

[54] METHOD AND SYSTEM FOR DETECTING
WHEEL FLATS ON RAIL VEHICLES

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1971, abandoned.

[30] **Foreign Application Priority Data**

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[58] Field of Search..... 246/169 R, 40, 41, 54,
246/249, 246, 128, 122, 129, 34 R, 89

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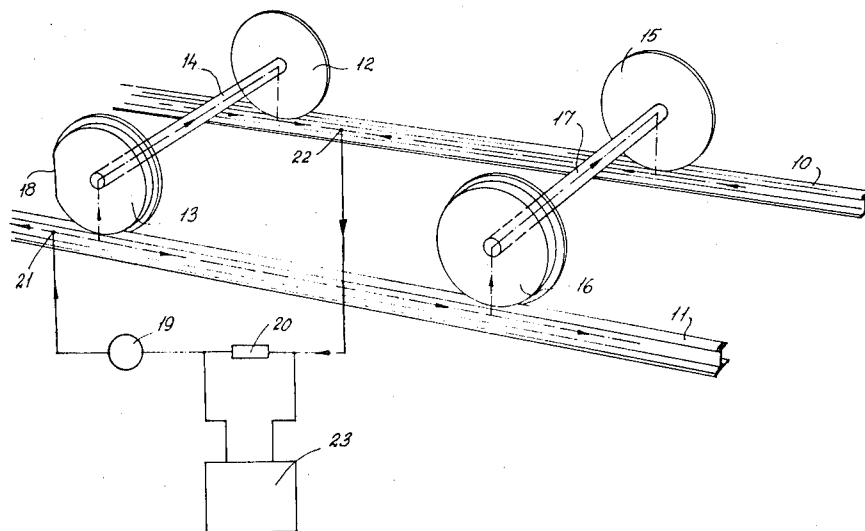
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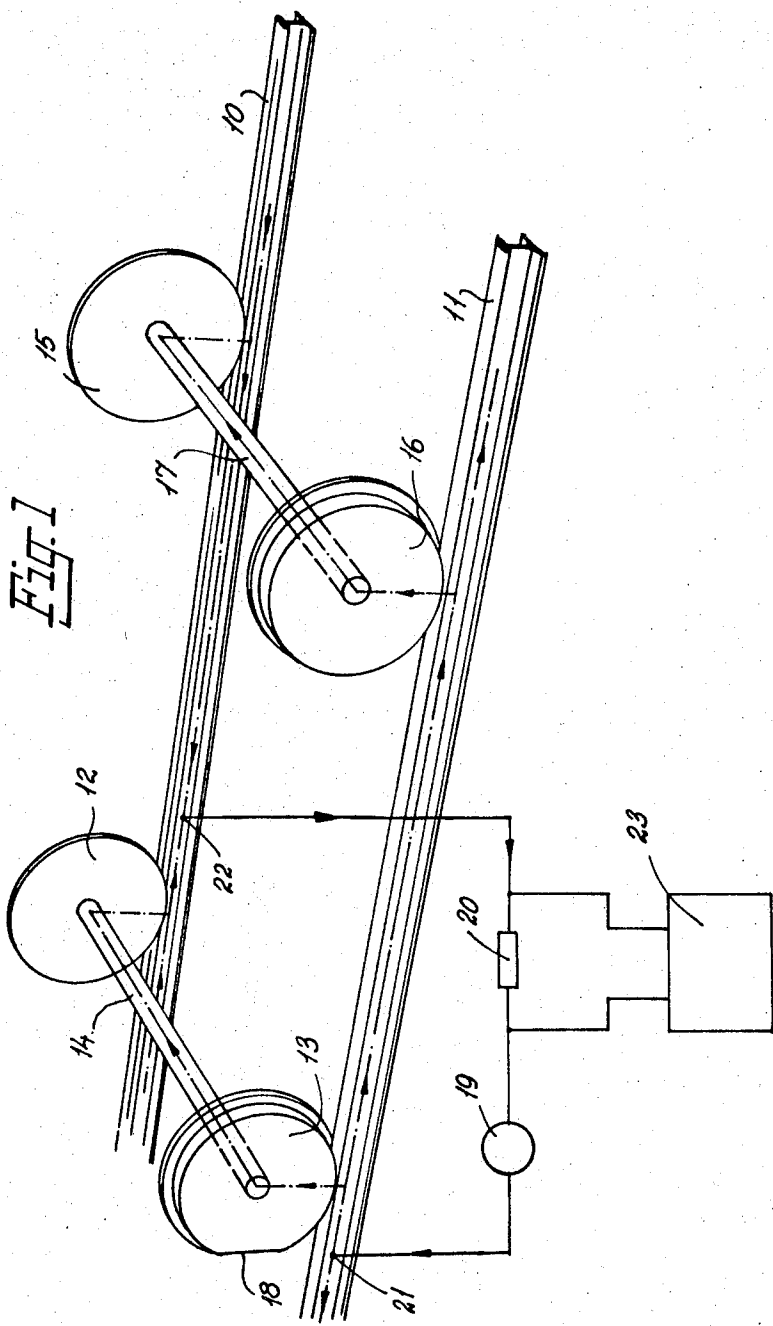
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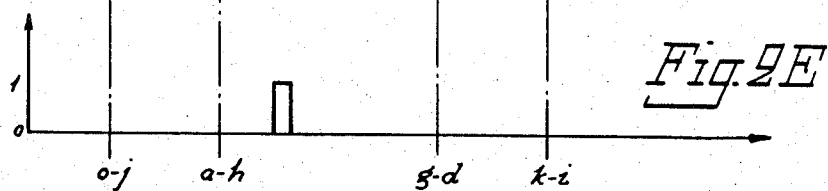
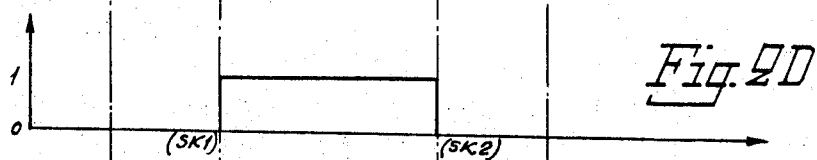
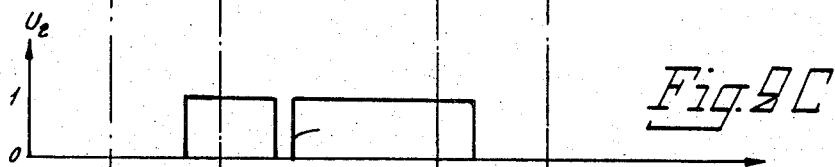
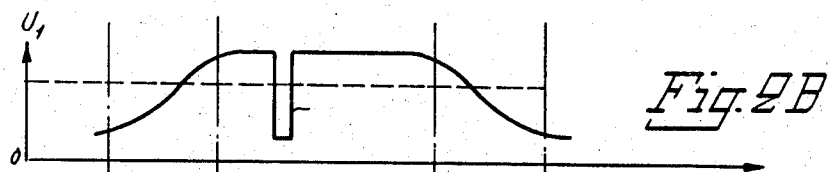
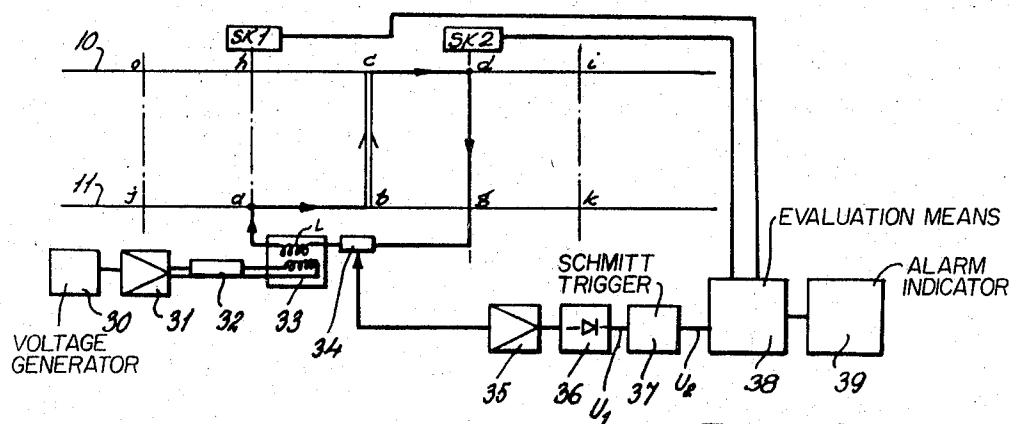
ABSTRACT

A system and method for detecting the presence of wheel flats on rail vehicles. The system includes a voltage source, one side of which is connected to a first rail of a track and the other to a second rail extending parallel with the first rail in a manner whereby the current circuit includes the rim of the wheel being sensed. The connection points are spaced in the longitudinal direction of the track such that the distance between the connection points is shorter than the smallest axle distance occurring in the vehicle. The circuit also includes an impedance and a detecting means connected over a portion of the impedance to sense changes in voltage resulting from a break in the circuit caused by a wheel flat.

9 Claims, 23 Drawing Figures







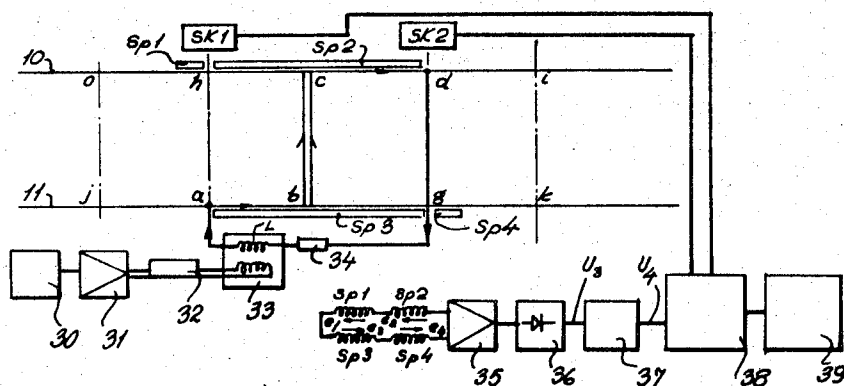


Fig. 3A

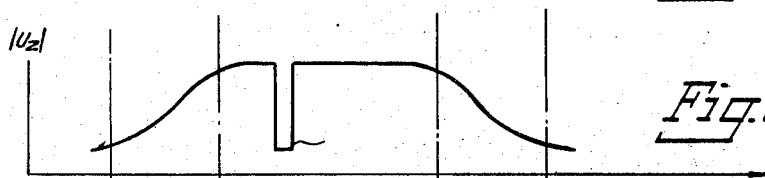


Fig. 3B

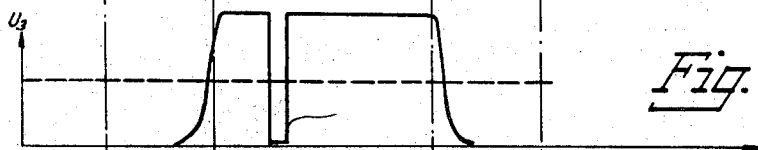


Fig. 3C

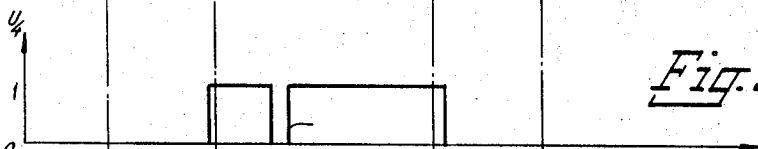


Fig. 3D

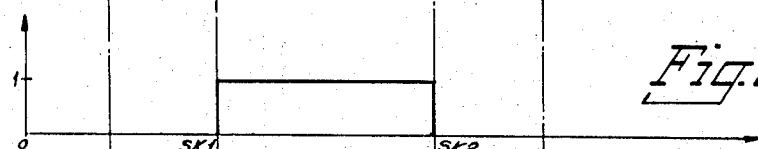


Fig. 3E

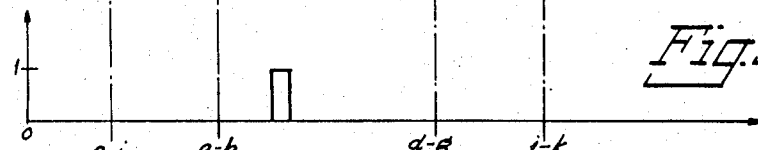


Fig. 3F

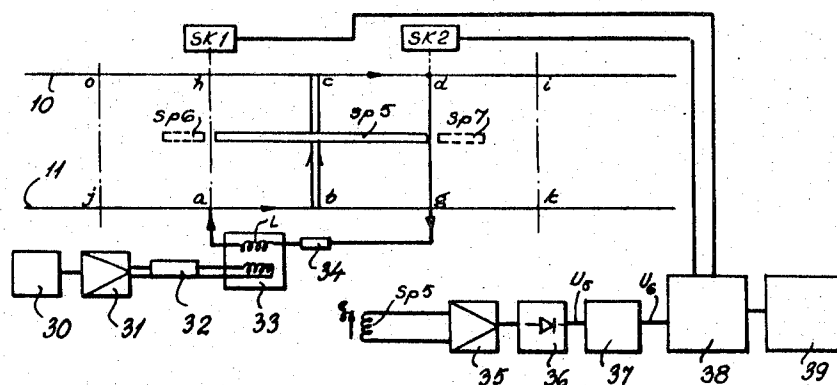


Fig. 4A

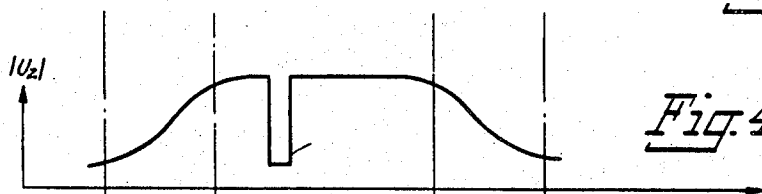


Fig. 4B

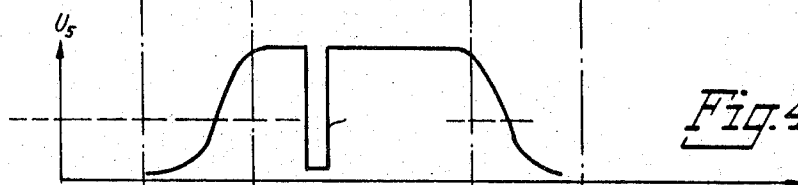


Fig. 4C

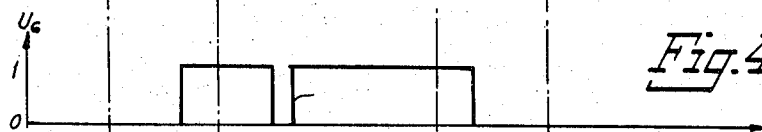


Fig. 4D

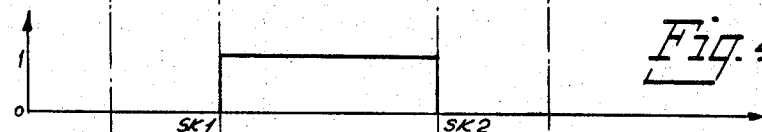


Fig. 4E

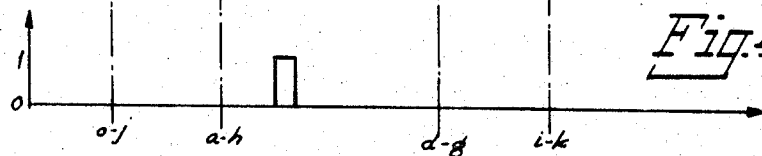


Fig. 4F

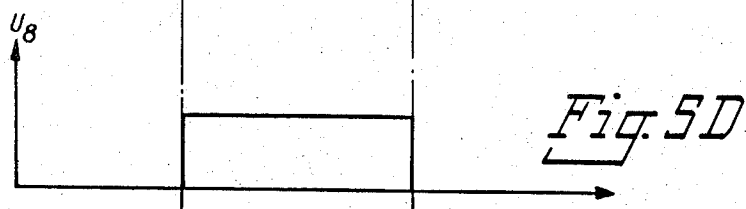
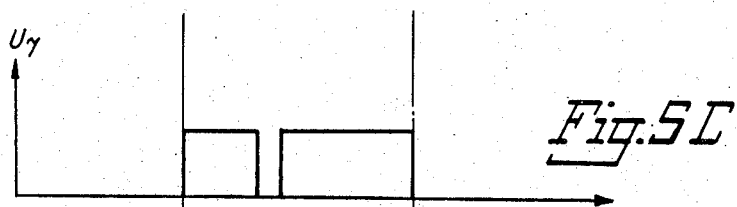
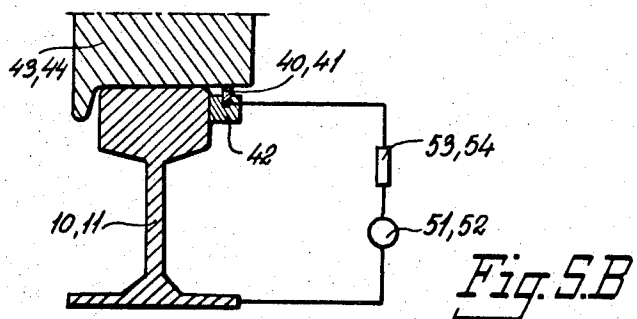
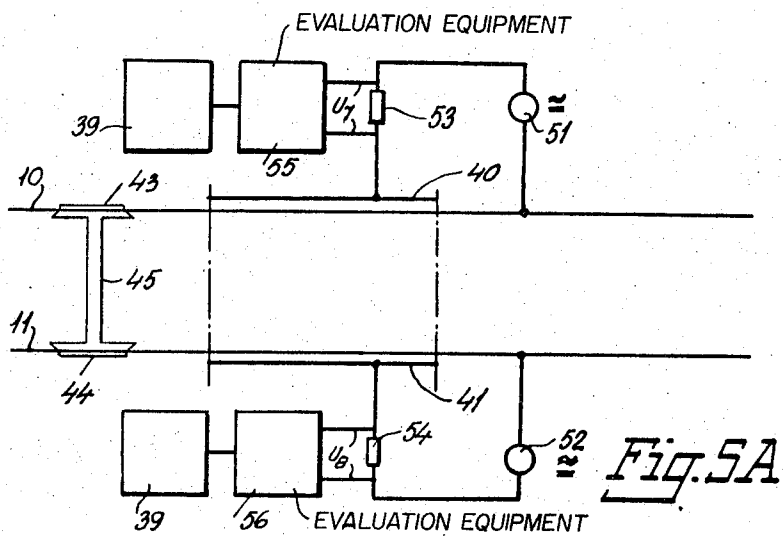
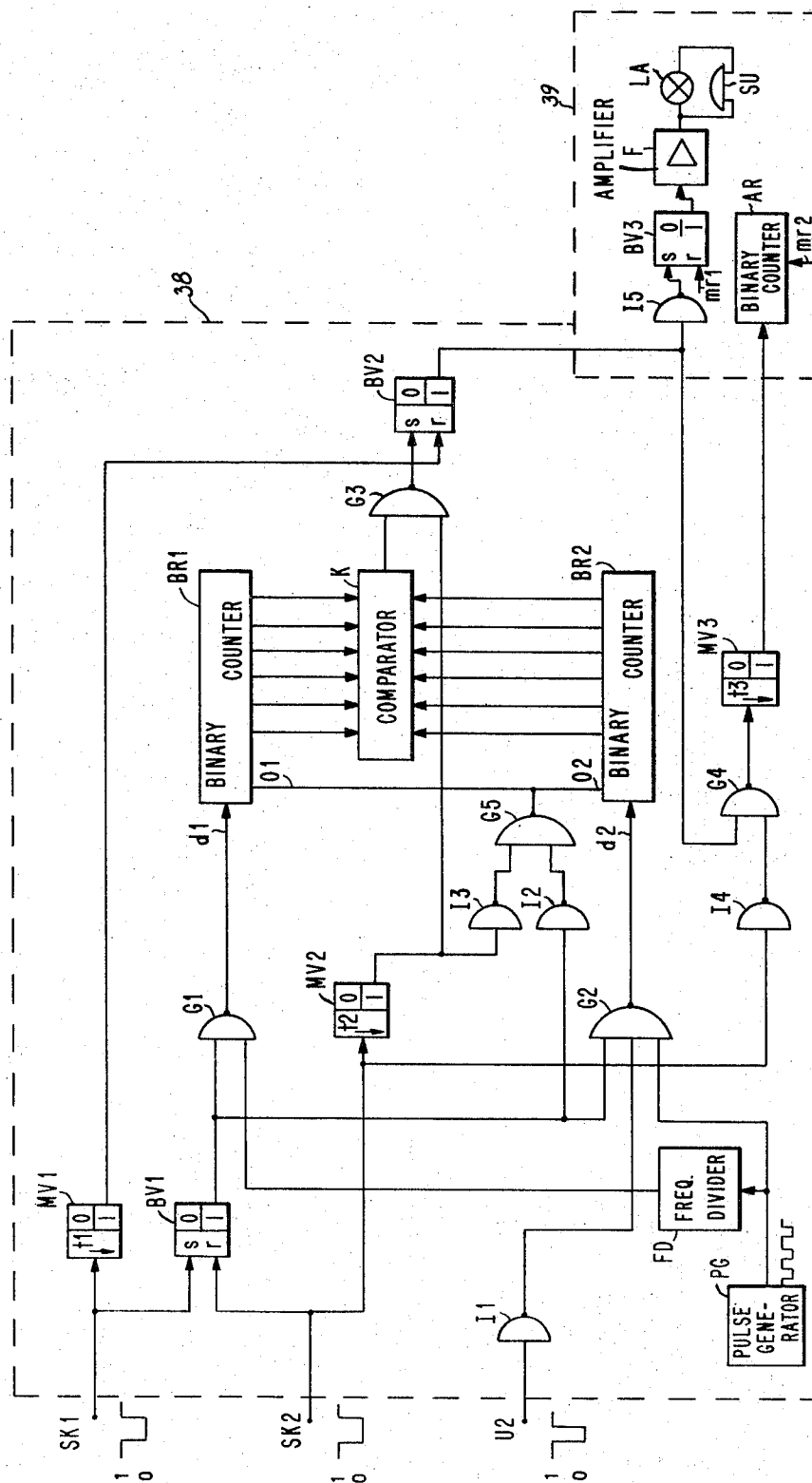


Fig. 6



METHOD AND SYSTEM FOR DETECTING WHEEL FLATS ON RAIL VEHICLES

This is a continuation-in-part of application Ser. No. 135,600 filed Apr. 20, 1971, and now abandoned.

The present invention relates to a method and a system for detecting wheel flats on the rims of rail vehicles, particularly railway cars.

The term wheel flat is used herein to define irregularities in, or the flattening of, the rim of a rail car wheel. Such wheel flats may be sustained, for example, when a wheel is braked and slides on its supporting rail. In addition to the constant pressure applied by the wheel, wheel flats cause the rail to be subjected to dynamic forces and impact stresses, the magnitude of which depends on the size of the wheel flat, the mass and the speed of the wheel and the weight acting thereon. These dynamic forces can be relatively high and are liable to result in damage to the rails, particularly in winter time at low temperatures, when the rails are brittle and subjected to high tension stresses. Wheel flats can also cause damage to the rolling stock.

It is therefore extremely important that wheel flats be discovered as early as possible, so that those cars having sustained wheel flat damage can be taken out of service and repaired.

A number of methods have been proposed for detecting wheel flats.

According to one known method, sound from a passing train is recorded and the sound caused by the impact between a wheel flat and the supporting rail is distinguished by detecting the sound effect or frequencies in the sound. This method, however, does not provide a practically acceptable solution.

Another method known in the art is one in which the accelerations in the rail caused by a passing wheel are measured. If a wheel which has sustained wheel flat damage rotates at speeds above a certain value, the wheel will "release" the portion of the rail opposite the flat. This release causes accelerations in the rail with different signs on both edges of the flat.

A further method known in the art is one in which the changes in force caused by a wheel flat on the rails are measured by means of strain gauges placed along the rails.

These latter, known methods have the disadvantage that a number of sensing elements, strain gauges or the like, must be placed along the rail in order that the accelerations and force changes in the rail can be measured with the requisite accuracy irrespective of where the wheel flat is located on the rim of the wheel. This also requires a complicated evaluation apparatus.

Moreover, as will be discussed more thoroughly hereinafter, the latter, known methods also have the disadvantage that the determined magnitude varies, not only with the size of the wheel flat, but also with the prevailing axle load, i.e., the load on the wheel, which considerably complicates an evaluation of the measuring values obtained.

The present invention is based on a completely different principle. In accordance with the invention, a method for detecting wheel flats on rail vehicles whose wheels are made of an electrically conductive material is mainly characterized by the step of arranging a current circuit, which includes the wheel to be sensed and a part of the supporting rail, so that the contact point between the peripheral surface or rim of the wheel and

the rail is included in the circuit, and by detecting a break in the current circuit caused by a wheel flat.

The invention also relates to a system for putting the method of the invention into effect, the system being mainly characterized by a voltage source having one terminal connected to a first rail of the track and another terminal connected to a second rail extending parallel with said first rail, e.g., the other rail of the track, in a manner whereby the current circuit includes the peripheral surface of the wheel to be sensed, and wherein the connection points are arranged in spaced relationship with respect to each other in the longitudinal direction of the track, said spacing being less than the smallest axle distance occurring in the vehicle.

The voltage source may be a DC source or an AC source. When an AC source is used, an impedance is preferably connected to the circuit so that the circuit forms a resonance circuit which is tuned to the frequency of the voltage source.

A break in the current circuit as the result of a wheel flat can be detected by sensing the voltage over a portion of the impedance or by inductively sensing the current in the current circuit.

One important advantage afforded by the method and the system of the present invention is that the axle load has considerably less effect on the result of the measurement when compared with the previously known methods. Moreover, the detection of wheel flats can be effected to advantage with the method and system of the present invention at normal train speeds, 70 km/h and above, which is not so, for example, with methods in which the force changes in the rail are measured.

Under certain assumptions, including a certain minimum speed of the vehicle, the time (t_s) during which the wheel loses contact with the rail, inter alia due to the presence of a wheel flat, can be expressed by the formula:

$$t_s = l/v + \sqrt{K \cdot M}$$

where l = the length of the flat,

v = the vehicle speed; i.e., the speed of the center point of the wheel,

M = total mass of car and load divided by number of axles,

$K = rg(1/m + 1/2 m_r)$, where m is the rigid mass of the axle, r = the wheel radius and m_r = the virtual mass of the rail's mobile part.

With $m = 1,500$ kg, $m_r = 800$ kg and $r = 0.5$, which is the normal values on these variables in practice,

$$t_s = l/v + \sqrt{6.5 \cdot M}$$

By inserting $t = l/v$ the relationship $t/t_s = 1.5$, for a mass per axle of $M = 16,000$ kg at a speed of 72 km/h, and the relationship t/t_s varies between ± 6.8 percent when the mass per axle (M) varies between 8,000 and 20,000 kg.

When applying a method in which the length of a wheel flat is determined indirectly by the prior art method of measuring the acceleration in the rail, it is found that for the same numerical values on m , m_r and r the measuring result will vary by ± 22 percent at a speed of 72 km/h when the mass per axle varies between 8,000 and 20,000 kg.

The prior art method which involves determining the additional energy in the rails also has the disadvantage that it is strongly dependent on the axle load. In a de-

scribed embodiment of the method (Rangiertechnik, No. 27, 1967) the axle load is therefore measured over separate measuring channels and the measured value is stored for later correction in the final measurement of the wheel flat. It is presumed herewith, however, that the speed of the train is reduced between 20 and 40 km/h during the measuring process, in contradistinction to the method proposed according to the present invention, wherein measurements can be made to advantage at normal train speeds (70 km/h and more).

The invention will now be described in more detail with reference to an embodiment thereof illustrated in the accompanying drawing, in which:

FIG. 1 is a diagrammatic view of a railway track and two pairs of wheels of a train unit illustrating the principle of the invention.

FIGS. 2A - 2E illustrate an embodiment of a system for detecting wheel flats with associated diagrams of electrical signals.

FIGS. 3A - 3F illustrate another embodiment with associated diagrams of electrical signals.

FIGS. 4A - 4F illustrate a further embodiment with associated diagrams of electrical signals.

FIGS. 5A - 5D illustrate an embodiment including an auxiliary rail with associated electrical signal diagrams.

FIG. 6 shows a schematic diagram of an evaluation means and alarm indicator used in the present invention.

In FIG. 1 there is illustrated diagrammatically a railway track consisting of two rails 10, 11. A train unit moving on the track 10, 11 is illustrated by means of two pairs of wheels 12, 13 and 15, 16 having respective axles 14 and 17. For detecting wheel flats, such as at 18 on wheel 13, a voltage source 19 is connected to the track 10, 11 over an impedance 20 in a manner whereby one side of the voltage source 19 is connected to a first rail 11 of the track at a connection point 21 and its other side is connected with the other rail 10 of the track at a connection point 22. Evaluation equipment 23 is connected over the impedance 20, or a part thereof.

As will be evident from the following, FIG. 1 illustrates only one of many conceivable embodiments of a system for detecting wheel flats, but the exemplary embodiment is particularly suitable for illustrating the principle of the invention.

The connection points 21 and 22 to the rails 11 and 10 respectively are offset with respect to each other when viewed in the longitudinal direction of the rails 10, 11. A pair of wheels 12, 13, which travel to the right, for example, as seen in FIG. 1, approach and pass the connection point 21 to the rail 11. The pair of wheels 12, 13 and the axle 14 then close a circuit from the voltage source 19, via the connection point 21, the rail 11, the wheel 13, the axle 14, the wheel 12, the rail 10, the connection point 22 and the impedance 20. This circuit remains closed providing that no wheel flat is present on any of the wheels 12, 13. If, however, one of the wheels 12, 13 has sustained a defect, such as a wheel flat 18, the circuit will be broken momentarily as a result of the wheel 13 "releasing" the rail 11 at the wheel flat 18. This break in the circuit is detected by means of the evaluation equipment 23 in a manner hereinafter described.

As will be evident from FIG. 1, current also flows through surrounding wheel pairs, such as 15, 16, 17. To

eliminate extraneous influence on the measuring result, i.e., on the current conditions in the current circuit 19, 21, 11, 13, 14, 12, 10, 22 and 20 and back to 19, the rails 10, 11 may, of course, be cut and provided with insulating joints at the connection points 22 and 21, although this is an unnecessarily expensive and impractical solution. As hereinafter described with reference to preferred embodiments of the system for detecting wheel flats, there is used instead an auxiliary rail, with which DC or AC voltage can be used, or there is used with embodiments similar to that illustrated in FIG. 1 a relatively high frequency AC voltage, the impedance 20 being so adapted that the current circuit, including the rails 10, 11 and the wheel pairs 12, 13, 14 forms a series resonance circuit at the frequency in question. It should be noted herewith that the current circuit between the connection points 21, 22 is not changed electrically, provided that a fault free wheel pair is located between the connection points 21, 22, since the total rail length through which the current flows is constant and equal to the distance in the longitudinal direction of the track between the connection points 21, 22. The resonance condition is thus maintained as long as a fault free wheel pair is located on the measuring distance, which is defined as the portion of the track 10, 11 located between the connection points 21, 22.

The inductance in the rails 10, 11 increases relatively quickly outside the connection points 21, 22 whereby the influence on the current conditions from surrounding wheel pairs, such as will be evident from the following description as 15, 16, 17 is reduced to a considerable extent. In addition, influence from surrounding wheel pairs can be further reduced, by not using the high frequency current fed to the track primarily for detecting purposes, but instead using the current which is induced in specially arranged coils by the current fed to the track.

The distance between the connection points 21, 22 when seen in the longitudinal direction of the track must be less than the smallest axle distance occurring in the train unit, since otherwise two wheel pairs may be simultaneously located within the measuring distance, whereby possible defects in one wheel pair may be "short-circuited" by the other wheel pair. In the case of carriages provided with bogies and with special carriages adapted for heavy loads, for example, the smallest axle distance is often less than the circumference of the wheel and in this case the measuring distance must be divided into two or more part distances, which are displaced with respect to each other in the longitudinal direction of the track in a manner whereby an individual, preferably non-overlapping portion of the periphery of the wheel is sensed through each part distance.

The manner in which the measuring distance is divided into part distances and the distance between said part distances is naturally determined beforehand with knowledge of the rolling stock to be moved through the section in question.

Railcar wheels have a circumference of approximately 3 m. The axle distance in a bogie, however, is only 2.5 m and, hence, with respect to bogie carriages the measuring distance must be divided into two part distances of approximately 1.5 m each with an interspace of $n \cdot 3$ m, where n is a whole number preferably equal to 0 or 1. On certain track systems special carriages or tracks are used having an axle distance of 1.5

m and in this instance the measuring distance must be divided into three part distances of $1/3 m$ each. The interspace between the part distances may be selected in a number of ways, provided that one portion of the wheel rim is sensed through each of the three part distances. The interspaces between the part distances are also in this instance selected preferably to $n/3 m$ with n equal to a whole number preferably 0 or 1.

Even though the distance between the connection points 21, 22 is preferably selected so that said distance is of the same order as, but slightly smaller than, the smallest axle distance occurring in the train unit, it can be made less and even equal to 0, whereby the connection points 21, 22 are located opposite each other. The detection of possible wheel flats 18 is made somewhat more difficult in this instance, although the advantage is gained whereby a number of sensing means 19 - 23, which, for example, use separate frequencies, can be placed adjacent to each other, thereby enabling the full wheel circumference to be sensed on a track distance of approximately the length of the wheel circumference irrespective of the axle distances.

The location of the measuring distance on the track section is naturally important. The train unit should travel along the measuring distance without it being necessary to brake to any appreciable extent or to accelerate, and the measuring distance should be placed on a straight section of track, since when the train section is driven round a curve the wheel flanges often rest against the rails and may thus short circuit a possible wheel flat.

A number of embodiments of the system for detecting wheel flats will now be described in more detail with reference to FIGS. 2 - 5.

FIG. 2A illustrates an embodiment of the detecting system and FIGS. 2B - 2E show diagrams of the function of the system according to FIG. 2A with electric signals occurring thereon as a function of the position of the wheel axle b-c on the track 10, 11.

The signal voltage from a voltage generator 30 having a frequency f is amplified in an amplifier 31 and fed via a cable 32 and a transformer 33 to a series resonance circuit consisting of a secondary inductance L of the transformer, an impedance 34 and the impedance in the current path portions between the points a and b (rail) b and c (the wheel axle and the transition resistances between wheel and rail), c and d (rail) and the impedance in the connection lines. Since the connection points a and d are displaced in relation to each other in the longitudinal direction of the tracks 10, 11, with a fault-free wheel, the impedance in the series resonance circuit is not dependent on the position of the wheel axle bc within the measuring distance, which is defined by the lines ah and dg. The current through L and thereby the voltage over the impedance 34 only have their maximum value, corresponding to series resistance, when a wheel axle b,c is located within the measuring distance and the two wheels are in contact with the rails 10 and 11, respectively.

A part voltage is taken out from the impedance 34, amplified in an amplifier 35, rectified in a rectifier 36 whose output voltage is identified by the reference U_1 , and sensed by a Schmitttrigger or limiter 37, which triggers when the wheel pair bc approach the measuring distance, as shown in FIGS. 2B and 2C. If a wheel having a flat is located within the measuring distance, contact between wheel and rail is briefly broken by the

flat and the voltage U_1 drops to beneath the threshold value of the Schmitt limiter.

Rail contacts SK1 and SK2 actuated by one of the wheels in the wheel pair are placed at the points h and d and transmit signals for starting and stopping an evaluation means 38. The passage time, corresponding to the distance ah-gd, for the whole wheel perimeter or for the part of the wheel perimeter sensed (e.g., half the wheel perimeter) can be determined in the means 38 as shown in FIG. 2D. The passage time can be determined in the evaluation means 38 by means of suitable logic together with the time during which the voltage U_1 , as a result of a wheel flat, FIG. 2E, has fallen beneath the threshold level during passage of the wheel.

If the quotient between this time, FIG. 2E, and the time for the sensed portion, FIG. 2D, exceeds a certain limit value corresponding to a maximum permitted wheel defect, an alarm, e.g., an acoustic and/or visual signal, is transmitted from an alarm indicator 39. This quotient will not vary with the speed v of the train unit, but depends solely on the size of the wheel flat and, as aforementioned, to a certain extent on the axle load. The alarm indicator 39 may be arranged at a distance from the remaining measuring equipment, e.g., in the nearest signal box. Subsequent to obtaining a signal from the evaluation means 38 to the effect that a wheel has sustained flat damage in excess of permitted limits, a signal can be transmitted from the means 38 to the indicator 39 for each passing wheel portion, from and including the damaged wheel. Unit 39 therefore also indicates the number of axles, calculated to the end of the train unit, thereby disclosing the position of the damaged wheel in the train unit. The indicator 39 is provided with an appropriate number of registering totalizers so that several wheel flats in the same train unit can be detected.

An oscillator may be incorporated in the evaluation means 38 to serve as a reference for the time measurement effected therein. Alternatively, the signal from the generator 30 may be utilized as the reference.

As aforementioned, for the purpose of serving a possible remaining portion or portions of the wheel circumference, identical equipment may be arranged in spaced relationship, the spacing being so adapted that each portion is sensed per se without overlapping of said portions.

As will be seen from FIG. 2B, the signal U_1 does not fall to zero in the presence of a wheel flat, owing to the shunting effect caused by the surrounding wheel pairs. The threshold or switch level of the Schmitt-limiter 37 can be set, however, so that the influence exerted by the shunting effect does not reach the evaluation means 38. The influence exerted by the shunting effect caused by the surrounding wheel pairs may also be reduced by increasing the Q-value of the series resonance circuit L , abcdg, 34, which may be effected by appropriate selection of components.

Because the frequency f of the generator 30 is relatively high, preferably of the order of 100 KHz, disturbances from the railway traction currents (e.g., 16 % Hz) and other low frequency signals, e.g., from domestic networks (50 Hz) are suppressed. The frequency f is also adjusted to the inductances appearing in the current circuit L , 34, abcdg.

FIGS. 3A - 3F illustrate another embodiment of a system for detecting wheel flats, corresponding units

being identified with the same reference as those shown in FIG. 2A.

A signal voltage from the generator 30 having a frequency f is fed to the track in same manner as with the system illustrated in FIGS. 2. The absolute value of the voltage U_z over the impedance 34 as a function of the position of a wheel pair on the distance between the defining lines $o-j$ and $i-k$ is shown in FIG. 3B.

Four coils, Sp1, Sp2, Sp3, Sp4 are provided for detecting the current conditions in the circuit L, $abcd$, 34, the coils being arranged along the rails 10, 11 and the turns of the coils lying horizontally. Voltages are induced in the coils if a current passes through the rail section along which the coils are placed. The coils Sp2 and Sp3 are placed along the whole rail section on the measuring distance, which is defined by the lines ah and dg . The coils Sp1 and Sp4 are relatively short and are placed outside the measuring distance $ah-dg$ at the points h and g .

As illustrated in the lower portion of FIG. 3A, the coils Sp1 - Sp4 are connected in series, and the resulting induced voltage $e_1+e_2+e_3+e_4$, where e_1 is the voltage induced in coil 1 etc., is amplified in the amplifier 35, rectified in the rectifier 36, whose output voltage is shown by U_3 as shown in FIG. 3C, and is sensed by the Schmitt-trigger 37. The absolute values of the voltages e_1 , e_2 , e_3 and e_4 are equally great for the same induced current in the rails 10 and 11 along the whole coil. Moreover, the coils Sp1 - Sp4 are connected in series in such a way that for the same direction of the induced current, e_1 is counter-directional to e_2 and e_3 is counter-directional to e_4 . For all axles which are located in positions outside the measuring distance $ah-dg$ at an arbitrary distance therefrom, no resulting input voltage to amplifier 35 ($\Sigma e = 0$) is obtained, owing to the current which is fed from the generator 30 into the track and which flows through the axles. If a wheel pair is located, for example, at oj in FIG. 3A, the current flowing through the wheel pair will pass the whole coils Sp1 and Sp2 in the rails 10 but not one part of the coils Sp3 and Sp4. The resulting induced voltage is thus close to zero, theoretically equal to zero, since the coils Sp1 and Sp2 are counter-directed and no voltage is induced in the coils Sp3 and Sp4. In a corresponding manner, the total voltage induced in the coils Sp1 and Sp2, Sp3, Sp4 is close to zero for wheel pairs located to the right of the line dg as seen in FIG. 3A, for example, at ik , since the coils Sp3 and Sp4 balance each other. On the other hand, a constant voltage is obtained from an axle having a faultless wheel pair on the measuring distance, irrespective of its position between ah and dg , since no contribution is then obtained from Sp1 and Sp4 and $e_2+e_3 = \text{constant}$ ($e_2 = k \cdot ab$, $e_3 = k \cdot cd$). The two counter-connected coils Sp1 and Sp4 are not required for the actual detection of the current conditions in the current circuit L, $abcd$, 34, but, as will be evident from the diagram of the voltage U_3 as shown in FIG. 3C, the influence exerted by wheel pairs located outside the measuring distance $ah-dg$ is reduced practically to zero by means of the coils Sp1 and Sp4, whereby the reliability of the system in operation is considerably increased.

The signal reaches the switch level of the Schmitt-trigger 37 just before the wheel has passed SK1 and falls below this level subsequent to the wheel passing SK2 as shown in FIG. 3D. If a wheel which has sustained flat damage passes the measuring distance, the

contact between the rails is broken as a result of the flat and the voltage U_3 below the re-trigger level.

The time taken for the sensed portion of the wheel circumference to pass, i.e., the time taken to move from SK1 to SK2 in FIG. 3E, and the time during which the circuit is broken by the flat, FIG. 3F, are compared in the evaluation means 38, as with the aforesaid arrangement illustrated in FIGS. 2A, 2E, and possible defects are indicated on the alarm indicator 39.

As with the previous embodiment, identical equipment must be arranged in spaced relationship for possible remaining portions of the wheel circumference, the spacing being adapted so that each portion is sensed individually without overlapping.

A further system for detecting wheel flats is illustrated in FIGS. 4A - 4E, like parts being identified with like references.

The signal voltage from the generator 30 having the frequency f is fed to the track in the same manner as with the embodiments of FIGS. 2 and 3. The absolute value of the voltage U_z over the impedance 34 as a function of the position of a wheel pair on a distance between the boundary lines $o-j$ and $i-k$ is illustrated in FIG. 4B.

The coil Sp5, the turns of which are arranged in a vertical plane, is equally as long as the measuring distance, defined by the lines ah and dg , and is placed centrally between the rails 10, 11. The voltage e_5 is induced in the coil by a current passing through the wheel axle bc when a wheel pair is located in the vicinity and within the measuring distance $ah-dg$. The voltage e_5 is amplified in the amplifier 35, rectified in the rectifier 36, whose output voltage is U_5 , as shown in FIG. 4C, and is sensed by the Schmitt-trigger 37.

The signal reaches the threshold level of the Schmitt-trigger 37 just before the wheel passes SK1 and falls below this level after the wheel has passed SK2, as shown in FIGS. 4C and 4D.

The influence exerted by wheel pairs located outside the measuring distance $ah-dg$ can also be reduced with the exemplary embodiment by means of extra coils, such as the coils Sp6 and Sp7 indicated by dash lines in FIG. 4A, the extra coils being placed outside the coils Sp5, when seen in the longitudinal direction of the tracks 10, 11, and connected in series with the coil Sp5 to the input of the amplifier 35 in a manner whereby the voltages, which are induced in the coils Sp6 and Sp7 as a result of the current in the illustrated wheel axle, are directionally opposed to the voltage e_5 induced by the same current in the coil Sp5.

When a wheel having a wheel flat passes the measuring distance, contact with the rail is broken by the flat and the voltage induced in the coil Sp5 falls beneath the threshold level.

The time taken for the sensed portion of the wheel circumference to pass SK1, SK2 in FIG. 4E, and the time during which the circuit is broken by the flat, FIG. 4F, is compared in the evaluation means 38 in the same manner as that described with reference to the embodiments of FIGS. 2 and 3.

As with previous embodiments, identical equipment must be arranged in spaced relationship for any possible remaining portion or portions of the wheel circumference, the spacing being adjusted so that each portion of the wheel circumference is sensed individually without overlapping.

Thus, with the illustrated embodiment a current which flows perpendicular to the longitudinal direction of the tracks 10, 11 is sensed. This has the advantage of reducing the influence from disturbing currents moving parallel with the tracks 10, 11, although the influence from the current in the supply lines to the points *a* and *b* in the rails 11 and 10 respectively and to the coils Sp5, Sp6, Sp7 must be eliminated. These supply lines, considered as magnetic field generating currents, are parallel with the wheel axle *b, c* in at least one section, and currents in the lines can give rise to troublesome disturbances. One method of reducing these disturbances is to place such line portions which extend parallel with the wheel axle at a long distance from the measuring distance *ah-dg*. Another possibility is to magnetically screen at least the portions of the supply lines which are parallel with the wheel axle.

An embodiment of the evaluation means and the alarm indicator will be described more in detail with reference to FIG. 6. In FIG. 6, the evaluation means 38 and the alarm indicator 39 have been indicated with the broken lines and the inputs "SK1," "SK2," and "U2," respectively, refer to the corresponding outputs from the rail contacts SK1, SK2 and from the Schmitt-trigger 37, respectively. The evaluation means 38 contains a retriggerable monostable flip-flop circuit MV1, the trigger input of which can receive an activating signal from the rail contact SK1. A bistable flip-flop circuit BV1 is also connected with its set inputs to the rail contact SK1, the reset input *r* of the flip-flop BV1 being connected to the rail contact SK2. In the circuit shown in FIG. 6 it is presupposed that the logic is such that the monostable flip-flops are set to their 1-state by an activating signal going from the 1-state to the 0-state and that the bistable flip-flops are set to their 1-state, i.e., the output is activated when an activating signal going from its 1-state to its 0-state appears on the set input *s*. The 1-output of the bistable flip-flops is inactivated when a signal going from its 1-state to its 0-state appears on the reset input *r* of the bistable flip-flops.

When a wheel pair is passing the rail contact SK1, i.e., the line *ah* in the FIG. 2A - 4A, an activating signal will be sent to the flip-flop BV1 so that the output "1" of both flip-flops MV1 and BV1 will be activated. When the wheel pair has passed the line *gd* in FIG. 2A - 4A an activating signal (a stop signal) will be sent from the rail contact SK2 to the reset input *r* of the flip-flop BV1 thus deactivating the output "1" of this flip-flop. Due to the fact that the set inputs *s* of the flip-flop BV1 is connected to the rail contact SK1 and the reset input *r* of the same flip-flop is connected to the rail contact SK2, the output "1" of the flip-flop BV1 will be activated as long as a wheel pair is situated between the rail contacts SK1 and SK2.

The input U2 is connected to the Schmitt-trigger 37 (FIG. 2A - 4A), the voltage U2 thereby appearing across the input of the inverter I1. PG denotes a pulse generator which delivers a pulse formed voltage with the frequency *f* on one hand to a frequency divider FD and on the other hand to an input of an inverting and-gate G2, the other two inputs of which are connected to the output of the inverter I1 and to the output of the bistable flip-flop BV1, respectively. The frequency divider FD divides the frequency *f* of the signal from the pulse generator PG by a factor *X* which is equal to the quotient between the measuring distance *ah-gd* and the maximum permitted length of a wheel flat registered.

For example, a measuring distance of 3 meters and a registered length of a wheel flat = 0.03 meter will give a factor $X = 3/0.03 = 100$. The output of the frequency divider FD is connected to one input of an inverting and-gate G1, the second input of which is connected to the output "1" of the flip-flop BV1.

The units BR1 and BR2 each consist of a binary counter, the outputs of which are connected in pairs to a comparator circuit K. This circuit carries out a comparison between the counting position of one counter BR1 and the corresponding counting position of the other counter BR2, a difference in two corresponding counting positions resulting in an activating signal being delivered to one input of an inverting and-gate G3 if the counting position of BR2 is greater than BR1. The second input of the gate G3 is connected to the output of a monostable flip-flop MV2 which is triggered by the stop signal delivered from the rail contact SK2. Thus, when such a stop signal occurs, an activating signal from the comparator circuit K can be delivered to the bistable flip-flop BV2, which thereby delivers a "1" signal to the indicator 39 for releasing an alarm signal.

The two inputs of an inverting and-gate G5 are connected via an inverter I2 and I3, respectively to the "1" output of the bistable flip-flop BV1 and to the "1" output of the monostable flip-flop MV2, respectively. The output of the inverting and-gate G5 is connected to an input o1 and o2, respectively, of each of the counters BR1 and BR2, so that when a "0" signal appears on the output of the gate G5, the counters BR1 and BR2 are zero-set. In dependence on the output pulses from the gates G1 and G2 which pulses are delivered as clock pulses to the clock input c11 and c12, each of the counters BR1 and BR2 is stepped forward. Thus, as long as the output signal from the "1" output of the flip-flop BV1 is activated and no output signal from the output "1" of the flip-flop MV2 is present, and the output signal from the gate G5 is "1", pulses from the and-gates G1 and G2 can be delivered to the counters BR1 and BR2 thus causing these counters to step forward. When a stopping pulse from the rail contact SK2 is being delivered, the flip-flop MV2 will be set so that its output "1" is activated. Simultaneously the flip-flop BV1 is reset so that its output is "0." After an additional time interval t_2 , the output of flip-flop MV2 is again "0." Therefore the inputs to the inverting gate G5 is "1" and its output is "0." The counters BR1 and BR2 are thus zero-set.

When a wheel pair passes across the line *ah* (FIGS. 2A - 4A), an activating pulse is delivered from the rail contact SK1 to the flip-flops MV1 and BV1, bringing them to their "1" state. Due to the fact that a reset pulse to the flip-flop BV1 is not delivered until the rail contact SK2 delivers an activating pulse, i.e., when the wheel pair has passed the line *dg*, the output of the flip-flop BV1 will be "1" as long as a wheel pair is located between the rail contacts SK1 and SK2. During the time that the output of the flip-flop BV1 is "1" set, stepping pulses can be delivered to the counter BR1 from the frequency divider FD. The counter BR1 will thus count the time elapsed for a wheel passage between the lines *ah* and *gd* (i.e., the measuring distance).

The condition for the gate G2 to give stepping pulses from the pulse generator PG to the counter BR2 is:

i. the output of the flip-flop BV 1 is "1" set, i.e., a wheel pair has passed the line *ah*.

ii. the voltage U2 across the output of the Schmitt-trigger should be low, i.e., a wheel flat has been detected and is passing over the rail section *hd* or *ag* (or both).

If these two conditions are accomplished, then stepping pulses are delivered from the pulse generator PG to the counter BR2 and the time for a wheel flat break is being measured. The counter BR1 is being stepped forward by pulses with the frequency f/X , the counter BR2 is being stepped forward by pulses with the frequency f and a comparison between the contents of the two counters is carried out. This means that if no wheel flat has been detected and thus no signal to open the gate G2 has been obtained, then no pulses has been delivered to the counter BR2, and the counting position of BR2 is less than that of BR1. Because the output from the comparator K is then "0", no activation of flip-flop BV2 can take place and its output is therefore "0." On the contrary, if a wheel flat of length greater than the maximum permitted value has passed the section *ah-gd*, the counting position of BR2 is greater than that of BR1 and the comparator K will give the output "1." At the passage of the section end (*gd*), SK2 activates MV2 and the corresponding input to the inverting gate G3 is "1." Thus flip-flop BV2 is activated to its "1" state, giving a "0" input to alarm flip-flop BV3 of alarm indicator unit 39 through inverter I5. This in turn activates alarm lamp LA and summer SU through amplifier F. The "1" — output from BV2 is also fed to inverting gate G4, whose second input is already "1," originating from SK2 through inverter I4. The binary counter AR (axle counter) is therefore stepped forward through the monostable flip-flop MV3, activated by G4, by SK2 and this is repeated for each succeeding axle since the "1" output from flip-flop BV2 remains due to the "alarm" setting of comparator K.

The monostable flip-flop MV3 has a pulse duration t_3 which is chosen less than the time interval to the next wheel passage of rail contact SK2. Thus MV3 will be reset before the next stop pulse from SK2. The output from retriggerable monostable flip-flop MV1 resets to "0" approximately 10 sec (or any other convenient time interval) after a wheel has passed SK1 and no additional wheel has actuated SK1 during these 10 seconds. Thus the output of BV2 is reset to "0" closing G4. No further axles can then be counted by AR. However, the setting of BV3 and hence the alarm indication remains. The axle-number indication of AR also remains. After observation the units BV3 and AR can be reset manually through actuators *mr 1* and *mr 2* respectively.

The rail contacts SK1 and SK2 used in the embodiments illustrated in FIGS. 2A, 3A and 4A, and which may also be used in the embodiment illustrated in FIG. 5A, for connecting and disconnecting the evaluation equipment and for determining the period of time during which a wheel is located within a measuring distance *ah-dg*, can be in the form of contacts actuated mechanically or electrically by the passing wheel. It is also possible to use, however, additional coils placed on the lines *ah* and *dg* respectively, e.g., adjacent, or instead of the coils Sp1, Sp4 or the coils Sp6, Sp7 which sense the current flowing through a passing wheel pair. The voltages induced in the additional coils may, for example, control Schmitt-triggers or limiters which are

set so that the evaluation equipment 38 is connected and disconnected when the wheel pair passes the lines *ah* and *dg*.

FIGS. 5A – 5D illustrate an embodiment of the system for detecting wheel flats in which an electrically conductive auxiliary rail 40 and 41 mounted to each rails 10, 11 is utilized for sensing the two wheels 43, 44 in a wheel pair.

FIG. 5B is a diagrammatic sectional view of the rails 10, 11, the wheel 43, 44 and the auxiliary rail 40, 41. The rail 40, 41 is insulated and is also preferably yieldingly mounted to the rail 10, 11 by means of a rubber suspension means 42 or the like.

Voltage sources for AC or Dc current 51 and 52 are connected between the rails 10 and 11 and the auxiliary rail 40 and 41 mounted externally of each rail 10, 11.

The current through the current circuit, including the rim of the wheel 43, 44, is measured easiest over an impedance 53 and 54 connected in series with rails and auxiliary rails, although inductive sensing of the current can also be used in this instance.

FIGS. 5C and 5D show the voltages U_7 and U_8 over the impedances 53 and 54 when a defect and a faultless wheel respectively pass the measuring distance. In the former case the circuit is broken by the flat and the current falls momentarily to zero, FIG. 5C.

The time taken for the wheel or a specific part of the wheel to pass and the time during which the circuit is broken by the flat are compared in the evaluation means 55 and 56. If the magnitude of the flat exceeds permitted limits, the fault indicator 39 transmits an acoustic and/or a visual alarm signal and the position of the axle in the train is registered by a counter device.

In this embodiment, the distance between the connection points to the rails 10, 11 and the auxiliary rails 40, 41 is naturally not critical, since the measuring distance is totally determined by the auxiliary rails 40, 41.

As with previous embodiments, identical equipment must be arranged in spaced relationship for possible remaining portion or portions of the wheel circumference, the spacing being adjusted so that each portion of the wheel circumference is sensed individually without overlapping.

Rail contacts, similar to SK1 and SK2 in the embodiments of FIGS. 2 – 4, can also be arranged to advantage with the embodiment of FIGS. 5A – 5D, at the end points of the measuring distance for connecting and disconnecting the evaluation equipment 55, 56. In this respect the auxiliary rail 40, 41 can be extended beyond the measuring distance so that contact between the wheel 43, 44 and the auxiliary rail 40, 41 is stable when measuring is commenced.

The arrangements illustrated in FIGS. 1 – 5 thus constitute preferred embodiments of a system for detecting wheel flats according to the invention. It is obvious, however, that only minor modification of the evaluation means and the alarm indicator is required for the described arrangements to operate simultaneously as a so-called axle counter. The reduction in the influence exerted by the surrounding wheel pairs, obtained with the aforescribed arrangement, is in this case a great advantage. The system according to the invention, can also be used solely as an axle counter, the measuring distance 21 – 22, *ah-dg*, preferably being made short so

that disturbances from the surrounding wheel pairs and the axles, are further reduced.

The invention is not restricted to the illustrated and described embodiments thereof but can be modified within the scope of the following claims.

What is claimed is:

1. A method for detecting wheel flats on rail vehicles having wheels made of electrically conductive material and an axle between oppositely situated wheels, comprising the steps of: passing an alternating current having a relatively high frequency through a current circuit which includes a first and a second wheel to be sensed and the axle between said wheels, said first and second wheels being the only wheels in said current circuit wherein a contact point between the peripheral bearing surface of each wheel and the associated rail together with a portion of a first and a second rail forms part of the circuit, and detecting a change of the current amplitude in the current circuit caused by the presence of a wheel flat on at least one of said wheels.

2. A method according to claim 1 wherein the step of detecting comprises detecting the current conditions in the current circuit inductively.

3. A system for detecting wheel flats on rail vehicles having a plurality of pairs of electrically conductive wheels, the wheels of each pair being situated on respective rails of a track and connected by an axle, comprising: a current circuit, having a high frequency alternating voltage source connected to the rails of the track, wherein the circuit includes the peripheral bearing surface of each wheel of the pair of wheels to be sensed and the axle, and wherein one side of the voltage source is connected at one point to a first rail in the track and the other side of the voltage source is connected at a second point to a second rail in the track extending parallel with the first rail and wherein the connection points are spaced apart from each other in a longitudinal direction of the track, said spacing being shorter than the smallest distance between adjacent axles occurring in the vehicle; and means, connected to the circuit, for indicating wheel flats.

4. A system according to claim 3 wherein the distance in the longitudinal direction of the track between the connection points of the voltage source is less than or equal to the circumference of a wheel to be sensed.

5. A system according to claim 3 wherein the current circuit comprises a resistance, the voltage drop over the resistance being applied to the indicating means for

indicating interruptions in the current circuit.

6. A system according to claim 5 wherein the indicating means comprises two contacts, arranged in spaced relationship with respect to each other, and actuated by a passing wheel for, respectively, connecting and disconnecting, the indicating means.

7. A system for detecting wheel flats on rail vehicles, having a plurality of pairs of electrically conductive wheels, the wheels of each pair being situated on respective rails of a track and connected by an axle, comprising: a current circuit including an AC voltage source connected to the rails of a track, the peripheral surface of each wheel of the pair of wheels to be sensed, the axle and an impedance which is adjusted so that the circuit containing the impedance, the rails, the axle and the wheels forms a resonance circuit tuned to the frequency of the voltage source, and wherein one side of the voltage source is connected at one point to a first rail in a track and the other side of the voltage source is connected at a second point to a second rail in the track extending parallel with the first rail and wherein the connection points are spaced apart from each other in a longitudinal direction of the track, said spacing being shorter than the smallest distance between axles occurring in the vehicle; and means connected to the circuit, for indicating wheel flats.

8. A system according to claim 7 wherein the indicating means is connected over a portion of the impedance to sense the voltage changes occurring as a result of a wheel flat.

9. A method for detecting wheel flats on rail vehicles having wheels made of electrically conductive material and an axle between oppositely situated wheels, comprising the steps of: passing an alternating current through a current circuit which includes a first and a second wheel to be sensed and the axle between said wheels, wherein a contact point between the peripheral bearing surface of each wheel and the associated rail together with a portion of a first and a second rail forms part of the circuit, generating a first signal corresponding to a first period of time, detecting, during said first period of time, a change of the current amplitude in the current circuit caused by the presence of a wheel flat on at least one of said wheels and generating a second signal corresponding to the time the wheel flat is detected, comparing said first and second signals, and generating an alarm signal if the comparison indicates the wheel flat is in excess of a predetermined limit.

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