bracket in front. The reflector is of glass, with silver (not mercury) on the back, and therefore will not lose its reflecting power by exposure to the weather.

The advantages of the system may be summarized as follows :

(1) The semaphore is the standard day signal, and there is therefore no other night signal, the general introduction of which would render identical day and night systems.

(2) No other *form* of semaphore is known which will give enough light to be visible at the distance required by fast trains.

(3) No night signal would conform to well-established railroad rules which did not also show red for danger.

(4) No reflector, other than silvered glass, will stand exposure to the weather.

(5) No other known signal can be fitted to existing castings and equipment.

HELIOCHROMY.

BY FRED. E. IVES.

[Read at the Stated Meeting, Wednesday, November 21, 1888.]

JOS. M. WILSON, President, in the Chair.

MR. IVES: In my lecture, on "Some Recent Advances in Photography," delivered before this INSTITUTE in February last, I briefly described and illustrated a method devised by me for producing photographs in natural colors. I now have illustrations of the process, comprising a sufficient variety of subjects to more fully demonstrate its capabilities and value.

I claimed for this process that, unlike any similar process yet suggested, it was based upon a true conception of the nature of light and color vision, and was a strictly scientific method of accomplishing the object sought after—which is to produce, by an automatic process, pictures which counterfeit not only the light and shade, but also the colors of all objects which may be photographed.

I explained how some others who experimented in this direction failed, because they built upon the false theory that there are only three primary spectrum colors. I recognized the fact that there are, strictly speaking, thousands of primary spectrum colors, but also that all colors, whether simple or compound, may be counterfeited to the eye by means of three type colors, separate and mixed in different proportions. I assumed that we might counterfeit all the colors of nature in a photographic picture, by making each ray of simple color select automatically, in the operation of the picture-making process, such a type color or mixture of type colors as will counterfeit it to the eye, and showed how this can be accomplished by means of photographic plates made sensitive to all colors, and exposed through compound light filters, which are suitably adjusted by experiment upon the spectrum itself.

For the mechanism of the process, and some demonstrations, I refer to my original communication, which appeared in the JOURNAL OF THE INSTITUTE in May. I believe the problem had never before been stated with reference to the possibility and necessity of representing most of the primary colors by color mixtures, which, though not the same, produce the same color-sensation.

In order to make clear the fact that my plan of operation is in accordance with what is now recognized as the true theory of the nature of light and color-sensation, I make the following quotations from a recently published text-book on *Color*, by A. H. Church, M.A., London :

“Young’s theory does not assume the existence of three primary colors, but of three primary color-*sensations* ; a very important distinction.

“Every ray of differing refrangibility in the visible part of the spectrum is in one sense a primary color, for it is simple, and excites a definite sensation. But there are many reasons, mainly connected with the structure and functions of the eye, which have led to the selection of certain colored lights—generally three in number—as yielding primary color-*sensations*. This primariness is then not objective, but subjective in respect of human vision.

“Young’s theory of color-perception amounts essentially to this, that in each elementary part of the retina of the eye there is, at least, one set of three different nerve fibrils, each of the three fibrils of a set being especially adapted for the production of its own specific color-sensation, yet in a less degree of the two others. Thus the receptive structure of the retina as a whole may be said to consist of an immense number of nerve fibrils of three orders; what we may call red fibrils being particularly acted upon by such long light waves as those in the red, but being also stimulated in a minor degree by the shorter waves in the green, and still less by those in the blue; the green fibrils will respond most actively to green waves, and in some measure, also, to red and to blue waves; while the blue fibrils will be most excited by the blue rays, though not uninfluenced by green and even by red rays.* It follows that when all three kinds of nerve fibrils are equally and simultaneously affected, the complex sensation of white light alone is produced.

“Colored lights may be, and often are, compound, sometimes consisting of two, and often of many more differently-colored elements, although the eye recognizes but a single color in the complex ray. A striking instance is afforded by yellow. There is an elementary yellow in the solar spectrum lying on the green or more refrangible side of the line *D*. By no contrivance can we optically decompose this, spectral yellow, to which belongs a definite wave-length. But there are many compound yellow lights—lights which give us, as the sum of the simultaneous visual impression of their several components, a sensation of yellow not to be distinguished by the brain from the simple yellow of the spectrum. Such a compound yellow may be formed by throwing on the same portion of a screen a part of the red light and a part of the green light of a pure spectrum.

* “Helmholtz remarks, that the choice of these particular colors is somewhat arbitrary, and that any three could be chosen, which, when mixed together, would furnish white light. If, however, the end and middle colors of the spectrum (red, violet and green) are not selected, then one of the three must have two maxima, one in the red and the other in the violet; which is a more complicated, but not an impossible supposition.”

Similarly there is a pure and simple blue in the spectrum, but a blue indistinguishable from this in hue may be obtained by mingling green and violet light."

Now, although I originally worked out my process on the simple plan of making each primary ray of spectrum color select from and combine three pigment colors to counterfeit it, it becomes evident that in accomplishing this I might have produced one negative by the action of solar rays nearly in proportion as they excite the "red nerve fibrils" of the eye, another in proportion as they excite the "green fibrils," and another in proportion as they excite the "blue fibrils." I did not do this at once, but after experimenting with several sets of reproduction pigments, adjusting color-screens so that I could make the process counterfeit the spectrum with either set of pigments, I finally adopted reproduction colors which call for negatives of the spectrum showing curves of intensity approximating to the curves in Maxwell's diagram, illustrating the action of the spectrum upon the different sets of nerve fibrils. These reproduction colors are certain shades of red, green and blue light, or their complementary colors in pigments, which approximate to Prussian blue, magenta red and aniline yellow, the first two of so light a shade that it is necessary to superimpose one upon the other to obtain a full violet blue, the blue upon the yellow to obtain green, and the magenta upon yellow to obtain red.

When I made my first communication upon the subject, I assumed, with Helmholtz, that there might be some latitude in the selection of type (reproduction) colors, and therefore did not commit myself to the use of any particular ones, but merely showed how I would produce at will negatives of the spectrum having any curves of intensity that might be required in order to secure the proper distribution of such colors or pigments as were selected. The adoption of reproduction colors corresponding to what are now recognized to be the primary color-sensations, has made it possible for me to state more definitely my mode of procedure, as above.

What I claim as new and original in my method is (1) the

production of heliochromic negatives by exposing color-sensitive plates through compound color-screens, which have been adjusted to secure negatives showing curves of intensity which bear a certain definite relation to the colors employed to produce the heliochromic pictures; and (2) the production of heliochromic negatives by a procedure calculated to yield negatives of the spectrum showing curves of intensity which probably correspond to the action of the spectrum upon the sets of nerve fibrils.

Admitting the theoretical soundness of my mode of procedure, which I believe I have fairly demonstrated, there remains only the question of practicability and commercial value to be considered. The process is practicable, if the same operations, repeated in the same manner, can be relied upon to produce pictures which counterfeit the light and shade and color of all objects. Three subjects, which I shall show to-night, a delicate oil-painting, a brilliant Prang chromo and a beautiful sea-shell, were made with the same light, same camera, same preparation of sensitive plates, same set of color screens, same relative exposures and same development. They show a very great variety of colors, mostly compound in the painting and chromo, but pure spectrum colors in the sea-shell; yet the colors of all are alike faithfully counterfeited to the eye. Although there should be no question of the fact, I will here state that these finished results have been obtained without any retouching or artificial manipulation whatever.