June 5, 1951 W. C. BARNES 2,555,308

FLAW DETECTION APPARATUS

Filed Oct. 30, 1946

Fig-1

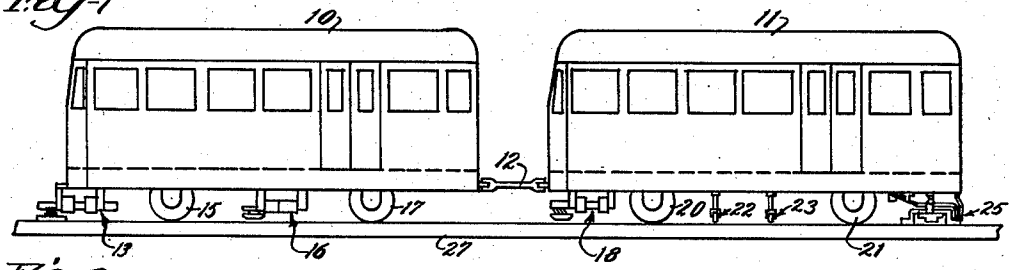


Fig-2

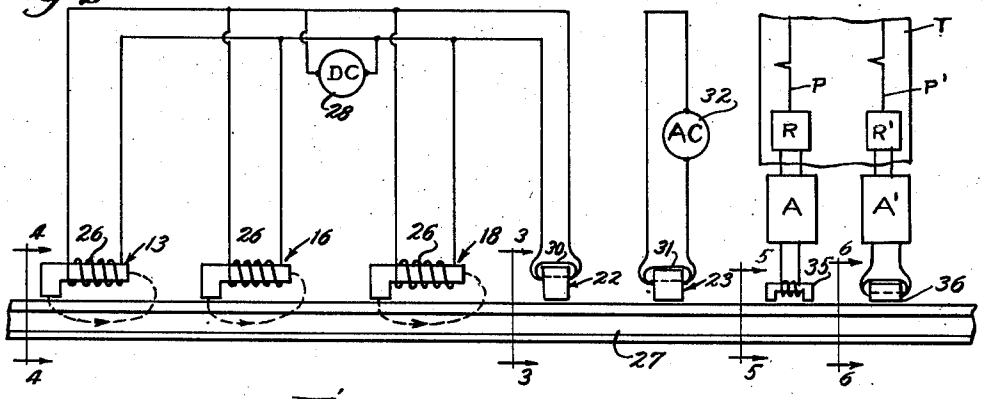


Fig-4

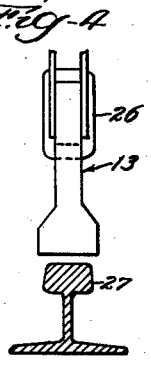


Fig-3

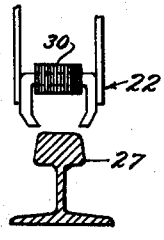


Fig-5

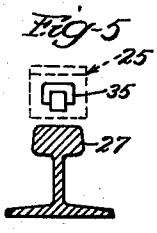


Fig-6

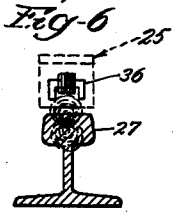


Fig-7

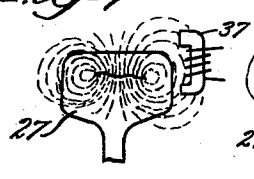
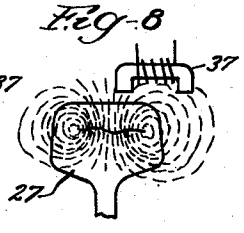


Fig-8



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FLAW DETECTION APPARATUS

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11 Claims. (Cl. 175—183)

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My invention relates to the art of detecting structural flaws in rails, and is particularly directed to the method that is characterized by applying flux to a rail and subsequently exploring the residual fields of magetism in the rail for flaw indications.

In general the structural flaws in a rail are of three principal types: transverse fissures perpendicular to the axis of the rail; vertical splits parallel to the side of the rail; and horizontal splits parallel to the top of the rail. Of these three types of flaws transverse fissures are the most serious threats to rail-road safety, and the vertical splits are second in importance. The installation of controlled cool rails has materially reduced the number of transverse fissures but has had less effect in reducing the number of longitudinal splits in rails.

The difficulty involved in attempting to detect more than one of the three types is that applying magnetic flux to a rail of optimum orienttation for residually polarizing the flaws of one of the three types will usually fail to polarize flaws of at least one of the other two types to sufficient intensity for detection. Thus the usual procedure of applying magnetic flux to a rail longitudinally thereof for the primary purpose of polarizing transverse fissures usually fails to polarize vertical splits and horizontal splits to sufficient degree for adequate effect on the detector or pickup means.

The general object of the present invention is to provide a method and means for detecting more than one of these types of flaws, and preferably all three types, with adequate effectiveness. A specific object of the invention is to provide a means and method for applying magnetic flux that will effectively polarize longitudinal defects in addition to carrying out the primary function of polarizing transverse fissures. In general these objects are attained by applying what may be termed a primary flux for residually magnetizing the rail in a longitudinal direction for polarization of the transverse fissures and applying what may be termed a secondary flux of lesser magnitude transversely of the rail to polarize longitudinal splits with special reference to vertical splits, the secondary magnetization preferably following the first magnetization. The secondary flux is usually of lesser magnitude than the primary flux, but is sufficient to cause longitudinal defects to be detected in addition to transverse fissures. In other words, the application of the primary and secondary flux successively produces a resultant pattern

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of residual magnetism that will reveal both types of flaws.

The above and other objects of the invention will be apparent in the following description taken with the accompanying drawings, in which

Fig. 1 is a diagrammatic view of an apparatus mounted on railway vehicles for carrying out the method;

Fig. 2 is a schematic arrangement of the principal parts of the apparatus, including a wiring diagram of the circuits involved;

Figs. 3, 4, 5 and 6 are transverse sectional views taken at the locations indicated by section lines in Fig. 2 bearing corresponding numbers; and

Figs. 7 and 8 are views showing modifications of the invention.

The embodiment of the invention shown in the drawings, and hereinafter described, is merely illustrative of many forms in which the invention may be embodied, and the appended claims should be construed as broadly as the prior art will permit.

Since the specification is addressed to those skilled in the art, and apparatus of the present type is well known in the art, it will be sufficient to describe the invention with the aid of drawings that are for the most part diagrammatic.

The particular type of flaw detection procedure here in mind is disclosed in Patent Nos. 2,317,718, 2,317,719 and 2,317,720, issued on April 27, 1943, to Walter C. Barnes and Henry W. Keevil as joint inventors, which patents, as far as consistent, are incorporated in the present disclosure by reference. The present application is a continuation-in-part of application Serial No. 435,763, filed March 23, 1942, now abandoned, which application is also included in the present disclosure by reference in so far as consistent therewith.

Fig. 1 shows how apparatus incorporating the present concept may be constructed for practical rail testing. The figure shows a four-wheel test car comprising a forward section 10 and a rearward section 11, preferably interconnected by non-magnetic coupling means 12. The forward section 10 carries an L-shaped electromagnet, generally designated 13, forward of front wheel 15, and carries a second L-shaped electromagnet, generally designated 16, between the front wheel 15 and the rear wheel 17.

The rearward section 11 carries a third L-shaped electromagnet, generally designated 18, forward of its front wheel 20. Between the front wheel 20 and the rear wheel 21 the second car carries a D. C. electromagnet, generally desig-

nated 22, positioned transversely of the rail, followed by an A. C. electromagnet, generally designated 23, also positioned transversely of the rail. Rearward of the rear wheel 21 the second section of the test car carries a pickup assembly or detector unit, generally designated 25.

The three electromagnets 13, 16 and 18 are of the same polarity for a certain additive effect, and each applies magnetic flux of relatively high density to the underlying rails. The third electromagnet 18 acts as a cleaner and is constructed and arranged to minimize any concentration of laterally-directed lines of flux at the rail in its magnetic circuit, thereby to favor leaving the rail with a relatively high degree of longitudinal residual magnetism in the vicinity of fissures. The flux applied by these three electromagnets effectively polarizes the transverse fissures.

The D. C. electromagnet 22 being positioned transversely of the rail applies transverse flux to the rail, and thereby tends to polarize selectively any longitudinal fissures that may exist, especially vertical longitudinal fissures. The vertical penetration of both the longitudinal flux and the transverse flux adequately polarizes the horizontal split heads, as shown in Figs. 7 and 8.

The purpose of the transversely positioned A. C. electromagnet 23 that follows the electromagnet 22 is to wipe out any troublesome surface polarizations that might be created by the magnet 22, such as shelly incrustations and, to some extent, burns. This A. C. electromagnet, which may be omitted in some practices of the invention, has a frequency high enough to limit the wiping out action to a desirable shallow zone at the surface of the rail.

When the car is operating on track characterized by magnetic spots left by the lifting magnets employed at the mill where the rails are made, a second A. C. magnet may be employed in advance of the D. C. magnet 22 and/or the A. C. transverse electromagnet 23 may be interchanged with the transverse D. C. electromagnet 22, so that the magnetic spots may be erased ahead of the D. C. magnet 22. In such an arrangement a lower alternating frequency may be used in energizing the erasing electromagnet 23 so that the erasing magnetic flux will penetrate more deeply into the rail for removing the undesirable magnetic spots.

The electromagnets 22 and 23 are preferably shaped as shown in Fig. 3. With these forms the magnets may move laterally with reference to the rail without affecting their ability to apply the desired transverse magnetic flux to the rail. The A. C. transverse electromagnet 23 may, if desired, be placed with its core extending parallel, or substantially parallel, with the longitudinal axis of the rail without materially changing the results obtained by the present arrangement.

Fig. 3 shows in a general manner the fundamental relationships in the above described apparatus. For more specific information reference may be made to the above-mentioned patents.

The three L-shaped electromagnets 13, 16 and 18 are all wound in the same direction for magnetizing the rail 27, and are shown as connected in parallel to a suitable D. C. generator 28. The D. C. electromagnet 22 has its coil 30 also connected in parallel with the generator 28. The A. C. electromagnet 23 has its coil 31 energized independently by a suitable A. C. generator 32.

The detector unit 25 includes two pickup or detector coils 35 and 36, each of which has a U-shaped core, as indicated, the detector coil 35 being positioned longitudinally of the rail 27 and the detector coil 36 being positioned transversely of the rail. Thus the longitudinally positoned detector coil 35 has the optimum orientation for response to transverse fissures that have been polarized by the longitudinally applied flux, and the transversely positioned detector coil 36 is positioned to favor response to the residual magnetic fields of longitudinal splits, which have been effectively polarized by the transverse D. C. electromagnet 22.

In the particular arrangement shown, the two detector coils 35, 36, are connected to the inputs of two corresponding amplifiers A and A', which amplifiers are in turn operatively connected to relays R and R' for independent control of two recording pens P and P', respectively. The two pens P and P' may trace lines side by side on the record tape T. Deflections of the two pens caused by flaw indications result in corresponding peaks or signals formed by the two record lines, as shown in Fig. 2.

The resultant magnetic state produced by the two successive magnetic treatments of the rail in different directions is distinctly different from any condition that can be produced by magnetizing the rail in only one direction, but just what is involved in the resultant magnetic state has not been clearly determined.

It may be that the first applied primary flux results in simple longitudinal residual magnetism, and that the later applied secondary flux, being 90° from the first applied flux, serves to shift the orientation of the residual flux from a longitudinal direction to some diagonal direction. The diagonally directed resultant residual flux would have both longitudinal and lateral components, and therefore would affect both the longitudinal detector coil 35 and the transverse detector coil 36.

It is also conceivable that the two successively applied flux fields result in different layers of magnetization, at least one layer or stratum of the rail being polarized longitudinally by the three electromagnets 13, 16 and 18, and at least one other layer or stratum of the rail being polarized transversely by the transverse electromagnet 22.

In either event both lateral and longitudinal components of residual magnetism coexist in the rail as a result of the two successive applications of magnetic flux, and the transverse component as well as the longitudinal component has sufficient strength to cause an indication to be made on the record tape T.

My invention may be aptly described as being based on the concept of first magnetizing the rail in one direction primarily for revealing one type of flaw, and then magnetizing the rail in a different direction to a sufficient degree to modify the effect of the first applied flux, the purpose of the modifying step being to bring about a sufficiently strong component of residual magnetism at a sufficient angle from said one direction to reveal another type of flaw.

If desired a third detector coil 37 may be used in conjunction with other amplifying and recording elements (not shown) also associated with the tape T for indicating particularly the presence of horizontal split heads. The coil 37 is preferably placed in a vertical position alongside and adjacent to the gauge side of the rail head, as shown in Fig. 7, or in a horizontal posi-

tion, as shown in Fig. 8, where it is in a favorable position to respond to the residual field in the vicinity of horizontal fissures. When placed in a vertical position, as shown in Fig. 7, alongside the gauge side of the rail head the coil preferably is positioned high enough not to conflict with joint bars or other track structure.

Both the arrangement shown in Fig. 7 and the arrangement shown in Fig. 8 are characterized by the concept of positioning at least one of the poles of the detector coil **37** outside the plane of one side of the rail and above the level of the top of the rail. Both arrangements are also characterized by the positioning of the axis of the core of the coil in a transverse plane perpendicular to the longitudinal axis of the rail.

It will be noted that the coil **36** in Fig. 6, which is particularly sensitive to vertical split heads, is centered over the rail head, whereas the horizontal coil **37** (Fig. 8), which is particularly sensitive to horizontal fissures, is positioned off center and over the gauge side of the rail. The flux lines indicated in the drawing at a vertical split head (Fig. 6), and at a horizontal split head (Figs. 7 and 8), show clearly why the respective coils are particularly sensitive to the two types of fissures. Obviously the coil **37** may be placed in any position intermediate the vertical position shown in Fig. 7 and the horizontal position shown in Fig. 8.

Since the longitudinal detector coil **35** is particularly responsive to transverse fissures, the transverse detector coil **36** is particularly responsive to vertical split heads, and the detector coil **37** is particularly responsive to horizontal split heads, there is little opportunity for a fissure of any description to escape detection.

While only one principal embodiment of the invention has been shown and described, it will, of course, be understood that it may be carried out in many ways. The preferred sequence of the two magnetizing steps set forth herein may, for example, be reversed, the transverse flux being applied ahead of the longitudinal flux.

I claim as my invention:

1. A method of locating flaws in a rail including the steps of progressively subjecting the rail to two magnetizing forces successively, one of which forces is substantially longitudinal of the rail, the other of which is substantially transverse of the rail, the last applied magnetic force permitting survival of residual magnetism from the first applied force, longitudinally progressively freeing the rail from the two applied magnetizing forces thereby longitudinally progressively establishing in the rail a composite pattern of residual magnetism having coexisting components derived from both of the magnetic forces, and progressively exploring the residually magnetized rail outside the field of said forces for at least the transverse components of the composite pattern.

2. In an apparatus for detecting flaws in a rail, the combination of two magnetic flux-creating means spaced apart longitudinally of the rail for movement in one longitudinal direction along the rail with one of the means trailing the other, one of said means creating transverse flux, the other of said means creating longitudinal flux, said trailing means permitting survival of residual flux created by the leading means, and detecting means trailing said two flux-creating means outside the created flux fields, said detecting means being responsive to transverse and longitudinal components of residual magnetism in the rail.

3. A method of locating flaws in a rail including the steps of progressively subjecting the rail to two magnetizing forces successively, one of which forces is substantially longitudinal of the rail, the other of which is substantially transverse of the rail, the last applied magnetic force permitting survival of residual magnetism from the first applied force, longitudinally progressively freeing the rail from the two applied magnetizing forces thereby longitudinally progressively establishing in the rail a composite pattern of residual magnetism having coexisting components derived from both of the magnetic forces, and progressively exploring the residually magnetized rail both in a longitudinal zone defined by the planes of the side surfaces of the head of the rail and in an adjacent longitudinal zone outside of one of said planes.

4. In an apparatus for detecting flaws in a rail, the combination of two magnetic flux-creating means spaced apart longitudinally of the rail for movement in one longitudinal direction along the rail with one of the means trailing the other, one of said means creating transverse flux, the other of said means creating longitudinal flux, said trailing means permitting survival of residual flux created by the leading means, and detecting means trailing said two flux-creating means outside of the created flux fields, said detecting means including two detector coils magnetically coupled to the rail, one selectively responsive to transverse components of residual magnetism and the other responsive to longitudinal components of residual magnetism, the former coil having at least one pole lying outside the longitudinal zone defined by the planes of the sides of the rail head.

5. An apparatus as set forth in claim 4, in which the former coil lies entirely outside of said longitudinal zone.

6. In an apparatus for detecting flaws in a rail, the combination of two magnetic flux-creating means spaced apart longitudinally of the rail for movement in one longitudinal direction along the rail with one of the means trailing the other, one of said means creating transverse flux, the other of said means creating longitudinal flux, said trailing means permitting survival of residual flux created by the leading means, and detecting means trailing said two flux-creating means outside the created flux fields, said detecting means having at least one coil positioned above the top surface of the rail with its axis substantially longitudinal of the rail and having another coil positioned to one side of the rail with one pole above the level of the top of the rail and the other pole below that level.

7. In apparatus for detecting horizontal flaws in rail, means for creating a magnetic flux in the rail with a vertical component, and a detecting means including a magnetic core having at least one of its poles outside the plane of the side of the rail and above the level of the top of the rail, the axis of said core lying in a plane intersecting the longitudinal axis of the rail, said detecting means being located beyond the direct field of action of the flux-creating means so as to be responsive to only local residual magnetism.

8. In apparatus for detecting horizontal flaws in rail, means for creating a magnetic flux in rail with a vertical component, and a detecting means including a magnetic core having one pole located at the top of the rail and the other pole located

beyond the vertical plane of the side of the rail, said detecting means being located beyond the direct field of action of the flux-creating means so as to be responsive to only local residual magnetism.

9. In an apparatus for detecting flaws in a rail, the combination of two magnetic flux-creating means spaced apart longitudinally of the rail for movement in one longitudinal direction along the rail with one of the means trailing the other, one of said means creating transverse flux, the other of said means creating longitudinal flux, said trailing means permitting survival of residual flux created by the leading means, and detecting means trailing said two flux-creating means outside the created flux fields, said detecting means including one longitudinally positioned detector coil and two transversely positioned detector coils, both magnetically coupled to the rail, and at least one of said transversely positioned detector coils having at least one of its poles lying outside the longitudinal zone defined by the planes of the sides of the rail head.

10. The method of locating flaws in a rail including the steps of subjecting the rail to repeated applications of longitudinal magnetic flux to longitudinally magnetize the rail, then applying a transverse magnetic flux of insufficient strength to materially affect the longitudinal residual flux in the rail, but of sufficient strength to introduce a transverse component of residual flux in the rail, and then testing the rail for both longitudinal and transverse components of residual flux.

11. In an apparatus for detecting flaws in a rail, the combination of two magnetic flux-creating means spaced apart longitudinally of the rail for movement in one longitudinal direction along the rail with one of the means trailing the other, the leading means creating a longitudinal flux through the rail, and the trailing means creating transverse flux through the rail, said trailing means being of a strength insufficient to wipe out the longitudinal flux created by the leading means but leaving a composite field with both longitudinal and transverse components of residual magnetism, and detecting means trailing said two flux-creating means outside the created flux fields, said detecting means being responsive to at least the transverse components of residual magnetism in said composite field.

WALTER C. BARNES.

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