## STEREOSCOPIC MOVING PICTURES IN NATURAL COLORS.

BY THE ENGLISH CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

During the past few months several devices have been perfected for producing moving pictures in their natural tints, all carried out upon the same lines. All suffer from the same disadvantage—the color rendition upon the white screen is imperfect and untrue. Mr. William Friese-Greene, F. R. A. S., F. R. M. S., exhibited in London as far back as 1898 a series of animated natural-color pictures. The system, which he duly patented, was to revolve a disk of glass divided into three equal sized sectors, each representing one of the three fundamental colors, and revolving it in front of the lens as the exposures were being made, each section of the sensitized film (corresponding with the size of the ordinary cinematographic picture) being exposed through one of the three color filters. In making the subsequent projection the colored disk was again revolved in such a manner that the same relationship of picture to color filter that prevailed during the exposure of the negative was repeated. The rays of light consequently passed through the black-and-white film and thence through the color filter. The resultant picture was projected in accordance with the well-known phenomenon of visual persistence, producing the impression of a complete three-color image.

The demonstration aroused considerable interest, but the inventor soon realized that such a system possessed one serious disadvantage. The glass disk had necessarily to be of a certain thickness—from one-sixteenth to one-twelfth of an inch—so that there was a certain depth of transparent glass through which the light rays had to pass before or after reaching the color filter, depending on whether the color side of the disk was next to the transparent film or reverse. This fact produced disturbances in light refraction and reflection, of such a severe character that the projected image as seen upon the white sheet was a color distortion and a crude reproduction of nature. The extent of the deflection of the light rays in passing through the transparent thickness of the glass disk varied considerably, and in the resultant picture occurred an undue predominance of one or two colors, which completely destroyed the natural effect. It is this system which is now being developed by various experiments in the field of chromo-photography, but which the original inventor abandoned for the foregoing reasons.

By continuing his experiments Mr. Friese-Greene was enabled to overcome all the incidental difficulties inherent in his first apparatus. He abandoned the revolving glass disk and resorted to a prism placed in front of the lens. This yielded a much more satisfactory result but was naturally somewhat primitive and commercially impracticable. Recently, however, he has completed and patented an entirely new system, which, together with many other important improvements he has effected in connection with the apparatus itself (both camera and projector) and also in the preparation of the sensitized films, promises to improve chromo-photography.

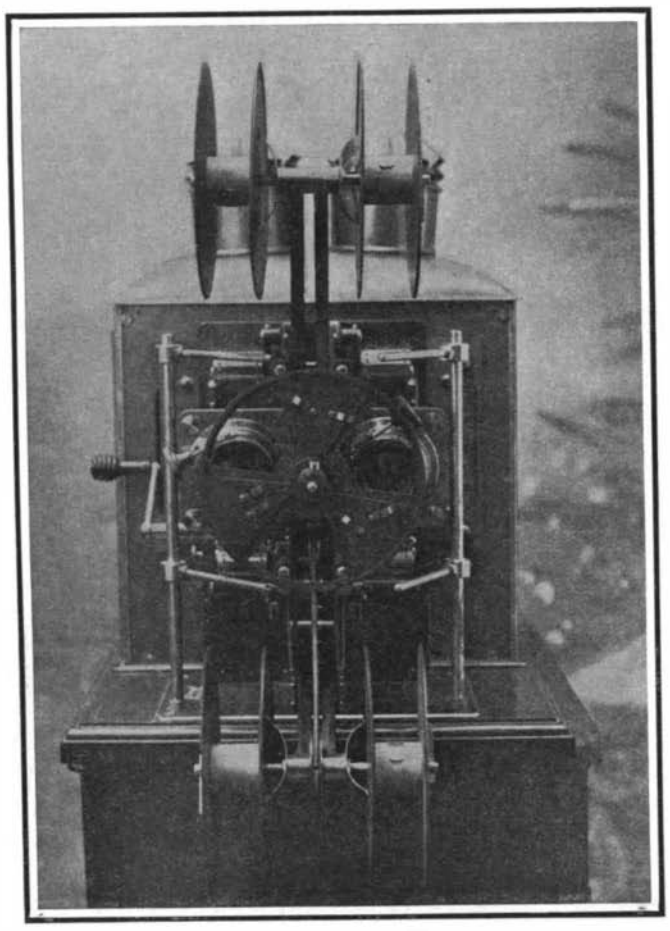


Fig. 4.—Front view of stereo-chromo-cinematograph projector, showing how the twin lenses are alternately exposed by the shutter.

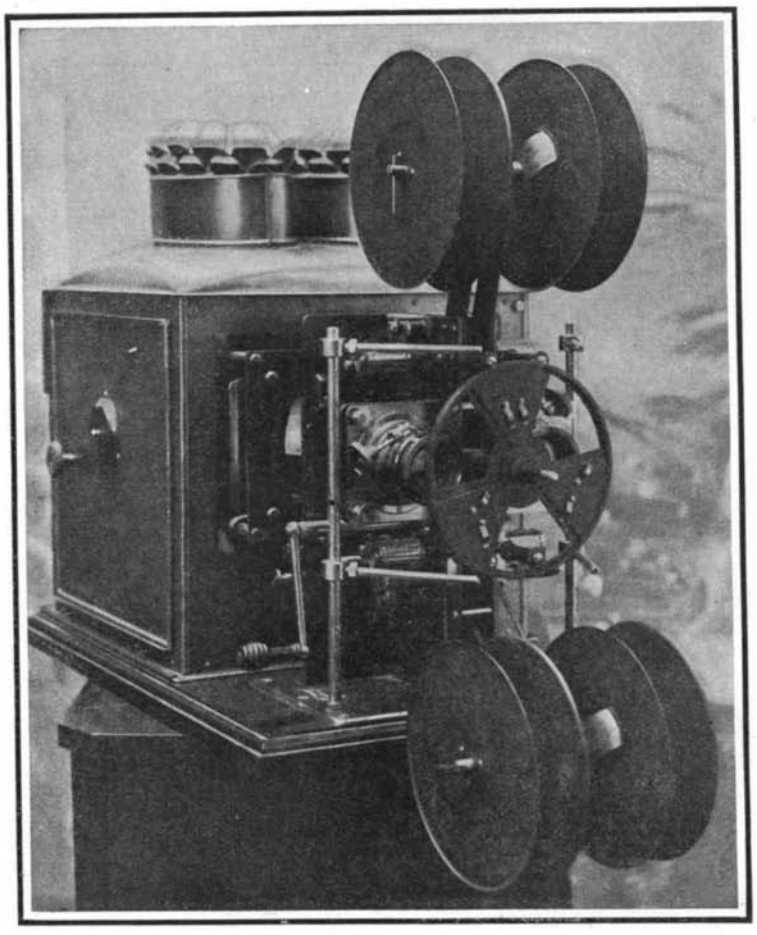
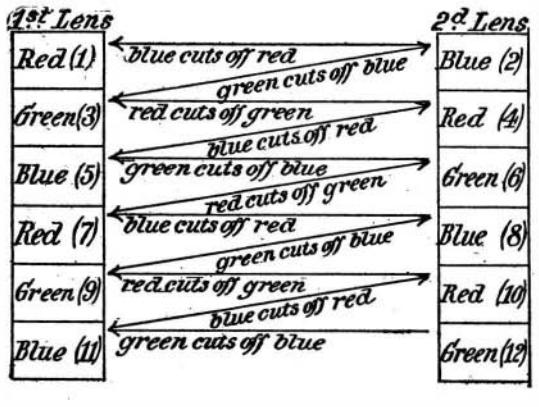


Fig. 5.—A three-quarter view of the stereo-chromo-cinematograph, showing the mechanism for carrying the endless color band.

DIAGRAM SHOWING METHOD OF WORKING COLOR FILMS OF TWO LENSES ALTERNATELY IN FRIESE-GREENE'S CHROMO-CINEMATOGRAPH.




Red (1) in first lens is exposed followed by Blue (2) second lens
Green (3) " " " " " " " Red (4) " "
Blue (5) " " " " " " " Green (6) " "
Red (7) " " " " " " " Blue (8) " "
Green (9) " " " " " " " Red (10) " "
Blue (11) " " " " " " " Green (12) " "

Through the courtesy of the inventor the writer was afforded an opportunity of examining the apparatus, and the whole process of taking and projecting films by this new system, for the SCIENTIFIC AMERICAN, while the accompanying illustrations, specially taken for these pages, serve to show the camera and its method of operation. At the time of writing some twenty films had been secured, depicting varying scenes in natural life from incidents in busy streets to studies of insects and growing flowers. Not only are the color effects obtained, but they are stereoscopically projected. The effect produced upon the screen is precisely the same as that obtained with ordinary stereoscopic photographs when observed through the hand instrument devised by Oliver Wendell Holmes.

With this apparatus, moreover, a continuous picture is obtained, which is not the case in the ordinary machine. In the latter instance, as is well known, the

(*Continued on page 269.*)

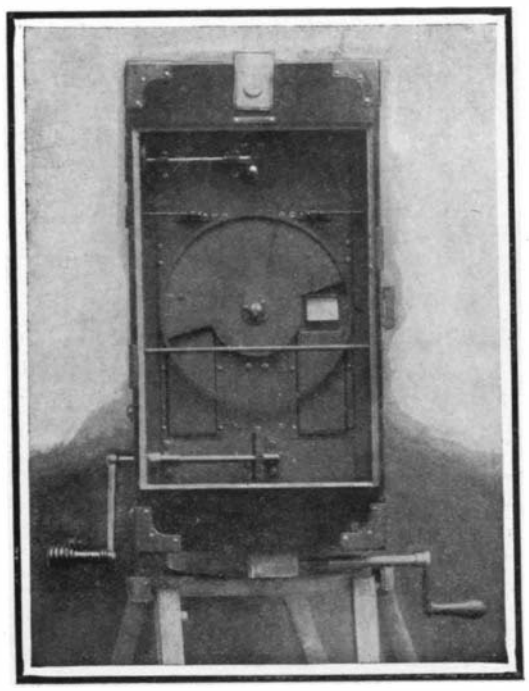


Fig. 1.—The face of the camera with lenses removed.

The shutter exposes one lens while the other is closed to bring a fresh section of film and its relative color filter before the lens aperture. In the aperture shown open, the blue filter may be seen.

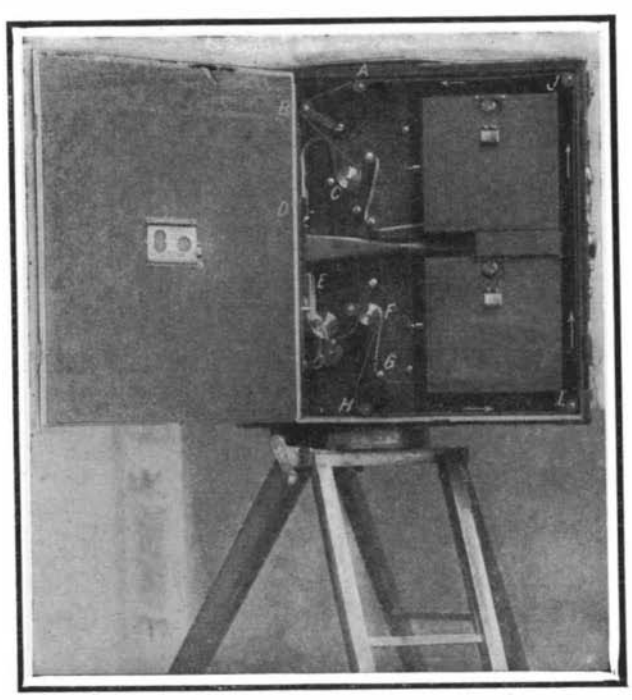


Fig. 3.—Interior of one side of the camera.

Showing system and mechanism for operating the endless band of color filters and how it is brought into juxtaposition with the sensitized film before exposure and separated therefrom after exposure.

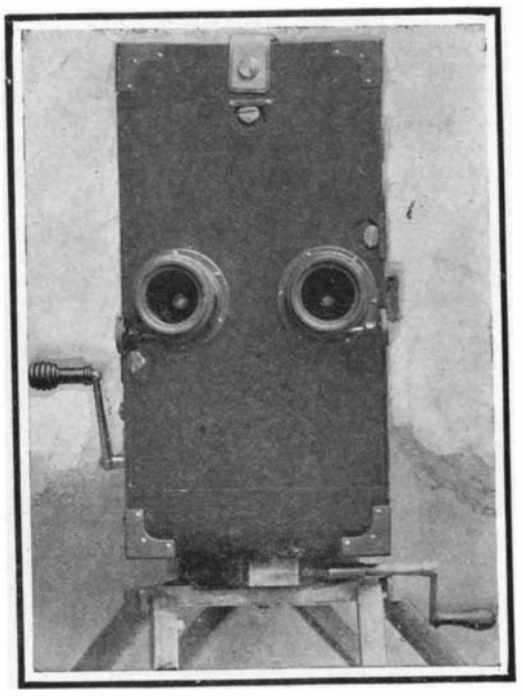


Fig. 2.—Face of the machine, showing twin lenses for securing stereoscopic effects.

The handle at the left drives the photographing mechanism, while on the right the sighting device is shown closed.

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## STEREOSCOPIC MOVING PICTURES IN NATURAL COLORS.

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pictures are taken and projected intermittently, the shutter both in the camera and projector being a sector having an area approximately one-seventh of the area of a circle. While the shutter is closed the film is jerked forward by an interval equal to the height of a single picture on the film. In the Friese-Greene apparatus, however, a continuous picture is secured, since the operation of the twin lenses is alternating, that is to say, while one is closed the other is open. Consequently although the separate films carry images intermittently recorded, the one secures those which the other lost during the short space of time its lens was closed by the shutter.

In regard to the arrangement of the color filter and its manipulation a highly important development has been effected. The color filters are disposed on an endless band of transparent celluloid in the order of red, green, and blue. Each filter is of the same size as the cinematographic image on its film, namely, ¾ inch deep by the standard width, and like the latter is perforated along its edges so that the movement of the color filter and sensitized films are synchronous and the two being kept in dead juxtaposition. By reducing the thickness of the color filter medium to the infinitesimal proportions of a thin celluloid band all troubles concerning light refraction and reflection are completely overcome.

By reference to the accompanying illustration showing the interior of one side of the stereoscopic camera, its operation may be clearly understood, as well as the disposition of the color filter band. Starting from the point *A*, which is a pulley, the color filter band passes to and over the jockey pulley *B*, thence around the drum *C*, where it picks up the unexposed sensitized film issuing from the unexposed-film spool-box at the top on the right, and is superimposed on the sensitized surface of the film. The color filter and film are now caught with their respective edge perforations in dead register, and carried down through a guide channel *D* to the point of exposure behind the lens. As the shutter is closed the oscillating twin pronged arm *E* falls, and the teeth engaging with the perforations of the two superimposed films pulls them down together over the lens for a distance of three-quarters of an inch—the height of a cinematograph picture—and holds them firmly there during exposure. This completed, the turning of the driving handle raises the pronged oscillating arm *E* so that the films are released, and the arm rising in its travel falls and grips the films, once more jerking them down another three-quarters of an inch over the lens aperture. This cycle of operations is repeated while exposures are being made, successive filters and corresponding sections of sensitized film being brought forward in this manner.

As the exposed film surface and its color filter pass away from the lens they travel together over another jockey pulley and drum *F*, after which the two separate, the exposed film passing over the pulley *G* and entering the exposed film box, where it is wound on the spool in the usual manner, while the color filter band travels over the pulley *H* along the base board of the camera under the guide pulley *I*, up the back of the apparatus over pulley *J* and along the top to pulley *A* and *B* to *C* where it picks up the sensitized film once more. The same cycle of operations is repeated during the period exposures are being made.

The second half of the camera is precisely the same in construction and operation as the first half. There is one important difference in the disposition of the color filter band in regard to its exposure, relatively to that in the other half of the camera. A blue instead of a red screen passes before the second lens aperture synchronously with that before the first lens. The effect is that in the course of the exposures there is a continual cutting off of the respective colors. That is to say, when red is exposed for the first lens, it is immediately succeeded by the blue in the second lens, followed in turn by green in the first lens, the latter then being cut off by the red in the second lens, then blue in the first, succeeded by green in the second lens, and so on. The accompanying diagram will best illustrate how the successive cutting off of the colors is effected.

Another notable point is that the inventor does not require three separate negatives taken through the red, green, and blue color filters respectively and then similarly superimposing their transparencies through relative color filters to secure the three-color effect. Such is the process generally followed in accordance with the Ives system of still-life color photography. By this last named process the film would obviously have to be three times the length of the monochrome record, in order to secure the three fundamental negatives, and would need to be projected at three times the speed to secure the desired effect. Mr. Friese-Greene, however, has ascertained that in chromo-photography such a process is unnecessary when carried out upon his lines and that the continual cutting in and out of the colors will enable them to be blended so easily and rapidly that the brain sees the heliochromic image only.

It will be realized from a study of the shutter arrangements in the accompanying illustration that each lens is insured an equal period of exposure. The shutter area is exactly one-half of that of a complete circle, and as one lens aperture is being cut off the other is being cut in, which materially assists in the blending of the colors, through their respective filters, there being an entire absence, from the eye point of view, of any sharp line of demarcation. The sighting and focusing of the camera follow the usual practice in such cinematographic apparatus, as does also the method of operation for taking photographs, though certain improvements have been incorporated. The camera itself is practically the same size as that of the single-lens instrument, everything being rendered as compact as possible.

The projector follows the lines of the ordinary instrument for this purpose, with the exception that there are two lenses placed side by side. Here again the exposure is intermittent. The two lenses are each fitted with a micrometer screw so that their angle to one another can be adjusted to a nicety and varied according to the size of picture projected, which of course is relative to the distance of the screen from the projector. The facilities whereby the angle of the lenses to one another is adjusted insures that irrespective of the size of the image exact superimposition of the two pictures projected from the twin lenses is absolutely certain upon the same given area.

In the projector two similar endless color filter bands have to be used. Their arrangement is very similar to that adopted in the camera, and suitable devices are employed for keeping them in absolute register with the picture film. It is quite impossible, therefore, for any difference in register upon the screen or confusion of color filter and its relative picture to result. Moreover, there is the same relationship in regard to the cutting in and out of the respective color filters to secure the desired blending of the colors, so as to insure in conformity with the phenomenon of visual persistence the impression of a perfect three-color image being conveyed to the brain. This result is also assisted by the fact that projection is really carried out at twice the usual speed, thirty-two pictures being thrown on the screen in the course of a second from the two lenses—sixteen from each. Owing to the perfect superimposition of the pictures from the

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two lenses upon the white wall, remarkable clearness and definition are obtained, the color beauty of the image being appreciably enhanced by the stereoscopic effect which is produced. As also the two pictures depict continuous motion there is an entire absence of flickering due to the shutter, the effect being practically the same as if one were resorting to the camera obscura.

In order to secure the requisite stereoscopic effect in projection the apparatus for this purpose has necessarily to be of special design. Its general characteristics are plainly shown in the accompanying photographs (Figs. 4 and 5). There is the lantern body for carrying two illuminants, one for each lens. The lenses themselves are rendered angularly adjustable by means of a micrometer screw so that in stereoscopic work the two images may be exactly superimposed upon the screen and yet at the same time rendering it feasible to use the apparatus for ordinary work by cutting one-half of the lantern out of service.

The operating mechanism while broadly following that of the ordinary single projector is simpler. The feed spools are carried on a common axle at the top and the films lead down to their respective lines of travel through the gateway behind each lens, subsequently being wound up on the lower spools, these working synchronously through a central spring pulley drive.

Color projection can be effected either by a revolving disk carrying three equal-sized sectors of red, green, and blue glass, respectively, the cutting in and out of each color being precisely the same as in the camera. That is to say, while one lens is being uncovered the other is being closed, so that in reality the image from one lens is being thrown on the screen at one time instead of the two exposures being made simultaneously as in ordinary stereoscopic practice. It is the speed with which projection is made and the cutting in and out of the colors on each lens—about 25 per second—that in accordance with the peculiar law of visual persistence yields not only the natural color but also the stereoscopic effects.

Though the rotating disk is the simplest means of projection, the color effects are not technically correct nor so beautiful as are produced by the endless traveling band, composed of small color screens red, green, and blue, successively. This is attributable to two factors. In the first place, as the rotating disk is placed in front of the lens there is a certain distance through which uncolored light travels—that is, between the film and the color screen—and in projection there is a tendency toward jumbling of the three colors into the white light. On the other hand, when the color screen is in immediate juxtaposition with the film no white light whatever is projected.

The apparatus shown in the accompanying illustrations is applicable to either disk or endless band operation. If the band is used it is only necessary to withdraw the colored screen sectors from the revolving shutter, which is readily effected by means of clips which hold the screens in position, the three remaining opaque sectors acting as the cut-off between each successive color filter and its picture on the band. The band itself is carried over a jockey pulley and sprocket drum at the top of the projecting mechanism and carried down through the gateway with the transparent film against which it is tightly held during the instant of projection. Issuing from the gateway it passes over a lower sprocket drum and jockey pulley, where it leaves the picture film, which is wound on the spool below, the color band passing over a rigid horizontal arm shown in the illustration set at an angle of about 45 deg., so that the upward traveling part may clear the field of the lens, passing over another similar angular arm at the top which deviates it

*(Concluded on page 271.)*

once more over the top sprocket drum and pulley where it meets the picture film traveling from the upper spool, and the operation is repeated.

The grave disadvantage of the revolving disk is that the screens therewith have to be, as it were, standardized; that is to say, must be such that they are equally applicable to any picture that may be used in projection irrespective of the densities of the color filters used in photographing. This often destroys or depreciates the true color effects and values. On the other hand, with the band it is possible to secure the same relative color screens that were used in taking the picture, so that the latter is virtually projected through the same color filters as were employed for photographing.

With the band, moreover, a new film can be far more easily fed into the machine. In this apparatus the gateway is of special design. The picture film has a short length of lead indicating successively red, green, blue, in the order in which the exposures are made. All that is necessary to do is to open the gateway, superimpose the one color filter of the endless band upon its corresponding indication upon the lead, and then all is ready for projection. The apparatus has been demonstrated in London and Paris, and the possibilities of the Friese-Greene system, owing to its simplicity and economy combined with truthfulness of color value and density, have attracted considerable attention.

## THE VISITING WARSHIPS—A COMPARISON.

(*Continued from page 262.*)

point of bearing is most advantageous for her batteries and least advantageous for those of the enemy.

Now, from what we have said above, it will be evident that when an all-big-gun ship meets one that carries a mixed armament of big guns and guns of medium caliber, she will endeavor to place herself at sufficient distance from the enemy to be outside of the armor-piercing range of its medium-caliber guns and within the armor-piercing range of her own big guns. She can only do this, however, by possessing a reasonable superiority of speed, and the greater her excess of speed the more completely will she be master of the position.

Applying these facts to the "Connecticut," "Justice," and "Inflexible," we can see at once how completely the all-big-gun, high-speed, fighting ship of to-day outclasses the big and medium gun, moderate-speed battleship of the pre-"Dreadnought" period. The big-gun ship is *vitally* vulnerable only by the penetration of her waterline or of the barbettes and turrets in which the 12-inch guns are mounted. The greater part of the personnel of the pre-"Dreadnought" battleship, on the other hand, is stationed at the numerous guns of the secondary battery, where they are protected by comparatively light armor; and even at the fighting range of five miles they would be exposed to complete destruction by the high-explosive, 12-inch shells.

GUN POWER.—Comparing the three ships on the basis of gun power, we find that the "Connecticut" carries four 12-inch 45-caliber guns, eight 8-inch 45-caliber guns, and twelve 7-inch 50-caliber guns; the "Justice" mounts four 12-inch 50-caliber guns and ten 7.6-inch 45-caliber pieces; while the British "Inflexible" mounts eight 12-inch 45-caliber guns, but no secondary armament. Now, at a fighting range of five miles, the 12-inch gun of the "Connecticut," firing an 850-pound shell at 2,700 feet per second velocity, can penetrate 8 inches of Krupp armor; the 12-inch gun of the "Justice," firing a 731-pound shell with a muzzle velocity of 3,000 feet per second, can penetrate 7 inches of Krupp armor; and the 12-inch gun of the "Inflexible," firing an 850-pound shell at 2,900 feet per second, at the same range can penetrate 9 inches. Now, since the belt armor of the "Connecticut" varies from 11 inches amidship to 4 inches at the ends, and that of the "Justice" varies from 11 inches to 5½ inches at the ends, it follows that the vitals of both these ships would be quite secure against the attack of the "Inflexible" at this range; although it would be possible for her to penetrate both ships at each end of the waterline. Since the 12-inch guns of both the "Connecticut" and the "Justice" are protected by from 10 to 12½ inches of steel, they should be practically safe against penetration. On the other hand, the "Inflexible" would not fare so well, since her belt protection varies from 7 inches amidships to 4 inches at the ends, and she would be theoretically penetrable by the guns of both her opponents at five miles range. Her 12-inch guns, however, with a turret and barbette protection of 10 inches armor, would be secure against penetration.

It should be borne in mind, however, that these figures of penetration are worked out for impact *at right angles to the armor*. At these distant ranges the projectiles would be falling at an angle of several degrees, and therefore the resisting power of the armor on all three ships would be considerably higher than that mentioned above.

The secondary armament, both of the "Connecticut" and the "Justice," could riddle the unarmored, but could not penetrate the armored portions of the "Inflexible," whereas the turrets and casements in which this secondary armament is mounted could be completely destroyed by the "Inflexible's" guns. Thus, for the 8-inch of the "Connecticut" to penetrate the 7-inch belt of the "Inflexible," they would have to be within 5,400 yards of that ship, and the 7-inch battery would have to be within 4,000 yards; while the 7.6-inch gun of the "Justice" would have to be within 5,000 yards to effect penetration at normal impact. On the other hand, the 6-inch and 7-inch armor which protects the secondary battery of the "Connecticut," and the 5½-inch and 4-inch armor on the turrets and bases of the secondary battery of the French ship, would be at the mercy of the "Inflexible's" 12-inch guns.

In this supposititious engagement to show the advantages of the "Dreadnought" type of battleship over the type with the mixed armament, the "Inflexible" with an advantage of 6 to 8 knots of trial speed (it will be understood, of course, that an engagement would never be fought at these maximum speeds) would elect to place herself at the maximum effective range for her own guns, which, if the weather were clear, would probably be not less than five miles. Her higher speed would give her the same advantage which the "weather gage," or windward position, gave to the old fighting frigates in the days of sail power and the smoothbore. Her probable plan of attack would be to assume a position somewhat ahead of the leading ship and then concentrate the whole of her eight guns upon that vessel, in the endeavor to cripple each ship in detail; and it is an interesting question whether this concentration of fire on each ship in turn, coupled with the vulnerability of the armored positions of the secondary batteries, and the great exposure of the crews of those batteries, would not go far to offset the lighter armor protection of the "Inflexible." By taking skillful advantage of her superior speed, and if the gunnery on all three ships were equal, it is conceivable that she might win the fight. Should she be getting the worst of it, on the other hand, her higher speed would leave her free to draw out of the conflict, whenever her commander saw fit. From what we have said, however, it is evident that ship for ship she would be more than a match for either vessel alone, and in a duel she would probably close in to 6,000 or 7,000 yards, and try to overwhelm the enemy quickly with her 12-inch guns.