June 24, 1941. D. B. BRADNER ET AL 2,246,501

GLOSSMETER

Filed March 1, 1939

Fig. 1,

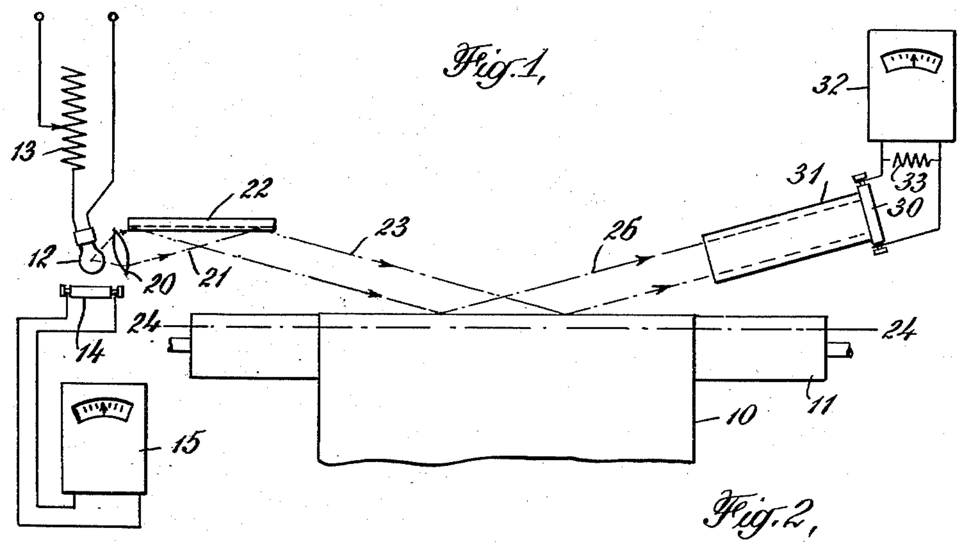


Fig. 2,

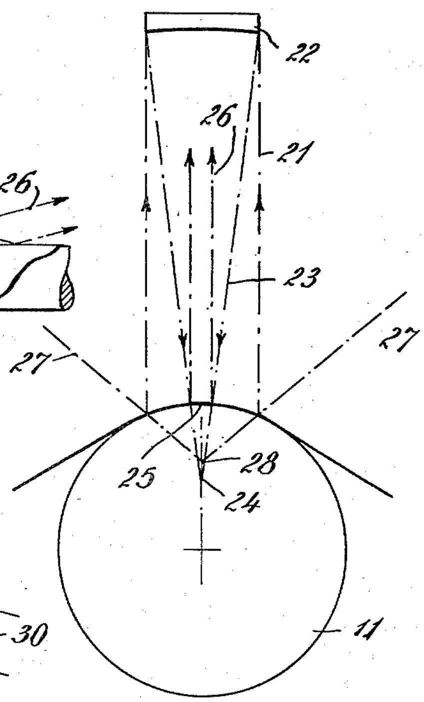


Fig. 3,

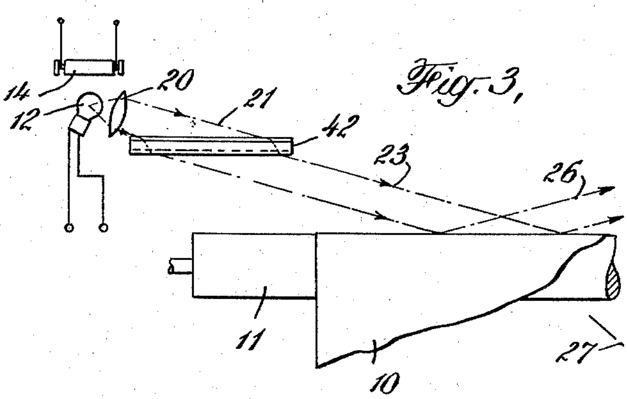
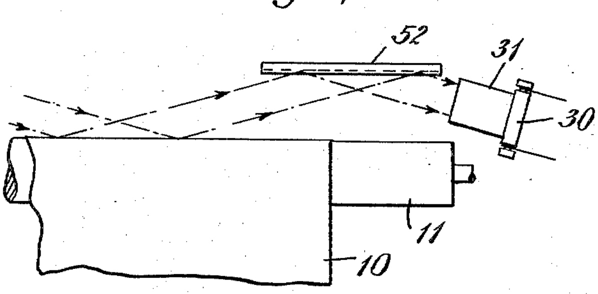


Fig. 4,



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2,246,501

GLOSSMETER

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8 Claims. (Cl. 88—14)

This invention relates to glossmeters, and more particularly concerns improvements in methods and apparatus for measuring gloss which make possible the measurement of gloss on a moving web of paper regardless of its speed of movement.

One of the most important properties of paper is its gloss, and more particularly the uniformity of the degree of gloss it possesses. The gloss characteristic is indicative to a great degree, not only of the appearance and feel of the paper, but also of the surface smoothness, density, and other of the properties which determine its printing quality. Thus if the manufacture of paper can be controlled to give it a uniform degree of gloss throughout, such control results in an enhanced uniformity of these other properties and consequently greatly increases its value to the printer.

It has heretofore been the practice to take samples periodically from the paper being produced, and compare their gloss with that of a sample to be matched, but in spite of the utmost care the gloss frequently varies considerably between samples taken, which therefore do not give a reliable index of the gloss throughout the length of the web. Attempts to decrease the space between samples taken give little better results and further seriously cut down production.

The prime requisite of an improvement in the uniformity of gloss throughout the length of a paper web is therefore a method and apparatus which will make it possible to get a substantially continuous, or at least a very frequent measurement of gloss on the web being produced without stopping production, breaking the web, or retarding its speed of movement.

The continuous measurement of the gloss on a paper web is a difficult problem. At usual paper web speeds, which may be of the order of 1,000 feet per minute, the web issuing from the calenders vibrates rapidly and the necessary web tension tends to produce longitudinal wrinkles therein. This is particularly true of light or moderate weight printing papers. Further, it is difficult to obtain gloss measurements over an area of the web which is large enough to be indicative of the gloss characteristic over the entire web surface, since the paper gloss characteristic usually varies considerably from foot to foot and even from inch to inch of the paper surface.

With the above considerations in mind, it is the primary object of the present invention to provide a method and means for continuously and accurately detecting and measuring the gloss characteristic of a rapidly moving paper web, such as a web of paper issuing from a calender, the method and means being of such a nature as to respond to the gloss characteristic of the paper over areas large enough to be representative of the entire paper web surface. An additional object is to provide a method and means of gloss measurement which corresponds closely with the visual gloss ratings made by those skilled in the paper finishing art, regardless of the color of the web. Other detailed objects of the invention will be apparent from the following description.

The method of gloss measurement which we prefer to use in connection with the present invention comprises directing a light beam of known or controlled intensity at an angle onto the surface whose gloss is to be measured and measuring the intensity of the beam after specular reflection from the surface. For measuring gloss on many grades of paper, high angles of incidence are of advantage—for example, angles of more than 60 degrees, and advantageously about 75 degrees with the normal to the surface, have been found to give results most closely approaching visual ratings by those skilled in the art, and least affected by the color of the surface. The measurement is ordinarily made photoelectrically, and to obviate fluctuations in the readings due to the variations in gloss on different parts of the moving web, we damp the variations in the current in the photoelectric circuit. In some cases, the gloss may be measured by determining the ratio of the specular to diffuse reflected light, but regardless of the particular method employed the output of the photocell should be damped.

The apparatus of a preferred embodiment of the invention includes means for supporting the paper web in a fixed and advantageously convex form, as by passing the moving web over a cylindrically convex surface such as a truly running roll. We prefer to use a cylindrical optical element in the path of the gloss measuring light beam to compensate for the dispersive effect of the convex form imparted to the paper web surface by its supporting means. The portion of the light beam specularly reflected by the paper surface is received by suitable light sensitive means such as a photoelectric cell whose output furnishes the desired indication of the gloss characteristic of the paper. The form and arrangement of the elements comprising our improved glossmeter, as hereinafter described, provide a gloss measurement over a sufficient width of the paper web to be fairly representative of the gloss of the entire web surface.

One preferred embodiment of the invention will be described by reference to the accompanying drawing in which;

Figure 1 is a diagrammatic view showing the general arrangement of the apparatus in relation to the moving paper web;

Figure 2 is a diagrammatic end view showing how the light rays are reflected by the cylindrical mirror and the cylindrical paper surface;

Figure 3 is a fragmentary view showing the changes in the structure required when using a cylindrical lens instead of the cylindrical mirror; and

Figure 4 is a fragmentary view showing the location of the photoelectric cell when using a cylindrical mirror in the path of the reflected rather than of the incident light beam.

In the disclosed embodiment of the invention, the surface of the paper web 10 issuing from a calender or other paper making or finishing machine, is held in a fixed form at any convenient location, by passing it over a freely turning, accurate, and truly running fly roll 11, with the side on which the gloss is to be measured away from the roll. This gives a cylindrically convex form to the surface on which the measurement is to be made. The tension on the web tends to hold it in intimate contact with the surface of the roll and thereby to give a definite geometrical form of known optical properties to the paper surface at this location. The angle of wrap of the paper around the roll should be sufficient to ensure that the entire illuminated area of paper will be given the desired cylindrical form.

Light is provided from any suitable source, here shown as an incandescent lamp 12 whose filament provides a high intensity source of small area. The lamp shown is operated on a low voltage circuit on which the voltage is kept constant by a constant voltage transformer or other known means, not shown. An adjustable resistance 13 is placed in the lamp circuit for adjusting the intensity of the light.

In order to make certain that the intensity of the light remains at a constant predetermined value, a photoelectric cell 14 is placed where it is continuously illuminated by the lamp 12. The cell 14 is connected to a meter 15 which may be adapted to continuously indicate, or record, or both, the intensity of the light. Variation from standard intensity due to aging of the lamp or other cause is thus immediately indicated and can be corrected by adjusting resistance 13.

Light from the source 12 is collimated by a condenser lens 20, or other suitable means. The substantially parallel beam 21 from the condenser falls upon the cylindrically concave surface of the mirror 22. The light beam 23 reflected from the mirror remains substantially parallel in the vertical projection illustrated in Figure 1, but converges, in the projection illustrated in Figure 2, towards the focal line 24 of the mirror 22. The mirror 22 is located so that its focal line 24 coincides with the virtual focal line of the cylindrical surface of the web 10 on roll 11. Consequently that part of the light in incident beam 23 which is specularly reflected from the surface of the web 10 on roll 11, leaves the cylindrical surface of the paper as a substantially parallel beam 26.

In the path of the beam 26, is placed a photoelectric cell 30 which is protected from extraneous light by suitable means such as a cylindrical shield 31. An electrically responsive meter 32 of any suitable type may be used to measure and visually indicate the output of cell 30 and thereby the gloss on the web, or a recorder may be added to the meter 32 to give an autographic, advantageously a continuous record of the gloss on the moving web. A resistance 33 is placed across the terminals of the meter 32. The value of this resistance is chosen with reference to the resistance of the meter 32 to provide means for electrically damping fluctuations in the current from photocell 30. In place of this electric damping element suitable mechanical damping means may be provided in the meter 32 in a manner well known in the art.

As can be seen from Figure 1, the incident light beam 23 is arranged to cover a considerable area along the length of the roll 11, i. e., across the width of the moving web. The width which needs be covered is not fixed, but is preferably over three inches and is advantageously not less than nine inches in order that the gloss reading may show the average over a fairly representative area of the paper surface. Thus on a thirty-six inch wide web the gloss reading may represent the actual average gloss of more than 25 per cent of the entire area of finished paper, and truly representative gloss measurements are accordingly obtained.

It should be noted that, as shown in Figure 2, the mirror 22 concentrates the light beam to cover a very small arc 25 on the circularly cylindrical surface imparted to the web 10 by the roll 11. Because of the direction of paper travel, narrowing the beam in this direction does not decrease the paper area on which the gloss is measured. This concentration of the beam not only increases the intensity of illumination, but, by virtue of the small arc, the surface so nearly approximates a parabola that it has an approximately true virtual focus at the line 24 parallel to the roll axis, and the specularly reflected beam 26 is much more nearly parallel than if reflected from a larger circle arc.

It is possible in accordance with the invention to substitute an equivalent cylindrical lens 42 (Fig. 3) for the cylindrical mirror 22, by arranging the lens to direct the incident light beam 23 to the focal line 24 of the cylinder, as was done with the mirror 22. With the high angles of incidence found advantageous for measuring gloss however, I generally prefer to use the mirror because it involves a smaller light loss.

It is also possible to introduce a cylindrical lens or mirror into the path of the specularly reflected beam 26 instead of the incident beam 21, and still secure a measure of compensation. However, if the parallel beam 21 is incident directly on the paper 10 on roll 11, specular reflection from the cylindrical surface disperses the beam as indicated by the broken lines 27—27 (Figure 2). In this case, the reflected rays no longer appear to issue from a virtual image at 24, but appear to come from an area between 24 and 28. To gather a substantial portion of this dispersed light, the cylindrical lens or mirror has to be much wider and closer to the roll 10 than is mirror 22. The reflected beam, even if rendered parallel thereby, is much broader and much less intense than with the arrangement illustrated in Figure 1. Furthermore, in order to secure even approximate compensation, special forms of lenses or mirrors are required, and it is further desirable to narrow the incident beam or greatly increase the diameter of the roll 11, or both, to reduce the arc illuminated and cut down the angularity of dispersion **27**. In case a mirror **52** is used in the path of the reflected beam, it is, of course, necessary to relocate the photoelectric cell **30** so that it receives the beam from the mirror, as shown in Figure 4.

Instead of passing the paper over roll **11**, it would also be possible to drag the web over a cylindrically convex surface of parabolic or any other desired form. It is simply necessary to make the cylindrical lens or mirror of proper form to at least approximately compensate for the dispersive effect of the convex surface on which the measurement is to be made. While cylindrical lenses can conveniently be made to compensate for only a limited number of forms of convex surface, it is possible to design a cylindrical mirror to compensate for the form of practically any convex surface which it may be desired to use.

Instead of directing the light beam transversely of the paper web, the beam may be directed at some other angle, for example, longitudinally of the web, in a plane perpendicular to the cylindrical surface. This arrangement permits measurement of the gloss in the direction of the grain, as it is commonly judged visually. In such case the angle of incidence should be held within the limits specified and the light should be directed onto the paper in such a manner that the light specularly reflected from the paper will be in the form of a substantially parallel beam. In the specific embodiments described, the specularly reflected light has been in the form of a substantially parallel beam. Although this has a number of advantages, the specularly reflected light may be in the form of a divergent or convergent beam so long as variations in the specularly reflected light corresponding to gloss changes are sufficient to actuate the photocell.

Although any of the known types of photoelectric cell may be used, the device is simpler and the results are more accurate when using a type of cell which does not require the application of potential from a source outside the cell. The type of cell described in United States Patent No. 2,034,334, for example, has been found satisfactory.

To facilitate the understanding of a construction and arrangement of parts which makes a gloss measurement over a wide area of the web, the following details of a specific embodiment typifying the invention are given.

The roll **11** is adapted to take a web up to 60 inches in width, is about 5.9 inches in diameter and its surface has a virtual focus approximately 1.475 inches below its outer surface. Lens **20** is a paraboloidal lens of 60 mm. focal length, and $2\frac{7}{16}$ inches diameter. The lamp **12** is a 50-candle power incandescent lamp of a type similar to those used for automobile headlamps, and is located approximately at the focal point of lens **20** or very slightly beyond. The concave mirror **22** is approximately $9\frac{1}{2}$ inches long and $2\frac{3}{8}$ inches wide and has a radius of curvature of approximately 16.692 inches and focal length of approximately 8.346 inches. It is set so that its focal line is substantially coincident with the virtual focal line of the surface of the paper web wrapped around roll **11**. The photocell **30** is of the type described in United States Patent No. 2,034,334, and has an effective diameter of approximately $2\frac{3}{8}$ inches. The incident beam **23** makes an angle of approximately 15 degrees with the axis of the roll **11** and covers an area over 9 inches along the length of roll **11**. Measured along the axis of the beam, the distance from lens **20** to mirror **22** is approximately $7\frac{1}{2}$ inches, that from mirror **22** to roll **11** is approximately $26\frac{1}{2}$ inches, and that from roll **11** to photocell **30** is approximately the same. The measurements of gloss secured with this arrangement have been found to be dependable and repeatable and to check well with the visual gradings made by those skilled in the art.

As pointed out above, it is preferred to locate the photoelectric cell **30** at a considerable distance from the area of the paper on which the light is reflected, and we have found that this distance may advantageously be at least ten times the greatest dimension of the exposed surface of the photoelectric cell. With these proportions, relatively little of the light diffusely reflected from the paper surface reaches the photoelectric cell, and the readings are found to check closely with the visual judgments of experts in the grading of paper.

The term "cylindrical light converging element," as used in the appended claims, designates an optical element having the property of a convergent cylindrical lens (or a cylindrically concave mirror) of deflecting parallel light rays in a manner to bring them to a substantially rectilinear focus parallel to the axis of the cylindrical element. Such an element has a focal line instead of the focal point of the common circular convergent lens or concave mirror.

The term "focal line," as used in the appended claims with respect to a cylindrical light converging element, designates the line towards which parallel light rays, directed along the light path used in the instrument, will be caused to converge after reflection or refraction by the element. The term "virtual focal line," as used with respect to a cylindrically convex reflecting surface, designates the line from which parallel light rays, directed backward along the path of the specularly reflected beam in the instrument, will be made to appear to diverge by specular reflection from the surface. As is well known, aberrations which vary with the effective aperture, prevent these from being true geometrical lines, but it is to be understood that, as in all optical instruments, the apertures or width of arc illuminated are so limited as to prevent these aberrations from exceeding practical limits.

In the appended claims the expression a "moving paper web" refers to a traveling web of paper continually presenting a new surface in contradistinction to a sheet of paper which may be pasted or otherwise held to a moving support and which recurrently presents the same surface to the gloss measuring device.

By describing our invention in connection with the measurement of gloss on paper, we do not preclude the use thereof for the measurement of gloss on other materials to which it may be found applicable.

We claim:

1. In a device for measuring gloss on paper, in combination with a moving paper web, a fixed cylindrical paper support for giving a cylindrical form to the paper where its gloss is to be measured, a light source, means for directing a beam of light from said source onto the paper web on said support, said means including means for collimating the light into a beam of substantially parallel rays and a cylindrically concave mirror in the path of the collimated beam, said mirror being set with its focal line approximately

coincident with the virtual focal line of the cylinder formed by paper on said support, whereby said light beam after reflection by said mirror converges towards said virtual focal line, and means for measuring the intensity of that part of the light from said beam which is specularly reflected by the paper.

2. In a device for measuring gloss on paper, in combination with a moving paper web, a fixed cylindrical paper support for giving a cylindrical form to the paper where its gloss is to be measured, a light source, means for directing a beam of light from said source onto the paper web on said cylindrical support in a plane substantially axial to said support, said light directing means including means for collimating light into a beam of substantially parallel rays and a cylindrically concave mirror in the path of the collimated beam, said mirror being set with its focal line approximately coincident with the virtual focal line of the cylinder formed by paper on said support, whereby said light beam, after reflection by said mirror, converges towards said virtual focal line, and means for measuring the intensity of that part of the light from said beam which is specularly reflected by the paper.

3. A device for measuring gloss on paper comprising a cylindrically convex support for giving a definite form and position to the paper whose gloss is being measured, a light source, a lens for collimating light from said source into a beam of substantially parallel rays, a cylindrical light converging element disposed parallel to said support and in the path of said beam with its focal line approximately coincident with the virtual focal line of the cylinder formed by the paper on said support, whereby that part of the light beam which is specularly reflected by the paper on said support is in the form of a substantially parallel beam, and means for measuring the intensity of that part of the light from said beam which is specularly reflected by the paper.

4. In a device for measuring gloss on a moving web, a truly running cylindrical roll over which the web travels to give it a fixed form and position where its gloss is to be measured, a light source, means for collimating light from said source into a beam of substantially parallel rays, a cylindrical light converging element mounted parallel to said roll in the path of said beam with its focal line approximately coincident with the virtual focal line of the cylinder formed by the web on said roll, said cylindrical light converging element being so disposed that the convergent light from said beam is caused to travel in a plane axial to said roll and to strike the cylindrical surface of the web on said roll at an angle of less than thirty degrees therewith, and to illuminate an area thereon which is long in the direction of the roll axis and narrow in the other direction, whereby that part of the light which is specularly reflected by the cylindrical surface of the web emerges therefrom as a substantially parallel beam, a photoelectric cell positioned to receive the specularly reflected beam and means for measuring the output of said cell.

5. The method of measuring gloss on paper, which comprises bending the paper around and in contact with a cylindrically convex surface to give it definite form and position, collimating light from a small area light source to form an approximately parallel ray light beam, concentrating the light rays in said beam in one direction to converge to a substantially rectilinear focus which is substantially coincident with the virtual focal line of the illuminated area of the convex surface of the paper, whereby that part of said beam which is specularly reflected by said surface leaves said surface as a substantially parallel beam, and measuring the intensity of said specularly reflected beam.

6. The method of measuring gloss on a moving web, which comprises passing the web in contact with a cylindrically convex surface to give it definite form and position, collimating light from a small area light source to form a substantially parallel ray light beam, concentrating the light rays in said beam in one direction to converge to a substantially rectilinear focus which is substantially coincident with the virtual focal line of the illuminated area of the cylindrically convex surface of the web, directing said convergent light beam onto said cylindrical surface at an angle of less than thirty degrees therewith and in a plane substantially axial thereto, whereby that part of said beam which is specularly reflected from said convex surface emerges therefrom as an approximately parallel beam in the same axial plane, and measuring the intensity of said specularly reflected beam.

7. The method of measuring gloss on a moving web, which comprises passing the web in contact with a cylindrically convex surface to give it definite form and position, collimating light from a small area light source to form a substantially parallel ray light beam, concentrating the light rays in said beam in one direction to converge to a substantially rectilinear focus which is substantially coincident with the virtual focal line of the illuminated area of the cylindrically convex surface of the web by projecting said beam onto a cylindrically concave mirror, directing said convergent light beam onto said cylindrical surface at an angle of less than thirty degrees therewith and in a plane substantially axial thereto, whereby that part of said beam which is specularly reflected from said convex surface emerges therefrom as an approximately parallel beam in the same axial plane, and measuring the intensity of said specularly reflected beam.

8. The method of measuring gloss on a moving web, which comprises passing the web in contact with the convex surface of a right circular cylinder to give it definite form and position, collimating light from a small area source to form a substantially parallel light beam, concentrating the light rays in said beam in one direction to converge to a substantially rectilinear focus which is substantially coincident with the virtual focal line of the illuminated area of the cylindrically convex surface of the web, and directing said convergent beam onto said cylindrical surface at an angle of less than thirty degrees therewith and in a plane substantially axial thereto, whereby it illuminates an area on said surface the width of which area is small relative to both the radius of curvature of the surface and the length of the area axially of the cylindrical surface, and whereby that part of said beam which is specularly reflected from said surface emerges therefrom as an approximately parallel beam, and measuring the intensity of the specularly reflected beam.

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