June 16, 1942. L. T. SACHTLEBEN 2,286,836

BOTTLE INSPECTION APPARATUS

Filed July 29, 1939 2 Sheets-Sheet 1

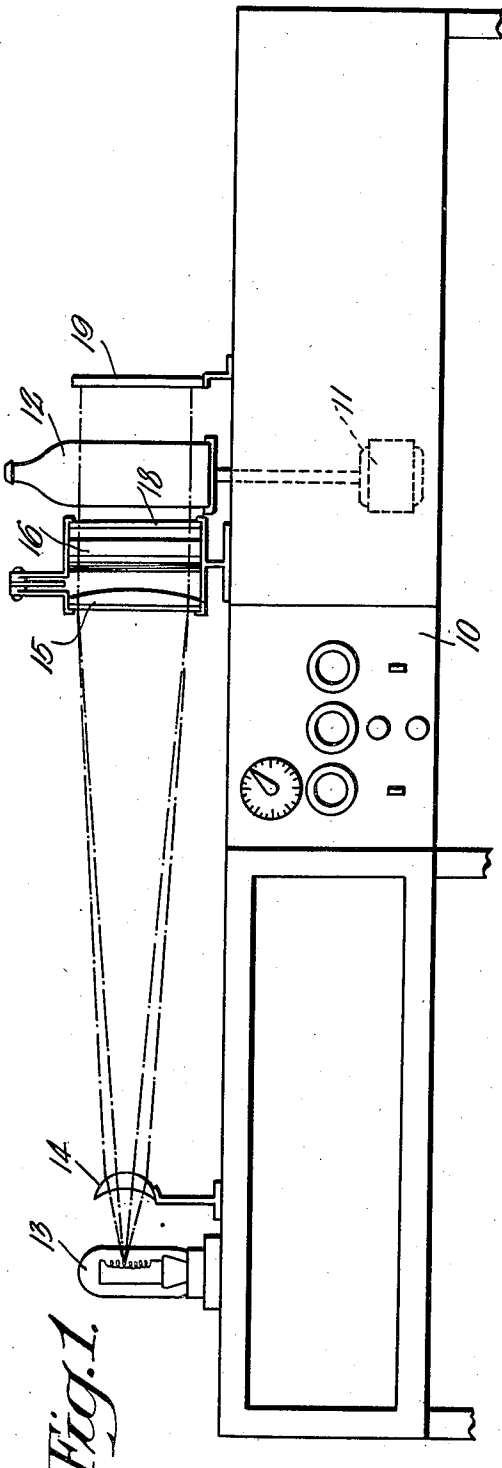


Fig. 1.

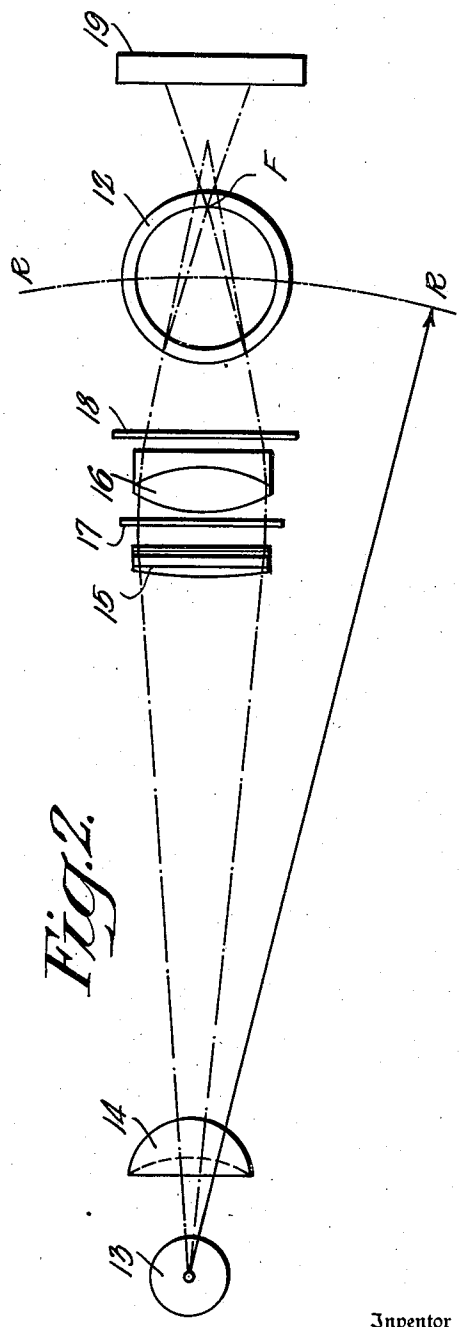


Fig. 2.

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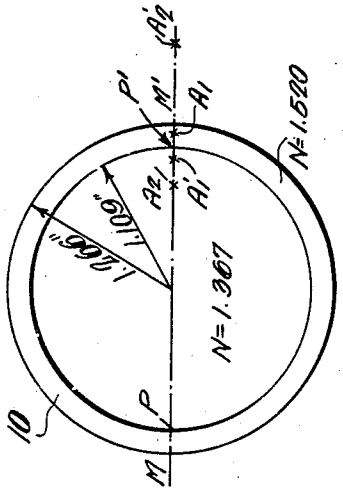


Fig. 3.

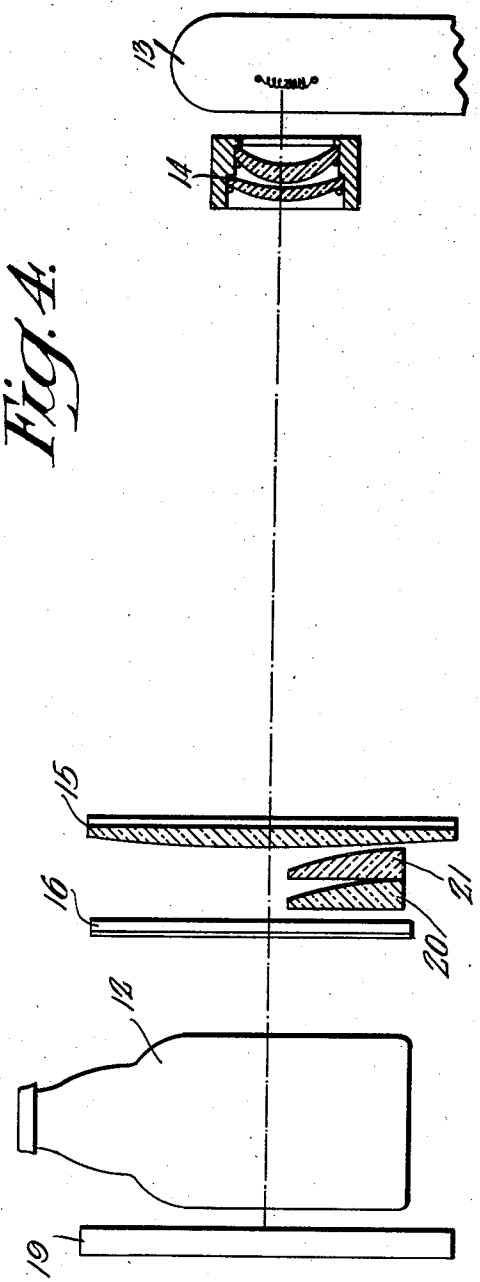


Fig. 4.

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2,286,836

UNITED STATES PATENT OFFICE

2,286,836

BOTTLE INSPECTION APPARATUS

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Application July 29, 1939, Serial No. 287,314

2 Claims. (Cl. 88—14)

This invention relates to apparatus for inspecting the contents of transparent bottles and relates particularly to apparatus for inspecting the contents of bottles having substantially straight sides such, for example, as beer bottles, as distinguished from fluted or otherwise oddly-shaped bottles.

The subject matter is related to and is an improvement on the bottle inspecting device of my application Serial No. 133,992, filed March 31, 1937, issued March 5, 1940, as Patent 2,192,580. It has heretofore been proposed to inspect the contents of bottles for foreign material without rendering the apparatus sensitive to defects in the bottle itself by rotating the bottle until the contents reach an appropriate speed of rotation and then stopping the bottle and permitting the contents to rotate in the inspection beam as, for example, in the Stout Patent No. 2,132,447. This procedure is particularly adapted to fluted bottles or bottles having other decorations or labels pressed or blown in the glass. In the case of a circular bottle, such as the conventional beer bottle, the same procedure is advisable for the reason that any flaws in the glass do not affect the inspecting apparatus and the inspection can be made accordingly with apparatus of very high sensitivity.

In order to secure the greatest advantage from the method of inspection just described, it is necessary to provide an optical system which will direct light in the form of a narrow brilliant line through the material adjacent the inner surface of the bottle. The centrifugal force in the rotating fluid throws any particles toward the outside and these particles interrupt the light. The light passes from this inspection point to a photocell or bank of photocells of appropriate type and interruption of the light beam causes an appropriate amplifier connected to the photocells to respond.

The present invention involves an optical system having such an arrangement of lenses as to produce a particularly accurate and brilliant line of light within the bottle.

One object of the invention is to provide an optical system of the type described which will transmit a large quantity of light.

Another object of the invention is to provide an optical system of the type described which is as highly corrected as the commercial tolerances in the bottle inspected render desirable.

Another object of the invention is to provide such an optical system, which is achromatically corrected.

Other and incidental objects of the invention will be apparent to those skilled in the art and from a reading of the following specification and an inspection of the accompanying drawings in which

Figure 1 is a side view of one type of inspection apparatus showing my improved optical system,

Figure 2 is a longitudinal section in the horizontal plane through the optical system of Figure 1,

Figure 3 is a diagram illustrating the refractive effects in a bottle, and

Figure 4 is a longitudinal vertical section through a modified form of the optical system.

Referring first to Fig. 1, the inspection apparatus generally indicated at 10 is provided with a motor 11 adapted to spin the bottle 12 together with its contents and to stop the bottle during the inspection period. Light from the source 13 passes through the meniscus condenser 14. The condenser collects the light and directs it on to the lens 15. This lens 15 is preferably in the form of crossed cylinders, one having its axis vertical and the other having its axis horizontal and with the focal length of each being 15 inches. If desired, other equivalent curves may be substituted for the crossed cylinders. This condenser renders the light divergent from the condenser 14 parallel. Appropriate diaphragms 17 and 18 may be provided for restricting the beam to the desired dimensions.

An achromatic cylindrical lens with its axis vertical is provided at 16. This lens preferably has a focal length of 5½ inches and the bottle is so located that a vertical line of light is focused by the lens 16 at the point *f* in Fig. 2. The light diverges from this focal point to the photocell 19. In the form of the invention shown in Figs. 1 and 2, the bottle 12 is not necessarily stationary but may be moved along an arc RR which has its center at the filament of the lamp 13, which is located at the focal point of the lens 14.

Since one commercial form of the invention has been described, it is desirable to describe the theory thereof:

Measurements on samples of Pilsner and Lager beer indicate the index of refraction to be 1.387 and 1.367, respectively. The index of the bottles is taken to be 1.520. The "regular" 12 ounce bottles have a representative inside diameter of 2.218" and wall thickness of $\frac{3}{16}$", while the "stub" bottles have a representative inside diameter of 2.594" and wall thickness of $\frac{3}{32}$". The inspectable height of the "regular" is 5" and the "stub", 3¾".

The purpose of the optical system is to produce a line image as sharp and bright as possible and of a width of the order of 1/64", upon the inside wall of the bottle, so that as the contents whirl in the stationary bottle, foreign particles following the bottle wall will produce the largest possible percent change in light as they pass through the beam. Inasmuch as the line image will be produced with a cylindrical lens its unit brightness will be proportional to the angle of convergence of the marginal rays as they approach the image plane, and also to the index of refraction of the medium in which the image is formed. If the optical power of the bottle (and contents) itself is employed in the formation of the image, the convergence angle and therefore the unit-brightness is improved about 50 percent over that which would be obtained only with the external cylindrical lens which is introducing light into the bottle, and this gain in illumination of 50 percent is obtained without appreciable introduction of aberration, and therefore reduction of image sharpness, due to the fortunate circumstance that the refractions at the bottle surfaces, both external (air to glass) and internal (glass to beer) are very nearly aplanatic refractions. An additional gain of about 37 percent is due to the index of the beer which is about 1.37, bringing the total increase to about 100 percent over the external cylinder alone.

Fig. 3 represents a section of a bottle of index 1.520 and contents of index 1.367, having radii of curvature as shown. The bottle is in air whose index is 1.000. If we assume a pencil of rays originating (actually or virtually) at some point on the axis M, M' (in the medium of index N) and travelling from right to left there will be a position of that point, A_1, for which

$$PA_1 = L_1 = r_1 \frac{N+N'}{N}, \quad (=2.342'')$$

at which position its refraction at the boundary P will produce an image at the point A_1' for which

$$PA_1' = L_1' = r_1 \frac{N+N'}{N'}, \quad (=2.110'')$$

said image being entirely free of spherical aberration. Likewise, if we assume a pencil of rays originating (actually or virtually) at some point on the axis M, M' (in the medium of index N') and travelling from right to left, there will be a position of that point, A_2, for which

$$MA_2 = r_2 \frac{N'+N''}{N'}, \quad (=2.098'')$$

at which position its refraction at the boundary M will produce an image at the point A_2' for which

$$MA_2' = r_2 \frac{N'+N''}{N''}, \quad (=3.188'')$$

said image also being entirely free of spherical aberration.

Since the point P', in whose image we are primarily interested, lies quite close to the aplanatic point A_1, its image, by refraction at the boundary P, will suffer only slightly from spherical aberration. $P'A_1 = 0.124''$ or about 11% of the radius r_1. $A_2A_1' = 0.169''$, but the image of P' lies closer to A_2 than does A_1', the actual separation between A_2 and the image (paraxial) of P' being 0.075" or about 6% of the radius, r_2, and it is therefore seen that the refraction at the boundary M will also be very nearly aplanatic. Actual trigonometrical traces of a pencil of 30° aperture originating at P' in the bottle described result in an image distance from M to the paraxial focus of 3.580", and from M to the marginal focus of 3.596", or a longitudinal spherical aberration of about 1/64". The condition in the stub bottle is not quite so good, as the inside diameter has been increased without a proportionate increase in wall thickness. In the stub bottle the paraxial image distance from M is 4.180" and the marginal image distance from M is 4.213" by trigonometrical trace, the longitudinal aberration LA being about 1/32". Although surface defects and the variations in radius of curvature of blown bottles will be large from the standpoint of precise optics, it will be seen that a sharp and bright line of light can be produced along the element P' of the cylindrical surface by suitably directing a beam of light into the bottle with a cylindrical lens corrected in conventional fashion.

In the form of the invention shown in Fig. 4, the optical system is slightly modified in that the condenser **14** is divided into two parts in order to secure higher efficiency. This arrangement permits a condenser of shorter focal length to be used and provides correspondingly more light. In addition, prismatic cylinder lenses **20** and **21** are inserted between the lens **15** and the lens **16** for increasing the illumination at the bottom of the bottle. This is desirable because heavy particles of foreign material tend to settle to the bottom and are more readily detected by a slight increase in illumination at that point. In this form of the invention, the characteristics of lenses **15** and **16** are the same as those given in connection with Figs. 1 and 2.

Having now described my invention, I claim:

1. An optical system of the class described including a light source, a condensing lens, means for positioning a substantially cylindrical liquid filled bottle at an inspection point, a second condenser lens adjacent said inspection position for rendering the beam of light from said first condenser lens substantially parallel, and effectively cylindrical lens means located between said second condenser means and said bottle and having a radius of curvature and spacing from said bottle so related to the radius of curvature of the bottle and its contents and the index of refraction of each as to form with the said bottle and its contents an aplanatically corrected system for an image plane within the side of the said bottle opposite said lens.

2. An optical system of the class described including a light source, a condensing lens, means for positioning a substantially cylindrical liquid filled bottle at an inspection point, a second condenser lens adjacent said inspection position for rendering the beam of light from said first condenser lens substantially parallel, and effectively cylindrical lens means located between said second condenser means and said bottle and having a radius of curvature and spacing from said bottle so related to the radius of curvature of the bottle and its contents and the index of refraction of each as to form with the said bottle and its contents an aplanatically corrected system for a linear image plane within the side of the said bottle and parallel to the axis thereof.

LAWRENCE T. SACHTLEBEN.