Sept. 8, 1925. 1,552,450

H. F. ROACH

METHOD OF INVESTIGATING MINUTE MOVEMENTS AND DISTORTION IN STRUCTURES

Filed April 29, 1922

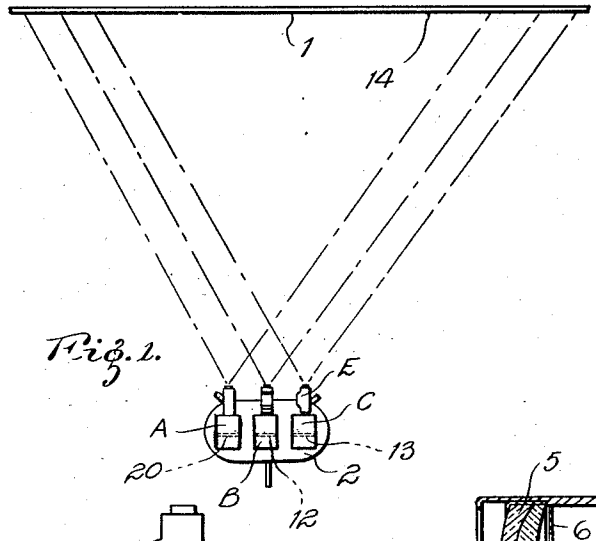


Fig. 1.

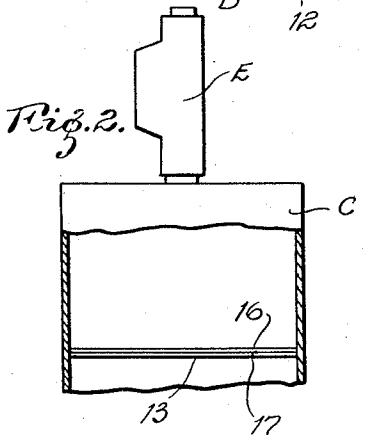


Fig. 2.

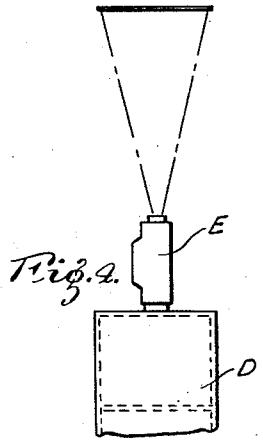


Fig. 4.

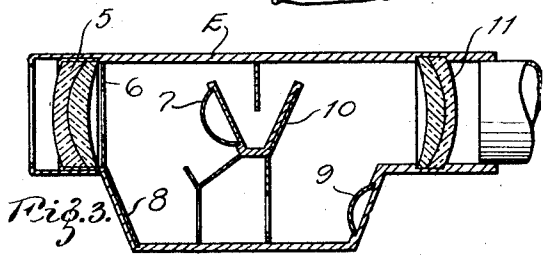


Fig. 3.

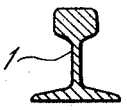


Fig. 6.

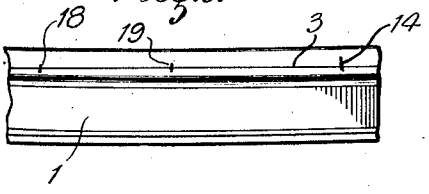


Fig. 5.

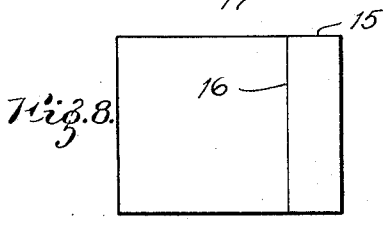


Fig. 8.

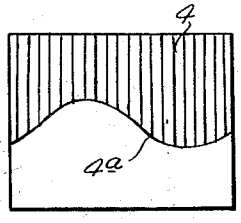


Fig. 7.

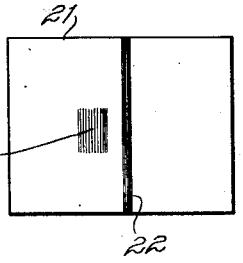


Fig. 9.

Inventor:
Harry F. Roach.
By Edwin Thurman
Attorneys.

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UNITED STATES PATENT OFFICE.

HARRY F. ROACH, OF ST. LOUIS, MISSOURI.

METHOD OF INVESTIGATING MINUTE MOVEMENTS AND DISTORTION IN STRUCTURES.

Application filed April 29, 1922. Serial No. 557,320.

To all whom it may concern:

Be it known that I, HARRY F. ROACH, a citizen of the United States, residing at St. Louis and State of Missouri, have invented new and useful Improvements in Methods of Investigating Minute Movements and Distortion in Structures, of which the following is a specification.

This invention relates to a method for observing or investigating minute movements which may occur in a body for any reason, and while the invention may be applied in any situation where a minute movement is to be observed, it is especially useful in observing or investigating the minute movements which occur in an engineering structure when the same is subjected to a load. By observing and determining the movements or distortion of any structure or member subjected to a load, much information may be deduced as to the fibre stresses which have been developed. The general object of the invention is to provide a simple method to enable such very minute movements to be rendered plainly visible, at the same time avoiding errors of chromatic magnification and aberrations incident to a dioptric optical system in great magnifications in one direction; also to make prominent the indicated movements in a direction parallel to an axis of selection. All the errors of a dioptric system may be eliminated if in any case found desirable by the use of a catoptric optical system in connection with my magnifying elements. As applied to the observation of distortions or movements of a member under a load, one of my objects is to provide a simple method for graphically indicating, and also for recording the distortions which occur by reason of the load. As one example of the use of my method, I have described it as employed to indicate to the eye the movements in a track rail which may occur on account of a load passing over the rail, and when my method is applied in such a case, it not only enables vertical movements and vertical distortions of the rail to be observed, but also enables the determination of simultaneous movements which occur in the rail in a longitudinal direction, and which give information useful in the solution of problems relating to rail creeping and ballast reaction.

Another example is the observing or recording of strains of a member, from which stresses may be deduced.

The information conveyed by such investigations is very useful in studying the engineering problems incidental to railway construction.

In practicing my method I may, if desired, produce simultaneously two images or two photographs of the object, one of which indicates to the eye the minute movements of the object with respect to one axis and the other indicates minute movements with respect to another axis.

Further objects of the invention will appear hereinafter.

The invention consists in the novel features, and in the general combination of steps to be particularly described hereinafter, all of which contribute to produce a simple and efficient method of investigating minute movements, and distortion in structures. A preferred embodiment of my invention will be particularly described in the following specification, while the broad scope of my invention will be pointed out in the appended claims.

Part of the subject matter herein described is embodied in a divisional application, Serial No. 729,730.

In the drawing, Figure 1 is a diagrammatic plan, illustrating the apparatus which I employ in using my method to determine movements in a rail on a railway track;

Figure 2 is a plan diagrammatically illustrating a camera partially broken away and shown in section, and further illustrating my method;

Figure 3 is a horizontal section through the camera attachment which I may employ to facilitate the practice of my method;

Figure 4 is a diagrammatic plan showing a camera partially broken away and shown in section, in order to illustrate one of the steps which may be employed in my method;

Figure 5 is a side elevation upon an enlarged scale showing a short portion of a rail and illustrating one of the steps which I may employ in practicing my method;

Figure 6 is an end elevation of the rail shown in Figure 5;

Figure 7 is a diagrammatic view indicating the character of an anamorphous photo-

graph which indicates the vertical rail distortions which occur under the action of the load upon the rail;

Figure 8 is a view illustrating the character of a transparent screen which I may employ in assisting to determine the longitudinal movements which occur in the rail, simultaneously with the vertical distortions indicated in Figure 7; and

Figure 9 is a diagrammatic view illustrating the character of an anamorphous photograph which indicates the amount of movement of a certain point on the rail, which occurs simultaneously with the vertical rail distortion indicated in Figure 7.

In practicing the various arts it is often necessary to investigate minute movements which may occur, due to physical, chemical or other forces. In physical laboratories it is, of course, possible to employ high-powered microscopes through the agency of which minute movements may be observed, but such microscopes must embody in their construction very carefully ground and expensive lenses which must have correction for aberration, astigmatism and other defects which are inherent in lenses, and they are limited to magnification in all directions, which, in very magnification, renders impracticable the imposition of scale into the image.

While my method may be employed under any circumstances to observe minute movements of any kind, it is particularly useful as applied to the solution of engineering problems through the investigation of the movements which occur in a structure when the load is applied to it. For example, the vibratory movements occurring in bridges can be investigated, or any movements occurring in columns, girders or any other members of an engineerng structure.

In the following specification, by way of example, I have described the method as applied to the observation or investigation of movements occurring in a rail on a railway track, when it is subjected to a load. When applied to such a purpose my method enables the vertical or perpendicular distortions of the rail to be determined with accuracy, and, if desired, the simultaneous movement of a predetermined point on the rail may be determined, thereby, giving data which is useful in solving problems of rail creeping and ballast reaction.

In Figure 1, 1 represents a rail on a piece of track which is to be investigated. Opposite this rail I set up a tripod, the head 2 of which offers a support for cameras, preferably three in number, and designated by the letters A, B and C. These cameras are focused upon the track so as to take in any desired length of rail, for example 35 to 50 feet.

The camera A is an ordinary camera and simply takes a normal photograph of the track in the usual way.

The camera B is provided with an attachment of my invention which produces an anamorphous image and an anamorphous photograph. The attachment produces a high magnification in one direction, only, parallel with a given axis. In the present instance this axis along which magnification occurs in the camera B, is a vertical axis and hence the image and photograph formed by this camera possesses a relative magnification in a vertical direction only. The camera C is provided with my attachment, but the attachment is so placed that an anamorphous image and photograph may be formed in which high magnification occurs parallel with another axis; in the present instance this axis is a substantially horizontal line, that is to say, the line along which the rail extends.

While in the present instance it will be noted that the two axes referred to are at right angles to each other, it should be understood that this is merely incidental and that the direction of magnification in the two images or photographs formed may have any angle with respect to each other that may be desired. In other words, this step of my method involves the making of two different anamorphous images simultaneously, each image having magnification on a certain axis different from the direction or axis of magnification in the other image or photograph.

In considering this subject it should be evident that a track rail even on a nearly perfect piece of track does not have its upper face disposed in a plane, in other words, as viewed in side elevation, no rail on a track is straight, hence if an image or photograph were made of it, in order to indicate how the r il has been distorted by the load upon it, such an image or photograph would not represent the net distortion which occurred in the rail due to the load. This difficulty might not arise in some structures, which would naturally present upon them a substantially straight line which, when an image is made, would be shown in the photograph as distorted from the straight position. In the present instance, however, I overcome this difficulty by placing on the side of the rail head, a straight line 3 (see Figure 5) which may be made, if desired, by means of a chalked line, or in any other manner which will insure a substantially straight line being formed on the side of the rail. Having formed this line in this way, I place the load, for example, a locomotive, on the rail at the point being investigated. The camera B, which produces vertical magnification only, will then produce an image of the line 3 in which the upper edge of the chalk line will be indicated as

bent into a curved or sinuous form, such as that indicated by the line 4^a on the plate 4, (see Figure 7). This magnification is effected by the use of lenses to be fully corrected to and including the actinic rays, and by means of a series of reflectors that divert the rays as they pass into the camera, the reflections occurring on curved reflectors in such a way that magnification occurs only parallel with a given axis; in this way in the camera B, magnification occurs in all vertical dimension, but the horizontal dimensions on the image or photograph are normal, that is, the same as would occur in a normal photograph or image formed with the same lenses, placed in the same way.

My attachment E, by means of which I effect this anamorphous result in the image, is illustrated in Figure 3 and comprises an object lens 5, fully corrected to and including the actinic rays, at the forward end of the attachment through which the rays pass into the camera. From this lens the rays pass through a suitable stop 6 and are reflected upon a curved reflector preferably a convex reflector 7 of cylindrical or elliptical form, the axis of curvature of the reflector being disposed in a horizontal position. From the reflector 7, the light rays are inclined up or down in a vertical plane and fall upon a reflector 8, which may be a plane reflector, if desired. From this point the rays pass over to another curved reflector 9, which is similar to the reflector 7 and from which they pass up on to a reflector 10, which may be a plane reflector. From this point they pass through a second lens 11, corrected similar to lens 5, and into the camera box where they produce an anamorphous image upon the plate or screen held therein.

It will be understood that the relative angular positions of the curved reflectors is such as to produce a balanced distortion of an image according to the principle fully explained in my pending application Serial Number 537,436, filed February 18th, 1922.

In the camera C, which produces an anamorphous image magnified in the horizontal direction, the attachment shown in Figure 3 is employed, but it is held in a position in which the axes of curvature of the reflectors 7 and 9 are in a vertical position. The attachment operates in the same way upon the rays of light, except that the magnification is produced in a horizontal plane instead of in a vertical plane as in the camera B.

The camera B enables minute movements which occur in a vertical direction in the rail or any other body, to be observed, for it will be evident that if this camera is held fixed, it will produce an anamorphous image on the screen or ground glass plate 12, in which the magnification occurs solely in the direction in which the transverse movements of the rail take place; this magnification will be sufficient to render the movements sensible to the eye; by observing the image on the ground glass 12 before the load has been put upon the rail and again after the load has been put upon the rail, the movements of the line, such as the line 4^a (Figure 7) will be observed, and the amount of movement can be noted.

In order to enable the camera C to produce an image on its ground glass plate 13, which will indicate the amount of movement of a predetermined point on the rail, I prefer to provide on the rail a short vertical line or mark 14 (see Figure 5) which extends at right angles to the line 3. Within the camera C I place a transparent screen 15, in front of the ground glass 13, and this screen is provided with a line or indicated mark 16, which passes vertically across it. An image of the point 14 will then appear on the ground glass screen 13; the camera box 6 should then, before the load is placed on the rail, be adjusted until the image of the point 14 coincides with the line 16. The locomotive or other load should then be placed upon the rail and when this occurs a shifting movement will occur of the point 14, and due to the magnification which occurs in the horizontal dimensions of the image, the image 17 of this point will be found to be moved slightly out of alignment with the mark 16. In this way the relative amount of movement of the point 14, incidental to a given rail distortion indicated on the ground glass 12, can be observed, and furthermore, if desired, these two images may be concurrently observed by placing the cameras close together, as shown.

The image on the screen 12, as intimated, will have the character of the sinuous line 4^a shown in Figure 7, and the character of this line will be of interest to the engineer or other observer, in investigating the distortion in the rail which a given load produces in a given position.

If it is desired to make a permanent record of the images formed in the cameras, it is simply necessary to place a sensitized plate in each camera in the proper position, and expose the same in the usual manner in taking photographs. It is necessary, however, to have in the finished photograph, some means for determining what the normal scale of the photograph is with respect to the rail. For this purpose it is merely necessary to photograph a two foot rule in the field of the camera and extending at right angles to the direction in which magnification is to occur; or I may place two marks 18 and 19 on the side of the rail, at a predetermined distance apart.

I prefer to ascertain this normal scale by

photographing the rule or other scale on a photographic plate exposed in the camera A, at the same time that the exposure of the sensitized plate is made in the camera B. The cameras are all at the same distance from the rail and arranged so that the images are alike and on the same scale except for the distortions in one direction. Hence a sensitized plate 20 exposed in the camera A will give what I call the normal scale for the photographs.

In Figure 7 the portion of the plate below the line 4^a represents a magnified area of the line 3, while the space above it will show a small portion of the side of the rail head above this line. The actual distortion and relative fibre stresses are indicated by the character of the bends in this line 4^a, and by reason of the fact that we know the amount of magnification, and also the normal scale of this photograph, we are enabled to compute by engineering formulas applied to this curve, the fibre stress which must have occurred in the rail to correspond with the actual distortion indicated by the photograph.

If desired, I may produce a photograph similar to that shown in Figure 7, by producing an anamorphous reproduction or photograph of the plate 20 of the camera A, after the same has been developed, the magnification in the new photograph occurring in a vertical direction. Figure 4 illustrates how this could be accomplished, by placing the photograph before a camera D, which is similar in construction to the cameras B and C. However, in Figure 4 the attachment 11 is illustrated in the position to produce magnification in a horizontal direction, only, and with the attachment in this position, I employ this camera D, if desired, to produce a photograph from the sensitized plate 13, after development. By doing so, a magnification occurs in a horizontal direction, and the result is a photograph or plate 21 such as indicated in Figure 9, in which the vertical band 22 represents the line 16 as it would be magnified, and the area 23 indicates a point or mark 14 magnified; the distance between the band 22 and the area 23, indicates or records permanently the amount of movement which occurs at the point 14 on the rail. The camera D in this position may be used on the plate shown in Figure 7, by turning the plate through 90 degrees before photographing it, or, if desired, the plate may be left in an upright position, and the attachment E rotated on its longitudinal axis.

In practice, when great accuracy in the deductions is desired, I prefer to produce the anamorphous plates by use of the cameras B, and C, and also by anamorphous enlargements of the normal photograph taken with the camera A. The two results operate as a check upon each other, and their conformity will be a criterion of the accuracy of the observations. More reliance may be placed on the use of the photographic plate 20 of the camera A, where the light conditions are not such as to produce the best results with camera B.

I have referred to the transverse movements of the rail as vertical movements, instead of lateral movements because the word "lateral" used in connection with a track would mean horizontal. But it is understood that my method renders it possible to investigate any movements or distortions which occur in a plane transverse to the longitudinal axis of the body.

In practice a relative magnification at the ratio of 400 to 1 can be readily obtained in the anamorphous images or photographs, which will be found ample for ordinary practice; but in case of special investigation, this relative magnification may be stepped up by repeated photographing as illustrated in Figure 4, to any degree desired.

It is understood that the embodiment of the invention described herein is only one of the many embodiments my invention may take, and I do not wish to be limited in the practice of my invention nor in my claims, to the particular embodiment set forth.

What I claim is:

1. The method of investigating minute movements which may occur in a body, which consists in producing balanced anamorphous image in a fixed position, of the body, in which magnification occurs solely in the direction in which the movements of the body are to be observed, the magnification operating to render the movements sensible to the eye, and observing the image before and after the movement has occurred.

2. The method of investigating minute movements which may occur in a body, which consists in producing a balanced distorted image in a fixed position of the body by successive anamorphous projections thereof, in which image magnification occurs solely in the direction in which the movements of the body are to be observed, the magnification operating to render the movement sensible to the eye, and observing the image before and after the movement has occurred.

3. The method of investigating minute movements which may occur in a body, which consists in simultaneously producing two balanced anamorphous images of the body, one of the images being magnified in a direction substantially parallel to a given axis and the other image magnified in a direction substantially parallel to another axis, the magnification of said images operating to render the movements sensible to the eye, whereby observation of the images will

disclose the effect produced in the body by such movements.

4. The method of recording minute movements which may occur in a body, which consists in producing a balanced anamorphous photograph of the body, in which only the dimensions substantially parallel to a given axis are magnified, the magnification operating to render the movement sensible to the eye, whereby observation of the photograph will disclose the extent of such movements.

5. The method of recording minute movements which may occur in a body, which consists in producing a balanced anamorphous photograph of the body by photographing the final of a series of successive anamorphous projections of the light rays reflected therefrom in which only the dimensions substantially parallel to a given axis are magnified, the magnification operating to render the movement sensible to the eye.

6. The method of investigating minute movements which may occur in a body, which consists in producing a balanced anamorphous photograph of the body in which only the dimensions substantially parallel to a given axis are magnified, producing a second balanced anamorphous photograph taken simultaneously with the first named photograph in which only the dimensions substantially parallel to another axis are magnified, the magnification in both photographs being sufficient to render the movements sensible to the eye, whereby observations of the photographs will disclose the effect produced in the body by such movements.

7. The method of investigating minute movements or distortions which may occur in a body having a substantially straight line upon the same, when at rest, which consists in producing a balanced anamorphous image of the said line, in which dimensions substantially at right angles to said line are so magnified as to render the said movements sensible to the eye, whereby observation of the image will disclose the extent of such movements.

8. The method of investigating the distortion in an elongated member subjected to a load which consists in placing a substantially straight line longitudinally on the member before the same is loaded, and producing an anamorphous photograph of the line while the member is subjected to the load, in which dimensions are magnified in a direction transverse to the longitudinal axis of the member.

9. The method of investigating the distortion in a track rail when subjected to a load, which consists in placing a substantially straight line longitudinally on the rail before the same is loaded, and producing an anamorphous photograph of the line while the rail is subjected to the load, in which magnification occurs in a direction transverse to the line.

10. The method of investigating a movement occurring in a member when subjected to a load, which consists in producing an anamorphous image of the member on a plate, juxtaposing a screen with a marked point thereupon registering with the image of a predetermined point on the member, then subjecting the member to the load, and observing thereafter the movement of the image of the predetermined point with respect to the marked point on the screen.

11. The method of investigating minute movements which may occur in a body, which consists in producing a balanced anamorphous photograph of the body in which magnification occurs in one direction only, and simultaneously producing a normal photograph having the same normal scale as the anamorphous photograph, whereby observation and comparison of the photographs will disclose the extent of such movements.

12. The method of investigating minute movements which may occur in a medium, which consists in producing a balanced anamorphous image of a phenomenon, by which the dimensions substantially parallel to a given axis are magnified a predetermined degree of that of the dimensions substantially parallel to any other axis of selection, the magnification operating to render the movements determinable, whereby observation of the image will disclose the character and extent of the movements.

In testimony whereof, I have hereunto set my hand.

HARRY F. ROACH.