A STUDY OF SCATTERING IN PHOTOGRAPHIC EMULSION

by

ROBERT JACOB RYCHEL

B. S., Kansas State College
of Agriculture and Applied Science, 1932

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Physics

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1939

TABLE OF CONTENTS

INTRODUCTION

Photography has offered a vast field for research since the date of its first appearance more than one hundred years ago. A discussion of photography in relation to cameras, lenses, emulsions, and the treatment of emulsions in order that the latent images might become a permanent record, would be superfluous here.

The subject matter of this paper is confined to a study of the scattering of light in the emulsion of photographic films and of those conditions that are necessary for the occurrence of internal reflection.

On rather rare occasions in this laboratory[1] it has been observed that a flat object having some design upon its face, such as a coin, might be photographed by merely placing the object directly upon the emulsion of photographic film with the face to be pictured in contact with the emulsion. If the film and coin were illuminated by means of a quartz mercury arc lamp for a certain period of time and the film then developed in the usual manner, a clear picture of the face of the coin in contact with the emulsion would appear. In order to produce this effect, the materials may be arranged as shown in Fig. 1.

---

[1] This effect was observed by the late Professor J. O. Hamilton of this College.

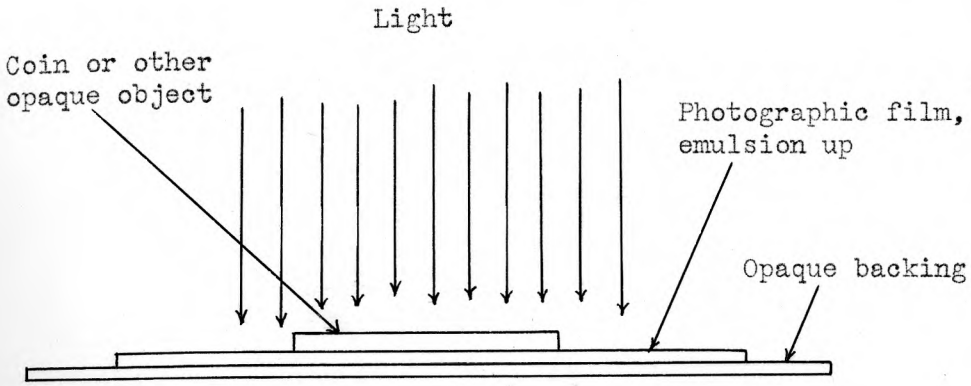

Fig. 1. Showing position of materials used in conducting experiments.

Plate I is an example of the effect under discussion. This plate was photographed by the late Professor J. O. Hamilton. Examination of Plate I shows the faces of various objects including the corks from several ink bottles, a key, and a fifty cent piece. These objects were placed directly upon the emulsion of a photographic film and the film, together with the objects in contact with the emulsion, was illuminated by means of light from a quartz mercury arc lamp. Unfortunately no information concerning the type of emulsion, exposure time, or developing process regarding this particular photograph is available.

This effect is rather paradoxical to the usual conception of the action of light upon the emulsion of photographic film. Ordinarily one would believe that the coin would shield from light the portion of the film upon which it was lying, and hence no exposure would take place at that point.

EXPLANATION OF PLATE I

Fig. 2. Picture photographed by the late Professor J. O. Hamilton. The objects pictured were placed directly upon the emulsion of the photographic film. Illumination was furnished by a mercury arc lamp.

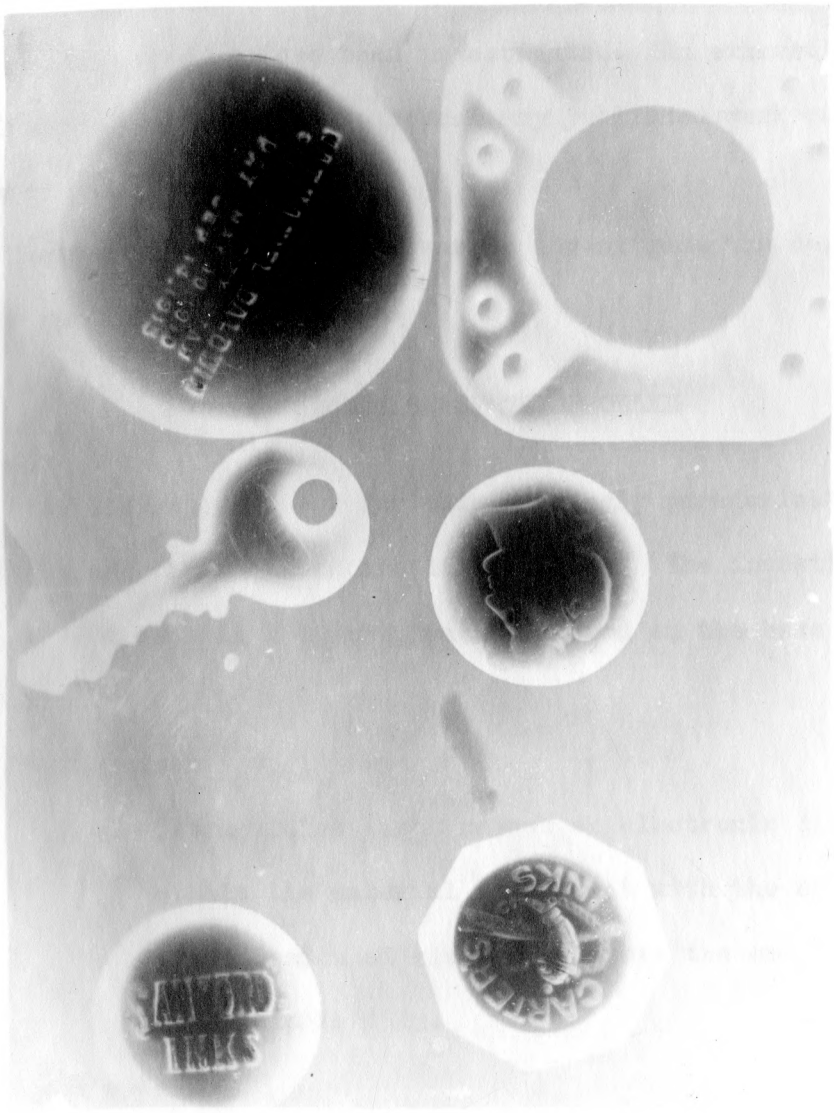

Fig. 2

Although this phenomenon has been observed occasionally, it apparently has never before been investigated. An exhaustive search of the literature has failed to reveal any published work on this phenomenon.

The purpose of this paper was to investigate the cause of this almost paradoxical phenomenon.

DISCUSSION OF THE PROBLEM

Possible explanations for this seemingly paradoxical behavior of the light and the emulsion are listed below. The investigation, of which this thesis is a report, was conducted on the base of these hypotheses.

Hypothesis A

1. Ultra-violet light causes an electronic disturbance within the material in contact with the emulsion; the transmission of electrons expose the emulsion of the photographic film.

Hypothesis B

1. Light passes between the material in contact with the emulsion and the emulsion itself and is reflected from the face of the object on to the emulsion.

Hypothesis C

1. Light travels through the emulsion.
2. Light travels through the emulsion as long as the upper

surface of the emulsion is in situation:

a. Contact with a solid.

b. Contact with a good reflector.

3. Light is not internally reflected at upper surface of the emulsion when in situation:

a. Contact with a solid.

b. Not in contact with a solid; consequently less light passes through emulsion at this point.

4. Light travels through the emulsion as long as the upper surface of the emulsion is in situation:

a. Not in contact with a solid; consequently less light passes through the emulsion at this point.

5. In the vicinity of internal reflection in the emulsion, a photographic reversal occurs.

Hypothesis D

1. The result observed in Plate I is due to pressure of the object upon the emulsion.

2. The result observed in Plate I is due to a combination of pressure on the emulsion and light.

These hypotheses lead the writer to also consider certain other factors. These factors are:

1. Effect of variation of exposure time.

2. Reaction of different types and speeds of emulsions.

3. Effect of different reflecting and absorbing materials placed

on the under side of the film (opposite the emulsion side).

PROCEDURE

The first step in this investigation was to reproduce, under controlled conditions, the effects observed in Plate I.

The first requirement was to secure photographic specimens which would be consistent in design, weight, and thickness throughout the experiments. Three brass plates, three-sixteenths inch in thickness, and of various sizes as shown in the various plates, were obtained. Holes were drilled partially through these plates to form a design upon one face. In all cases herein described, the plates were placed with the design against the emulsion of the film.

For the final investigation, the metal plates were replaced with various cardboard and paper sheets. The cardboard was ordinary poster material having upon its surface several letters printed with black printer's ink. Paper sheets such as a portion from the page of a book, magazine or newpaper, colored advertisement, and printing in colors were used. Wood blocks were placed over these cardboard and paper specimens to secure uniform contact between the design and the emulsion and to prevent any passage of light through them.

The films used in these experiments were Eastman Par Speed Portrait, Eastman Panchromatic Dry Plate, and Eastman Super Panchro Press. They were held in a horizontal position, the emulsion side up. The films were exposed by means of a light source placed above the film

and the light directed thereon. Several experiments were made in which different colored materials were used as a backing for the film. It was found that black paper or cardboard produced the best results. For all pictures included in this study, black paper was used under the film. Films were developed in Eastman D-11 developer in accordance with recommended procedure for it.

Illumination was furnished by a quartz mercury arc vapor lamp with various filters, and an ordinary Mazda electric light bulb. Intensities were measured with a Weston foot-candle meter. The experiments were conducted in a photographic dark room.

All pictures presented in this thesis are contact prints made from the negatives described. The dark portions of the negative appear light in the contact print.

Reproduction of the Effect Under Consideration

The purpose of this experiment was to reproduce the effects demonstrated by Plate I under known and controlled conditions. The three brass plates, previously described, were placed directly upon the emulsion of Par Speed Portrait film with the design in contact with the emulsion. The film was held in an ordinary camera film holder containing a black paper background for the film. The film, together with the metal plates upon its surface, was illuminated by means of a quartz mercury arc lamp with no filter. The light source, therefore, contained ultra-violet as well as visible light.

It was necessary to try several exposures before the proper exposure time was determined. Plate II was produced with a light intensity of six foot candles at the surface of the film with an exposure time of five seconds. An examination of Plate II shows that the design of the metal plate, which was in contact with the emulsion, is accurately reproduced upon the print. The effect produced by photographing objects placed directly in contact with the emulsion of photographic film has therefore been accurately illustrated under known and controlled conditions.

Line and Surface Contact Investigation

The metal plates photographed as shown on Plate II were used just as they came from the drilling process. The burrs formed in drilling were allowed to remain. In order to ascertain if the presence of the burrs had any effect upon the results, the small, square plate (Fig. 6) Plate III, was carefully smoothed so that no roughness remained. Figure 7, Plate III illustrates the small plate as it came from the drill. Figures 6 and 7 were produced on the same film at the same time so that possible variation in exposure time and development would not occur.

In comparing Fig. 6 with Fig. 7, it must be concluded that the effect is more pronounced when the burr remains on the plate and when the object makes contact with the emulsion on a sharp line.

EXPLANATION OF PLATE II

Fig. 3. The effect under consideration produced on Par Speed Portrait film exposed to the light from a mercury arc lamp without filter for five seconds.

Fig. 4. Same as Fig. 3 except for smaller plate.

Fig. 5. Same as Fig. 3 and Fig. 4 except for smaller plate.

PLATE II

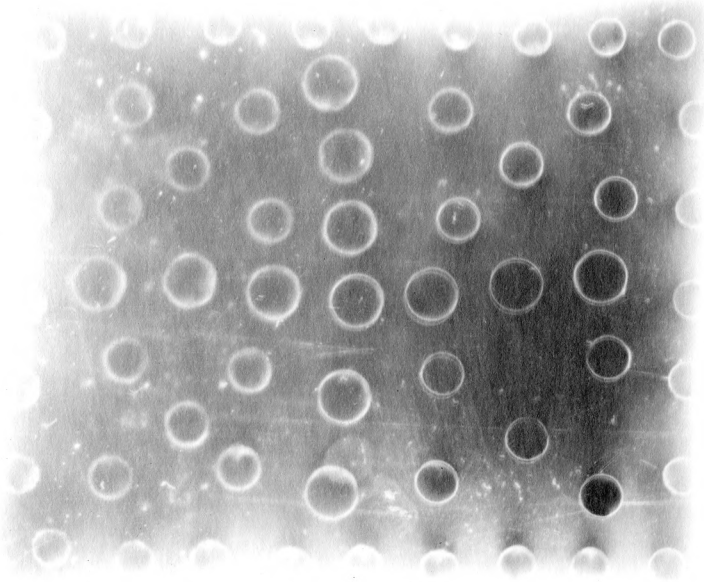

Fig. 3

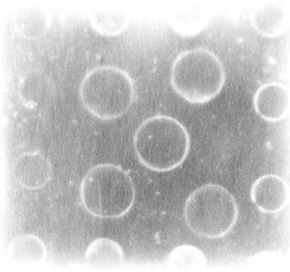

Fig. 4

Fig. 5

EXPLANATION OF PLATE III

Fig. 6. Effect produced by smoothed metal plate. The film was Par Speed Portrait illuminated by light from a mercury arc lamp for five seconds.

Fig. 7. Same conditions as those for Fig. 6. Object plate untreated.

PLATE III

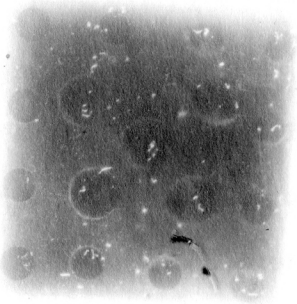

Fig. 6

Fig. 7

Pressure and Electronic Transmission Investigation

The purpose of this study was to determine whether or not the effect could be explained as being due to pressure of the metal plate on the emulsion and also to observe the possible effect of secondary radiation from the metal as a result of the ultra-violet light used to illuminate it.

A piece of Par Speed Portrait film was cut to a size slightly smaller than that of the large metal plate previously described. The metal plate was placed over this cut film with the design in contact with the emulsion, then taped down to the paper which was used as a backing for these pictures. The tape prevented light from entering around the edges of the metal plate. The material was arranged as shown in Fig. 8.

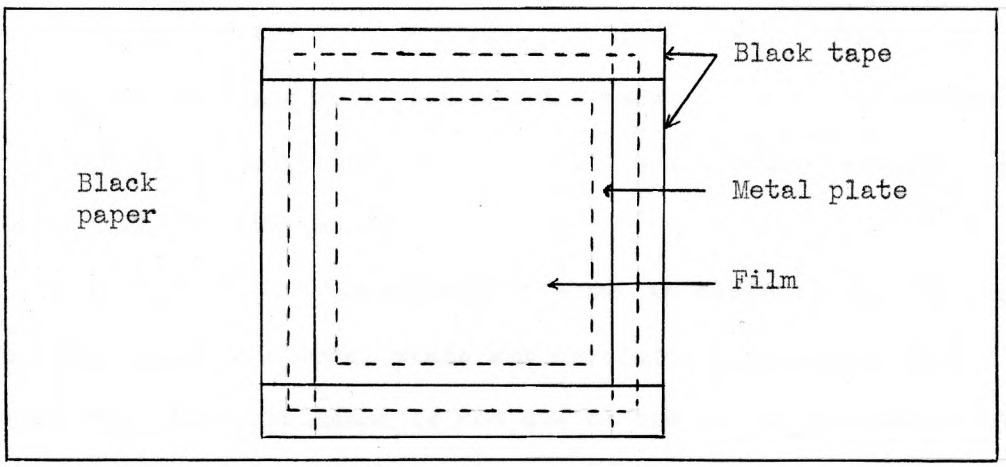

Fig. 8. Showing position of materials used for pressure and electronic transmission investigation.

The result is shown in Fig. 9, Plate IV. As the film was absolutely unexposed, it demonstrates that the phenomenon under discussion cannot be due to the pressure of the metal plate upon the emulsion nor can it be due to any radiation from the metal plate due to the ultra-violet light used to illuminate it.

Ultra-Violet Light Investigation

Since the light from a quartz mercury arc vapor lamp contains some ultra-violet light, it was desirable to ascertain the effect of ultra-violet light upon this photographic phenomenon. The lamp was equipped with a quartz filter which absorbed practically all of the light within the visible spectrum but allowed ultra-violet light to pass through it.

The large metal plate again was placed upon the emulsion of Par Speed Portrait film as in the preceding experiments. The illumination was furnished by the mercury arc lamp using the quartz filter. The light falling upon the film was then practically all ultra-violet. Various exposure times were used and the results in all cases were independent of the exposure time. Plate V was produced with an exposure time of five seconds.

The result of this experiment is shown on Plate V. As the portion of the film under the metal plate was absolutely unexposed, it is apparent that the phenonemon is not due to the action of ultra-violet light.

EXPLANATION OF PLATE IV

Fig. 9. By lack of any design, this picture demonstrates that the effect is not due to pressure or electronic radiation.

PLATE IV

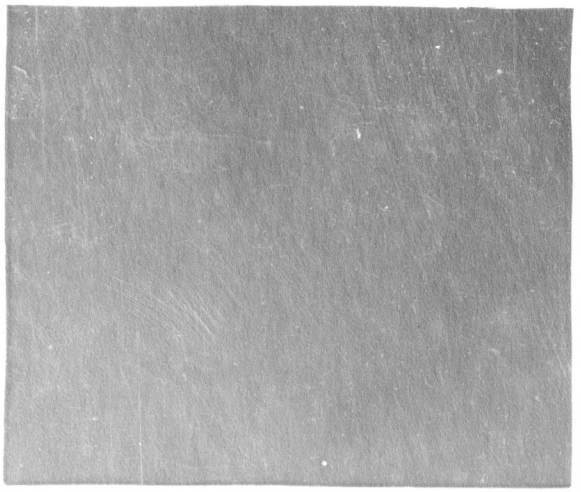

Fig. 9

EXPLANATION OF PLATE V

Fig. 10. This picture shows the inability of ultra-violet light to produce the effect under consideration. Par Speed Portrait film was exposed to light from a mercury arc lamp filtered through a quartz filter for five seconds.

PLATE V

Fig. 10

Visible Light Investigation

Plate VI was produced in the same manner as Plate V except that the quartz filter was replaced with ordinary window glass. Window glass transmits all wave lengths within the visible spectrum but absorbs all ultra-violet light. Consequently, all light reaching the emulsion of the film in this experiment was of longer wave length than ultra-violet.

The result is shown on Plate VI. As the phenomenon is very apparent in the illustration, it must be assumed that the effect is due to wave lengths longer than those of ultra-violet and is due to those found in the visible spectrum.

Investigation Involving Illumination From a Mazda Bulb

In order to verify the fact that the phenomenon is more or less independent of the light source, Plate VII was produced using as a source of illumination an ordinary Mazda bulb in a standard ceiling fixture. Other conditions remained the same as in the preceding experiments. The intensity of illumination was two foot candles on the surface of the emulsion so that an exposure of about fifteen seconds was necessary.

The result is shown on Plate VII. As the design is quite apparent in this illustration, this experiment verifies the fact that the phenomenon is due to light within the visible spectrum.

EXPLANATION OF PLATE VI

Fig. 11. This picture shows the effect to be present using light within the visible spectrum as a source of illumination. Par Speed Portrait film was exposed to the light from a mercury arc lamp filtered through plate glass for five seconds.

PLATE VI

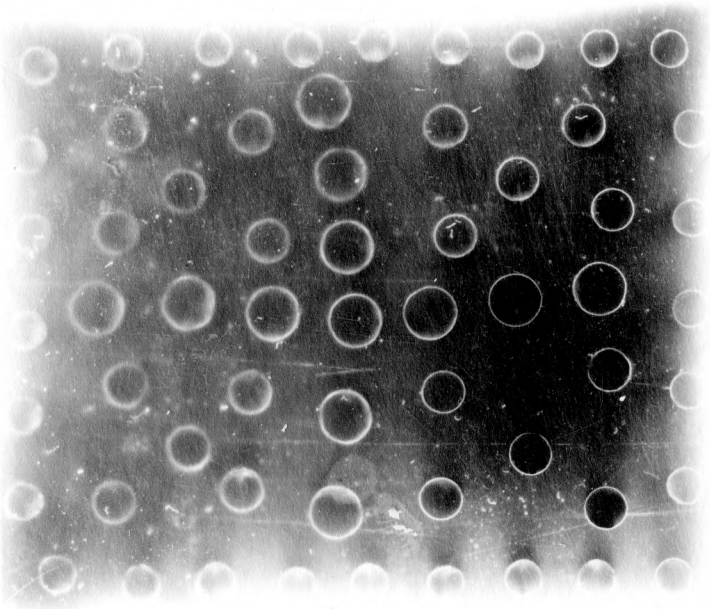

Fig. 11

EXPLANATION OF PLATE VII

Fig. 12. Par Speed Portrait film exposed to the light from a Mazda lamp for fifteen seconds.

PLATE VII

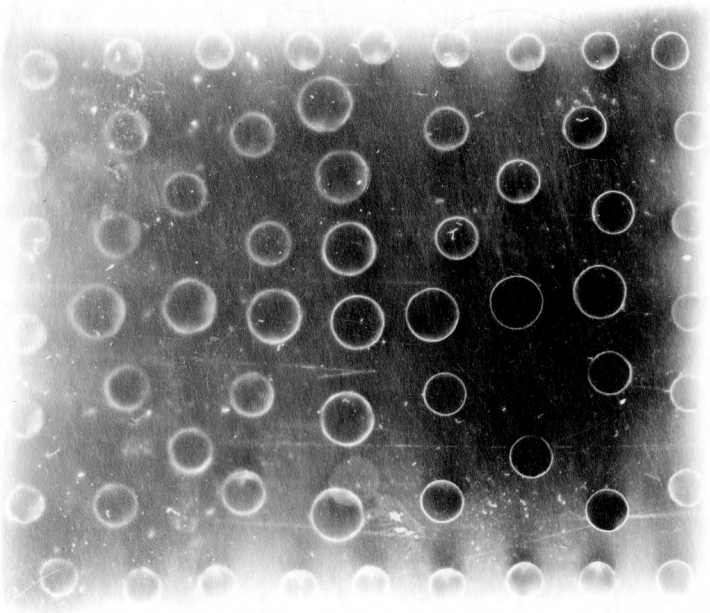

Fig. 12

Investigation of Light Path

The purpose of this experiment was to determine whether the light passed between the metal plate and the emulsion or if light entered and passed through the emulsion. The metal plate was securely taped to the emulsion on all four sides. The arrangement is shown in Fig. 13 when viewed from the exposed side.

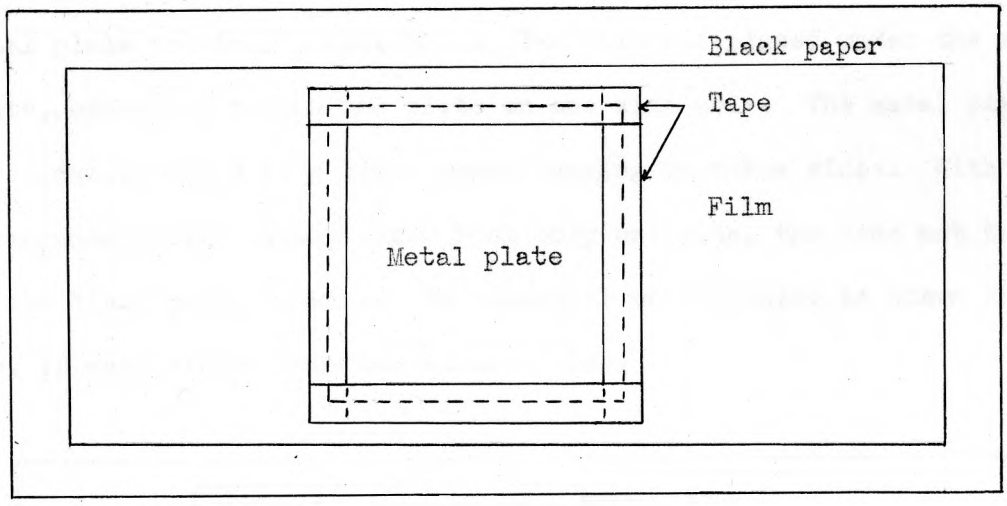

Fig. 13. Showing position of materials used in investigation of light path.

With this arrangement, light could not possibly enter between the metal plate and the film, as the light would be absorbed by the black tape. Since the design is reproduced on the developed negative, one must conclude that light enters the emulsion and passes under the metal plate through the emulsion. The result is shown on Plate VIII, Fig. 14 demonstrating that light passes through the emulsion and not between

the emulsion and the metal plate.

The preceding experiments demonstrate that this phenomenon is not due to pressure of the metal upon the emulsion, nor is it due to energy transmitted through or produced within the metal. It must be concluded that ordinary visible light is in some way transmitted to all parts of the face of the object in contact with the emulsion.

This scattering effect is shown on Plate VIII, Fig. 16. A strip of Par Speed Portrait film was cut about one inch narrower than the metal plate previously described. The film was placed under the metal plate, extending beyond the plate on one side only. The metal plate was securely taped to a black paper backing on three sides. With this arrangement, light could enter from only one side, the side not taped to the black paper backing. The material was arranged as shown in Fig. 15 when viewed from the exposed side.

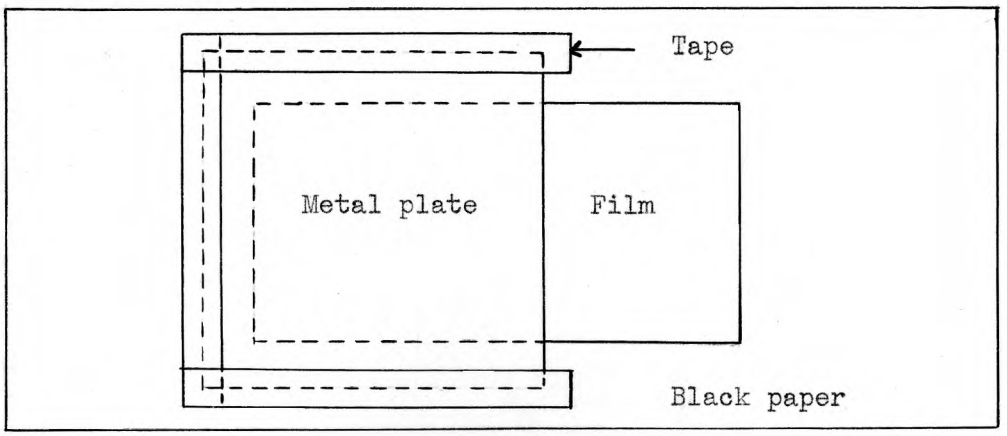

Fig. 15. Showing position of materials used in demonstration of scattering of light through the emulsion.

EXPLANATION OF PLATE VIII

Fig. 14. This picture demonstrates that light passes through the emulsion as the metal plate was taped to the emulsion. Par Speed Portrait film was exposed to the light from a mercury arc lamp without filter for five seconds.

Fig. 16. Demonstration of the transmission of light from the exposed edge toward the center of the metal plate. Par Speed film exposed to the light from a mercury arc lamp without filter for five seconds.

PLATE VIII

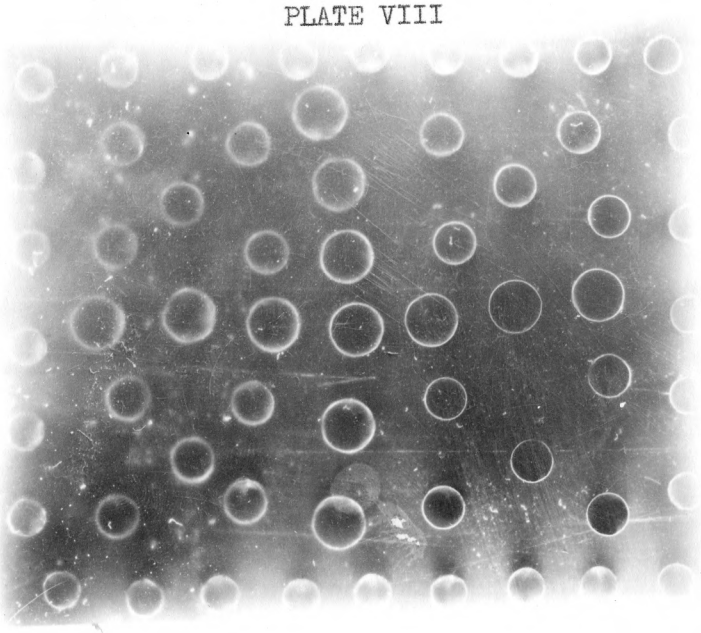

Fig. 14

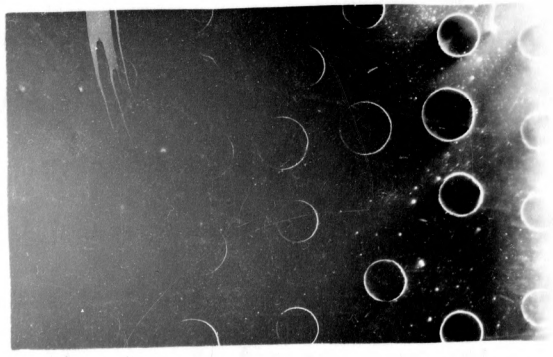

Fig. 16

The result is shown on Plate VIII, Fig. 16. One observes that there is a design upon the film which was immediately under the untaped edge. One also notes how the design fades out as the center of the plate is approached. This demonstrates that light entered under the edge of the plate and was scattered along toward the center, affecting the emulsion as it passed through leaving the design of the metal plate upon the developed negative.

The Effect of Changing Emulsions

The Par Speed Portrait film used in the previous experiments is considered an average speed emulsion. It has an American Scheiner Tungsten or Photoflood rating of 16. It was decided to test other emulsions and observe their response to this effect. The first attempt was made using a plate rather than a film. This plate, an Eastman Panchromatic Dry Plate, had a panchromatic emulsion with an American Scheiner Tungsten or Photoflood rating of 15. The results were negative. In every case, regardless of lighting conditions, the use of plates having the emulsion on glass backing gave no image of the object covering it. As the emulsion rating is very close to that of the Par Speed film, it is obvious that failure of Panchromatic Dry Plates was not due to its emulsion speed but to the glass backing upon which the emulsion is placed.

The next attempt was made with Eastman Panchromatic Super-Sensitive film. This film has a very sensitive high speed emulsion

with an American Scheiner Tungsten or Photoflood rating of 22. Except for the film, the conditions were exactly the same in this experiment as they were when Fig. 2 of Plate II was produced.

The result of this experiment is shown on Plate IX, Fig. 17. The design is quite apparent along the edges of the plate but fades out as the center of the plate is approached. This characteristic result was noted in several trials with this film. This fading out of the image near the center of the plate may be interpreted as being due to the greater light absorbing power of the Super-Sensitive film.

Investigation of Role Played by the Object's Surface

In all of the previous experiments metal objects with an irregular surface were used. As this irregular surface caused a variation in the pressure exerted upon the surface of the emulsion, distortion of the surface must take place. Under these conditions, it was impossible to determine if the resulting phenomenon was due to this distortion or pressure upon the emulsion or if it was due to reflected light from the surface of the metal plate.

In this experiment, the metal plate used previously was replaced by a square of white cardboard. The letters "H A" were printed upon the surface of the cardboard with black printer's ink. The white cardboard reflects most of the light incident upon it while the black letters absorb the light incident upon them.

EXPLANATION OF PLATE IX

Fig. 17. This picture shows the greater light absorbing power of Super-Sensitive film. Eastman Super-Sensitive Panchromatic film exposed to light from a Mazda lamp for fifteen seconds.

PLATE IX

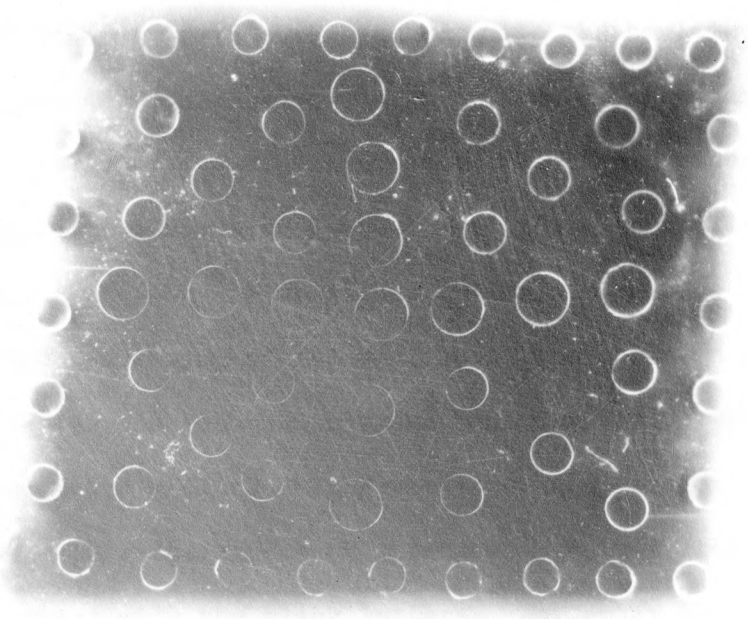

Fig. 17

The cardboard was placed upon the emulsion of Par Speed Portrait film, the surface containing the lettering being in contact with the emulsion. A wood block was placed over the entire cardboard so that the entire surface would be in contact with the emulsion. The film and cardboard were exposed to the light from a Mazda lamp for twenty seconds. The intensity of illumination was five foot candles.

The result is shown on Plate X, Fig. 19. As the letters "H A" are clearly reproduced on the illustration, it must be concluded that pressure and distortion of the surface of the emulsion cannot be responsible for the phenomenon under consideration. Observation of this illustration will readily reveal that the portion of the emulsion in contact with white cardboard underwent more complete exposure than that in contact with the black letters. Evidently the white cardboard reflected the light escaping from the emulsion causing it to return into the emulsion, thus giving greater exposure than the portions of the cardboard where the light was absorbed by the black letters.

Figure 20, Plate X shows the same result when the heading of an advertisement printed on a good grade high finish paper was used. The words "The practice of absorption spectrophotometry" are quite apparent.

Figure 18, Plate X shows a copy of a photograph. This was produced by merely placing the photograph directly upon the emulsion, assuring a good contact by placing a wood block over the picture and illuminating the emulsion and picture by means of a Mazda lamp for

twenty seconds. Although the picture lacks the contrast and detail of commercial photographic reproduction, it opens the door to an absolutely new field of photographic reproduction. For convenience this method will hereafter be referred to as "opaque contact photography".

CONCLUSIONS

A study of the results from the preceding investigations, which were selected from almost one hundred negatives, leads to the following conclusions:

1. Best results are obtained with the use of slow to average emulsion speeds. The more sensitive emulsions absorb light too rapidly, hence are very limited in the size of the opaque contact print being made.

2. The effect is independent of the nature of the light source provided the rays are within the visible range.

3. The effect is not due to any electronic transmission.

4. The effect is independent of the intensity of illumination.

5. The effect is not due to pressure of the object upon the emulsion nor is it due to the resultant distortion of the emulsion which is thereby produced.

6. The effect cannot be produced with the use of dry plates.

7. There is no evidence of photographic reversal.

8. Reproduction of black and white figures can be made by opaque contact photography.

EXPLANATION OF PLATE X

Fig. 18. Showcard reproduced by opaque contact photography.

Fig. 19. Photo copying by opaque contact photography.

Fig. 20. Printing reproduced by opaque contact photography.

PLATE X

Fig. 18

Fig. 19

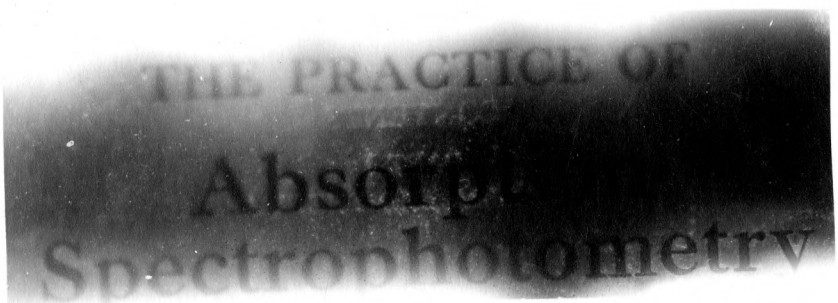

Fig. 20

9. These considerations seem to suggest hypothesis C 2 as given on page 5. Apparently the photographic process is as follows: It is known that light passes through the emulsion in a direction parallel to the surface. The grains in photographic emulsions are thin flakes and are for the most part parallel to the surface of the emulsion.[2] Thus the light meets the grains only on the thin edge and does not affect them. When, however, the emulsion is in contact with some solid the light passes out of the emulsion at that point and is either reflected from the object back into the emulsion thus exposing the grains with which it comes in contact, or is absorbed by the object in contact leaving the nearby grains unexposed. Since light of short wave lengths is quite easily absorbed by an emulsion[2], this proves to be a poor light to use.

ACKNOWLEDGMENTS

This investigation is the result of an observation made by the late Professor J. O. Hamilton, former head of the Department of Physics, Kansas State College of Agriculture and Applied Science.

The author wishes to express his appreciation to Dr. A. B. Cardwell and Dr. J. H. McMillen for the advice and encouragement received during the course of this investigation.

---

2 Corresponsence with J. H. Webb, Eastman Kodak Laboratories, June 7, 1939.