, provision of absorbing areas such as **58** and **60** (see FIGURES 5 and 7) is necessary to prevent the rays entering edge **47** from causing high levels of light intensity (hot spots) on surfaces **13** and **50** adjacent this edge.

The laminated wedge **16** employed in this embodiment is, as was pointed out above, identical with the wedge employed in the first embodiment, the distinction in the two embodiments being in the orientation of the wedge. In both embodiments then, light rays are entrapped in the laminae **46***a–d* at edge face **47** and transported without loss by internal reflection from the surfaces of the respective laminae to end face **52**. As they impinge on roughened end face **52** the rays are, in both embodiments, broken up and emitted from the face in a uniformly dis-

persed pattern. In the first embodiment the rays, after being emitted from face **52**, are, of course, reflected from an external reflector **62** through wedge **16** to surface **13** which is employed as the copying surface. In this embodiment, surface **52** itself is used as the copying surface. Highly uniform distribution of light across the copying surface is, it will be apparent, achieved in both embodiments since, in both, a uniform pattern of dispersement is established by light emitting face **52**.

Since lower surface **13** of lamina **46***a* is highly polished, thus constituting it a reflector, it is not necessary to employ an external reflector in this embodiment of the invention.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claim are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

In combination with an elongated light source, a wedge-like prism formed of a plurality of individual, superposed, light transmitting laminae of substantially uniform thickness bonded together to form a unitary structure,

each lamina having internal reflective surfaces and a light receiving first lateral surface, parallel second and third lateral faces intersecting and normal to said first lateral surface and fourth lateral face intersecting said third lateral face at an obtuse angle and intersecting said second lateral face at an acute angle, the said fourth lateral face of each lamina being aligned to lie in a single plane whereby the apex provided on the longest lamina is an acute angle which can be inserted into the binding of a book without damage thereto with the second and fourth lateral faces having complete area contact with the entire surface area of pages in said book, said prism being formed to transmit light from said source through one of said lateral faces selected from the second and fourth to substantially uniformly illuminate a facing book page.

References Cited by the Examiner

UNITED STATES PATENTS

2,347,665	5/1944	Christensen et al.	
2,480,178	8/1949	Zinberg	240—1
2,511,102	6/1950	Clouser	88—1 X
2,646,637	7/1953	Nierenberg et al.	240—1 X
2,995,970	8/1961	Hicks et al.	88—1
3,040,168	6/1962	Stearns	240—1 X
3,132,810	5/1964	Ostensen	240—1

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