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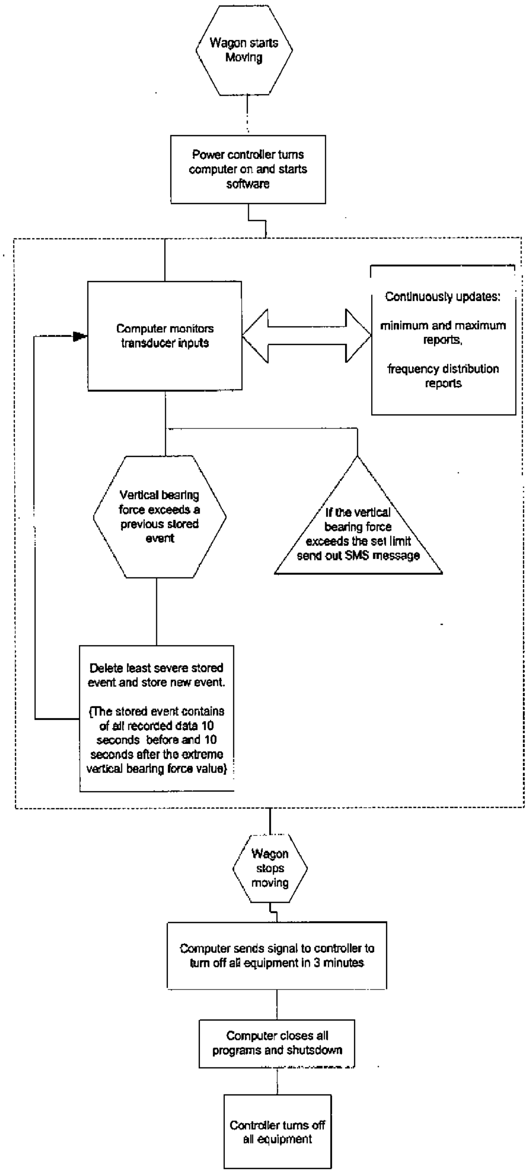
Abstract

The vehicle dynamics reporting system of the present invention describes an onboard system that monitors and records severe wagon-track events in respect to different event categories so that track sections that require further inspection and maintenance can be identified. The system can notify the rail operator of severe wagon dynamic events caused by track irregularities, uneven container loading or longitudinal train dynamics. The system is designed to be fitted to normal operating rail wagons to provide frequent reporting of the wagon dynamics that occur at normal operating speeds for a range of driving techniques, loading conditions and the wagon positions within a train.

Fig. 9


Wagon starts Moving
Power controller turns computer on and starts software
Computer monitors transducer inputs
Continuously updates:
minimum and maximum reports,
frequency distribution reports
Vertical bearing force exceeds a previous stored event
If the vertical bearing force exceeds the set limit send out SMS message
Delete least severe stored event and store new event.
(The stored event contains of all recorded data 10 seconds before and 10 seconds after the extreme vertical bearing force value)
Wagon stops moving
Computer sends signal to controller to turn off all equipment in 3 minutes
Computer closes all programs and shutsdown
Controller turns off all equipment

A VEHICLE DYNAMICS SYSTEM

Field of Invention

The present invention relates to systems and methods of measuring and analysing the forces acting on a vehicle during normal operation. The invention has particular but not exclusive application to systems and methods of measuring and analysing the forces acting on railway wagons.

Prior Art

Vehicle-track interaction is influenced by the profile and foundation characteristics of the track and suspension, mass, and speed of the vehicle and interactions between adjacent vehicles. The better these influences are understood, more accurate is the assessment of the risk of derailment.

Measurement of track profile is normally performed using dedicated track recording vehicles. These vehicles travel over a particular track section every six to twelve months. Due to the interval between runs, track recording vehicles will miss irregularities that develop over short periods of time. Certain types of track irregularities in heavy haul lines can develop to be a significant safety issue over a period of days.

Further, the weight, suspension characteristics, and speed of a track recording vehicle can differ from normal traffic that travels along the track. Track recording vehicles may not identify possible wagon-track interaction problems that may occur with freight wagons.

Object of the Invention

It is an object of the invention to provide an alternative system and method of measuring and analysing the dynamics of a railway wagon – track interaction.

Summary of the Invention

The present invention was developed as a result of using an alternative approach to measuring and analysing the dynamics of a railway wagon – track interaction by measuring input information from railway wagons during their normal operation.

In one aspect the present invention broadly resides in a vehicle dynamic reporting system including

input means for producing input information regarding vehicle movement and forces affecting a vehicle;

receiving means for receiving and analysing input information, said input information is analysed in separate predefined time segments, each separate predefined time segment forms an event, each event is analysed with reference to one or more dynamic event categories and if an event is more severe than a limit in a particular event category then the event is recorded on a severe event list, wherein the recorded event and related positional data locates the track position associated with the recorded event.

The recorded events are preferably recorded in the respective event category in order of severity. Where the number of recorded events is above the predefined limit, the least severe event in the particular event category is deleted until the predefined recorded event number is reached.

Recorded events and data may be downloaded directly to a laptop computer, to a remote computer through wireless LAN equipment and or SMS messaging.

The input means preferably includes determinations with respect to vertical wheel force on all wheels, lateral bogie force on both bogies, vertical coupler force, lateral coupler force, lateral coupler force, lateral coupler swing, longitudinal draft-gear displacement, bogie yaw, brake cylinder pressure for both bogies, brake pipe pressure, longitudinal wagon body acceleration, enclosure temperature, speed, GPS location, time, date, bogie weight, wagon weight, and track classification.

Wheel and bogie force measurement is preferably determined using strain gauges positioned on the side frame. The positioning of strain gauges on the side frame provides advantages over instrumented wheel sets in being comparatively cheaper to install and maintain and they can be used during braking of the wagon.

Strain gauges located on the side frame (as shown in figure 1) provide a signal proportional to side frame bending caused by axle box reaction force, F_w. However side frame bending also results from forces produced by brake applications (as shown in figure 2) and by wheel set inertia loads (as shown in figure 3).

Therefore the axle box reaction force, which can be scaled using bogie geometry to give an indication of wheel-rail reaction force can be calculated by:

$$F_w = (M_s - F_b d_b - F_i d_i)/ d_w$$

Where:

F_w is the axle box reaction force,

M_s is the moment measured via strain gauges,

F_b is the force produced by the braking application, proportional to brake cylinder pressure,

F_i is the inertia force, equal to wagon acceleration multiplied by half wheel set mass.

d_b is the distance between the line of action between F_b and M_s.

d_i is the distance between the line of action between F_i and M_s.

Noting that F_i is always zero for lead wheel sets during acceleration and F_i is always zero for trailing wheel sets during deceleration.

The following different states and moment equations apply:

1. Brakes off and wagon velocity steady $F_b = 0$, $F_i = 0$;
2. Brakes applied and wagon velocity steady $F_i = 0$;
3. Brakes off and acceleration or deceleration $F_b = 0$;

The preferred method adopted to obtain and combine the required data is as follows:

1. Complete Finite Element Analysis to determine the best place to position the gauge.
2. Carry out laboratory calibration to produce a mathematical relationship between strain measurement signals and side frame bending moment, M_s.
3. Install instrumentation, data recording and data compensation equipment as shown in figure 4.
4. The effect of brake application is further fine-tuned by calibration factors which are adjusted using data from field tests.

To stop the effect of drift, strain signals are continuously zeroed based on a running average over a defined distance. This method of continually checking and adjusting zeros is also applied to other strain measurement systems for embodiments include instrumentation for lateral bogie force, vertical coupler force and lateral coupler force.

The system preferably operates autonomously for long periods of time.

The computer system used on the infrastructure wagon is designed to measure and process data acquired from the on-board transducers and to communicate with other computer networks. The software controls the data acquisition, the positioning system, the power system and communication. The software has been designed and implemented as an object-oriented, multi-threaded application. This enables the computer to control several different subsystems simultaneously.

When the software starts a number of threads are initiated. The data acquisition thread acquires data from the on-board transducers, via analogue to digital converters. The data is then stored and processed by an alerting thread. The alerting thread processes the various channels of data and detects events, based on a configurable set of alerting parameters. If an event is detected, a section of data surrounding the event is stored and the location of the event is recorded. The event is then handed to a messaging thread to act upon. The messaging thread uses the priority of the event to determine whether a message needs to be sent immediately, or whether the data should just be stored until the next download operation. If the event is of sufficient priority the on-board mobile phone modem is used to send a SMS (short message service) message to the supervising engineer. The engineer is provided with enough information to act upon the event immediately. Viewing of the complete event's data would be possible after the next data download. The priority system can be tuned to provide alarms on different levels so that the engineer is not continuously alerted by wagon alarms.

The preferred functionality developed for operating autonomously is shown in an information flow diagram (in figure 5). The information flow diagram shows how information is shared between the threads. There are three main sets of data:

CdaqQueue this contains all the data acquisition data including the GPS location data. The data is written to the Queue by CdaqSystem. RunDaqThread uses this data to check for low velocity, low battery and also outputs the data to 'D' (or second) hard drive if it is present. RundaqWrite thread uses the data to write 20 second severe event reports.

CGGAQueue this is the GPS location data in integer and real numbers. RunParseThread writes the GPS data to this queue which is transferred to CdaqQueue by CdaqSystem.

CComControl this is the raw ASCII GPS data read directly from the GPS receiver. The data is placed in the queue by CcomControlRunThread and is used by RunParseThread.

The operation of the threads is detailed in figure 6.

OnInitDialog starts seven threads:

RunUpdateDialogThread:

This thread runs the dialog box that appears when the software runs. This dialog box displays information and enables the operator to stop the program. A computer monitor and keyboard is not normally connected to the computer so the dialog box is for maintenance and for remote access when dialling into the wagon using the mobile phone modem. The dialog box shows the current state of the program i.e. Starting, Operating normally, downloading, and shutting down due to low battery/high temperature. Also displayed is the present GPS location, speed and enclosure temperature.

RunCommsThread:

This thread controls the download operation through the ethernet port (connected to the wireless LAN). It continues to check if it is in range of the download computer, if it is then monitoring is stoped and the download procedure is initiated. After download monitoring is restarted. To limit the amount of downloads the runcomms thread also limits the number of downloads to only one every 8 hours.

RunDaqThread:

This thread checks the enclosure temperature and low battery signals. It also writes all the measurements to a second hard drive if it is connected. It receives information from the CDAQSystem-Run thread.

RunParseThread:

This thread converts the GPS ASCII messages received on the serial port into float and real numbers to be used by other threads. It controls the OnGGAFullMsg and the RunGGASerializeThread.

OnGGAFullMsg and **RunGGASerializeThread**:

These threads store the GPS data on the second hard drive if present.

ComControl Threads:

These threads control basic reading and writing operations on the serial communications ports for the GPS, power controller, and mobile phone modem.

CDAQsystem-Run Thread:

This thread is where the main data analysis occurs. This tread reads data from the data acquisition module, applies conversion rates, synchronises the GPS data with the data from the data acquisition module, checks for severe events, records frequency distributions and overall minium and maximum values since the last download, determines when the wagon changes tracks, calls OnDaqWrite and RunDaqWriteThread to control the storage of the severe 20s events on the primary hard drive.

Cwatchdog-Run Thread:

This thread checks that all the important threads are operating and if any have stopped then the watchdog shutsdown the computer. If there are no other errors and the wagon is moving the computer will be restarted by the power controller.

InitiateSendSMS and **SendSMSThread**:

This sends a SMS message as requested by the other threads.

The vehicle dynamic reporting system preferably has a total number of 150 recorded events and each event is recorded in substantially 20 second segments.

With regards to the wagon power management system, the wheel driven power supply preferably provides 12V DC power to the equipment and charges a battery used for power storage (as shown in figure 22).

The power controller preferably contains a microprocessor and relay, (as shown in the logic flowchart in figure 8). The power controller and speed transducer is preferably constantly powered. The power controller controls the power to the remainder of the wagon equipment via a switching relay. When the speed is above 5km/hr for 30 seconds the relay is turned on. Speed is calculated from the signal received from the speed transducer. The power controller also contains a low voltage detector and inactivity timeout watchdog system. When the voltage of the power storage falls below a preset limit a digital signal is sent to the Digital I/O device to advise the computer software that power should be cut until the voltage returns to an acceptable level. The inactivity timeout watchdog will turn off the power if no valid signal is periodically received from the computer. This provides a computer reset if a computer software lockup occurs. The computer sends signals to the controller via RS232 serial communications, these signals are sent by the computer software to specify when the controller turns off the power, watchdog signals and change settings of the controller. The power controller also modifies the speed transducer output and sends this to the analogue and Digital I/O device in a more suitable form.

The power converter preferably converts the power from an unregulated 12VDC supply to a number of regulated power levels required by the equipment on the wagon. The speed transducer is preferably a proximity switch device fitted to the bearing housing and a slotted wheel fixed to the axle. The speed transducer produces a pulsed waveform whose frequency is proportional to the rotational speed of the axle.

In another aspect the present invention broadly resides in the operational arrangement and combination of instrumentation equipment and software to form a dynamic reporting system. The on-board wagon system components are fitted to the railway wagon. The on-board wagon system components are installed in a compact arrangement so that it occupies minimal space and does not interfere with the operation of the wagon. Stationary equipment exists to allow automatic downloading of the data. The total system arrangement is shown in Figure 7.

The vehicle dynamic reporting system will automatically record and analyse data whenever the wagon is moving. If wagon dynamics exceed set limits the rail operator will immediately be notified of the severity and track location. The most extreme wagon dynamic events are stored as time history data with the corresponding track locations. Summary data is collated providing the maximum and minimum measurements and the distribution of the dynamic ranges since the last set of data was downloaded. When distributions are plotted against track sections they highlight track sections that produce the worst wagon dynamics. Downloading of the stored data may be automatic as the wagon slowly passes a download point, manual download via a laptop, or using the mobile phone network.

In another aspect the invention broadly resides in a method of monitoring and recording the train and track interactions using the system as described above and including

producing input information from the input means;

receiving and analysing input information by the receiver means, said input information is analysed in separate predefined time segments, each separate predefined time segment forms an event, each event is analysed with reference to one or more dynamic event categories and if an event is more severe than a limit in a particular event category then the event is recorded on a severe event list, wherein the recorded event and related positional data locates the track position associated with the recorded event.

The method of monitoring and recording the train and track interactions uses the system as described herein in its various forms and embodiments.

Brief Description of the Drawings

In order that the invention may be more readily understood, reference will now be made to the accompanying drawings which illustrate a preferred embodiment of the invention and wherein:

Figure 1 is a diagrammatic view of strain gauge instrumentation on the side frame of wagon showing side frame 10 and main strain gauge site 11;

Figure 2 is a diagrammatic view similar to Fig. 1 showing wheel reaction and braking forces on the side frame 10;

Figure 3 is a diagrammatic view similar to Fig. 1 showing wheel reaction and inertial forces on the side frame 10;

Figure 4 is a flow diagram of the strain measurement installation for the axle box reaction measurement;

Figure 5 is a flow diagram of the information processing with the wagon software;

Figure 6 is a flow diagram of the operation of the various threads of the operation of the wagon software (Shaded boxes denote persistent threads);

Figure 7 is a diagrammatic overview of the vehicle dynamic reporting system;

Figure 8 is a flow diagram of the operation of the power controller;

Figure 9 is a flow diagram of event reporting;

Figure 10 is a flow diagram of downloading of data from wagon;

Figure 11 is a diagrammatic view of forces acting on the wagon;

Figure 12 is a diagrammatic view of forces acting on a bogie where side frame 10, bolster 15 and wheel set 16 are shown;

Figure 13 is a sectional view of the bogie;

Figure 14 is a plan view of a coupler

Figure 15 is a table of the infrastructure wagon measured parameters;

Figure 16 is a plan view of the location of instrumentation on the coal infrastructure wagon;

Figure 17 is a photograph of the leading instrumented bogie;

Figure 18 is a photograph of the recorder enclosure and cabling;

Figure 19 is a photograph of the longitudinal accelerometer mounted underneath the wagon;

Figure 20 is a photograph of the speed sensor on the leading wheel set;

Figure 21 is a photograph of the bogie yaw measurement on the leading bogie;

Figure 22 is a photograph of the generator fitted to the second axle;

Figure 23 is a graph showing output in relations to wheel and bogie forces;

Figure 24 is an example of an event summary report;

Figure 25 is the event maximums and minimums of an entire trip;

Figure 26 is a graphical presentation of the vertical wheel force distribution of a loaded wagon; and

Figure 27 is a graphical presentation of the vertical wheel force distribution per track section of a loaded wagon.

Detailed Description of the Preferred Embodiment

The vehicle dynamic reporting system of the present invention is an on-board wagon reporting system having a number input devices including various transducers and GPS receiver, industrial computer with software for analysing input information, power supply and storage, wireless LAN device, mobile phone modem (see figure 7).

Transducers fitted to the wagon measure vertical bearing force, lateral bogie force, coupler forces, coupler swing, longitudinal draft-gear displacement, bogie yaw, brake pressures, longitudinal wagon acceleration and equipment enclosure temperature.

The vertical bearing force is the force that acts on the bearings of the wheel sets. The vertical bearing force measurements are achieved by strain gauges placed on the side frames. Stresses measured with the application of brake pressures and longitudinal accelerations are used in the calculation of the vertical bearing force to offset the effects on the strain gauges on the side frames when braking or during large longitudinal accelerations. Calculations of the corrected vertical bearing force measurements are based on the logarithms described herein. The vertical wheel forces are presented as a percentage of static wheel force ($W_{\%}$) as calculated below.

$$W_{\%} = \frac{W}{W_s} \times 100\%$$

where:

W Vertical wheel force, N

W_s Static vertical wheel force, N (ie. wheel force on horizontal track when the wagon is stationary and no external forces are applied)

$W_{\%}$ Vertical wheel force, % of static

The lateral bogie force is the lateral force between the bogie and the wagon body, and it is calculated by summing the lateral force between the bolster and the left and right side frames. The lateral bogie force measurements are achieved by strain gauges placed on the side frames. Correct placement of the strain gauges is crucial in order to obtain sufficient signal magnitude and minimal effect from braking and secondary forces. Longitudinal, lateral and vertical coupling forces are forces exerted by adjacent wagons. The longitudinal, lateral and vertical coupling forces are measured at both ends of the wagon. These measurements are valid for cases of knuckling and coupler pocket (striker) contact. The coupler forces are calculated from combining measurements of coupler strain and coupler movement. The coupler strain gauges measure the longitudinal strain and the lateral and vertical bending strains. Coupler movements that are measured include lateral coupler swing (rotation in the horizontal planewith respect to the wagon body) and longitudinal draft-gear displacement (longitudinal movement of the coupler with respect to the wagon body).

To stop the effect of drift, strain signals are continuously zeroed based on a running average over a defined distance. The signals zeroed using this method include vertical bearing force, lateral bogie force, vertical coupler force and lateral coupler force. Longitudinal coupler force is zeroed by using a running average when the coupler is in the slack or free state. Determination of the slack or free state uses the longitudinal draft-gear displacement.

Bogie yaw measures the rotation in the horizontal plane of one bogie with respect to the wagon body. Bogie yaw measurement is based on the rotation of the bolster with respect to the wagon body.

Brake pressures measure the air pressure of the brake system which is a measure of braking force. Also brake pipe pressure can be measured. Brake pipe pressure is used by the driver to control the brakes on wagons in the train.

Longitudinal wagon acceleration is measured on the wagon body, while enclosure temperature is the temperature measurement in the computer enclosure.

Brake pressures, longitudinal acceleration and enclosure temperature are measured using commercially available transducers.

The speed transducer is a proximity switch device fitted to the bearing housing and a slotted wheel fixed to the axle. The speed transducer produces a pulsed waveform whose frequency is proportional to the rotation speed of the axle.

The transducers signals and digital signals from the power controller and the pulse per second digital GPS signal are measured by an analogue and digital input/output (I/O) system and are converted into digital signals for use by the computer. The analogue and digital I/O system is connected to the computer via a controller PCMCIA card inserted into the PCMCIA socket on the computer. The analogue and digital I/O system also provides signal filtering and regulated voltages used by some of the transducers.

The GPS receiver supplies the location to the computer via a RS232 serial communication. A separate digital signal line from the GPS receiver also provides a pulse to indicate the exact point in time valid for the next location sent via the RS232 serial communication.

A wheel driven power supply provides 12V DC power to the equipment and charges a battery used for power storage.

The power controller contains a microprocessor and relay. Power is continuously maintained to the power controller and speed transducer. The power controller controls the power to the remainder of the wagon equipment via a switching relay. When the speed is above 5km/hr the relay is turned on. Speed is calculated from the signal received from the speed transducer. The power controller also contains a low voltage detector and inactivity timeout watchdog system. When the voltage of the power storage falls below a preset limit a digital signal is sent to the Digital I/O device to advise the computer software that power should be cut until the voltage returns to an acceptable level. The inactivity timeout watchdog will turn off the power if no valid signal is periodically received from the computer. This provides a computer reset if a computer software lockup occurs. The computer sends signals to the controller via RS232 serial communications, these signals are sent by the computer software to specify when the controller turns off the power, watchdog signals and change settings of the controller. The power controller also modifies the speed transducer output and sends this to the analogue and Digital I/O device in a more suitable form.

A power converter converts the power from an unregulated 12VDC supply to a number of regulated power levels required by the equipment on the wagon.

The computer is an IBM compatible computer system that consists of a processor, RAM, video output, keyboard interface, mouse interface, harddrive controller, TCPIP network controller, serial port controller, PCMCIA controller. The computer uses Microsoft Windows 98 operating system, software from the Centre for Railway Engineering and, other commercially available drivers and software. The computer receives data from the analogue and digital I/O system, receives GPS data from the GPS receiver, analyses this data, stores data on the harddrive, sends RS232 serial communication to the power controller, and interfaces to other computer systems. Interface to other computer systems are direct through the communication ports of the computer, through the mobile phone modem and wireless LAN Equipment. The mobile phone modem also provides access to the SMS message services.

The wireless LAN equipment consists of a wireless communication device, antenna and power converter. The wireless LAN equipment provides the computer an interface to other computer systems such as a stationary download computer and remote users.

The mobile phone modem provides the computer access to the SMS message services and to remote users.

The hard drive data storage is used to store the operating system files, the required software and, data and files generated by both. With the addition of a removable secondary harddrive the system will store extra data.

A stationary computer and wireless LAN equipment is required to enable automatic downloading of the wagon data.

The onboard wagon system automatically downloads data to the stationary equipment. The stationary equipment consists of a stationary computer system and wireless LAN equipment. The stationary computer system is an IBM compatible computer system. The wireless LAN equipment provides a TCPIP network link to the wagon computer when in range. This wireless network is used to receive data from the wagon computer. Information on the stationary computer can be accessed by a TCPIP network connection.

The dynamic reporting system starts analysis and recording for speeds above 5 km/hr. The analysis and recording stops if the speed drops below 5 km/hr for more than two minutes.

A limited number of the most severe dynamic event files are stored on the hard drive (see Figure 9). Each event file includes time series data for a period of 20 seconds of data. The data recorded in the file with respect to time includes vertical wheel force on all wheels, lateral bogie force on both bogies, vertical coupler force, lateral coupler force, lateral coupler force, lateral coupler swing, longitudinal draft-gear displacement, bogie yaw, brake cylinder pressure for both bogies, brake pipe pressure, longitudinal wagon body acceleration, enclosure temperature, speed and GPS location (see figures 1 to 3 and 11 to 22). Also included in the event file is the time, date, bogie weight, wagon weight, and track classification. The severity of a dynamic event is based on the dynamic wagon data. Several severity categories exist including minimum vertical wheel force, maximum absolute lateral bogie force, maximum absolute lateral coupler force, maximum longitudinal coupler force, minimum longitudinal coupler force, maximum vertical coupler force, minimum vertical coupler force and maximum longitudinal wagon acceleration. Separate severity categories also exist for two wagon load states, a lightly loaded wagon state and heavily loaded wagon state.

For each category a limited number of the most severe dynamic events are stored. In this preferred embodiment a total of 150 severe events are stored. Prior to the maximum number of events being recorded in a particular event category, all severe events that exceed the minimum severity limit are recorded. When the maximum number of recorded events is reached and a dynamic event occurs that is more severe than a stored event, then the least severe stored event will be deleted and the new dynamic event stored. Limiting the amount of stored events reduces storage and archive requirements and the time taken to download the data.

A summary file is produced summarising the details of the severe 20 second event files stored. This file simplifies searching for particular events.

On detection of an extremely severe event based on set limits of the dynamic wagon data, a SMS text message will be sent to the railway operator. The SMS text message includes the location and magnitude of the event. Viewing of the 20 second event file would be possible after the next data download.

Frequency distributions for each measured parameter are stored as files. These provide a summary of the range of each parameter since the last download. Frequency distributions are also provided based on 10km track sections. This allows the comparison of the wagon behaviour on different track sections. A complete set of frequency distributions is created for two wagon load states, a lightly loaded wagon state and heavily loaded wagon state. Frequency distributions are based both on time and distance travelled.

A "minimum and maximum" data file is stored that records the minimum and maximum values of each recorded parameter since the last download. A "minimum and maximum" data file is created for two wagon load states, a lightly loaded wagon state and heavily loaded wagon state.

Files are also stored containing information that can be used to check the calibration of the vertical wheel force determination. These files average the vertical wheel force measurements for a constant wagon loading.

Track position is determined by the GPS position data. When the wagon is in multiple track sections the track classification or track it is on is determined by the GPS position data, speed transducer and bogie yaw measurement. The GPS location data alone is not accurate enough to differentiate between multiple tracks. The bogie yaw measurement is used to identify when the wagon changes tracks. A change of track is verified by the known GPS position of all track crossovers. This allows the wagon to operate with the freely available non-differential GPS location data, without the additional infrastructure and expenses of a DGPS system.

Automatic downloading of the wagon computer data files occurs when a wireless communications link is established between the wagon computer and the stationary computer (see Figure 10). If a download has occurred then a time delay will occur before downloading is attempted again. This stops uninteresting data from being downloaded when the wagon is being shunted within range of the stationary computer.

Example 1: Instrumentation Of A VSA Class Coal Wagon And A BCZY Freight Wagon and Recorded Data From Instrumented Wagon

The coal infrastructure wagon (VSA 49430) was used for trial and experimentation purposes in the Goonyella coal rail system in central Queensland. The BCZY freight infrastructure wagon was similarly used in general freight operations on the main lines around Queensland. The only limitation of these wagons was that special care was taken during routine maintenance so as not to damage the recording equipment.

The infrastructure wagons were designed to operate autonomously and include a power generating system. A mobile phone modem and a computer network device provided two methods of communication between the wagon and the railway operator. The sensors as described herein were positioned on each wagon as shown in Figure 16 to 22.

The Infrastructure wagons automatically analyzed data whenever they were moving. If the wagon dynamics exceed safe limits the computer was programmed to send a text message to one or more mobile phones when in a mobile phone area. The text message contained a summary of the event including track position.

The 150 most extreme wagon dynamic events were stored on the recorder with the corresponding GPS track locations (see Figure 9 and 10).

These events were stored as time based data that could be imported into a spreadsheet (such as Microsoft Excel). Figure 23 shows sample data by way of example. Other output files stored included a event summary file, minimum maximum file and frequency distributions (see Figures 24 – 27).

The infrastructure wagons automatically downloaded analysis results at the conclusion of every haulage trip. Manual download was also possible by connecting a laptop via a cable to the wagon recorder.

Data downloaded from the wagon was in text format to read directly or used with a graphing spreadsheet such as Excel. The five types of reports were prepared and examples are provided in figures 23 to 27. These were a recordal of 150 most extreme events (20 second block of data) as shown in Figure 23. Production of a summary of extreme events as shown in Figure 24. Listing the maximums and minimums of an entire trip as shown in Figure 25. Graphical presentation of each measured parameter for the entire trip as shown in Figure 26. Graphical presentation of track section distribution for each measured parameter as shown in Figure 27.

Data collected from the infrastructure wagons was collated into a single database. This allowed searching and presentation of the data based on location, parameter levels, event type, time and date. Collating the results in this way was useful to detect patterns and trends.

<u>Advantages</u>

The vehicle dynamic reporting system described herein provides the advantage that it is an on board system and is operational during normal freight use. Being an on-board system of freight trains overcomes the problems of using recording vehicles in obtaining measurements that may not accurately represent interactions and forces produced by operational freight trains and allows the frequency of track reporting to be increased without interference to normal train traffic and without the construction of more recording vehicles. The measurements provided by the vehicle dynamics reporting system also complement existing track geometry measurement methods and provide a management tool for track infrastructure maintenance.

Variations

It will of course be realised that while the foregoing has been given by way of illustrative example of this invention, all such and other modifications and variations thereto as would be apparent to persons skilled in the art are deemed to fall within the broad scope and ambit of this invention as is herein set forth.

Throughout the description and claims this specification the word “comprise” and variations of that word such as “comprises” and “comprising”, are not intended to exclude other additives, components, integers or steps.

Claims

1. A vehicle dynamic reporting system including

input means for producing input information regarding vehicle movement and forces affecting a vehicle;

receiving means for receiving and analysing input information, said input information is analysed in separate predefined time segments, each separate predefined time segment forms an event, each event is analysed with reference to one or more dynamic event categories and if an event is more severe than a limit in a particular event category then the event is recorded on a severe event list, wherein the recorded event and related positional data locates the track position associated with the recorded event.

2. A vehicle dynamic reporting system as claimed in claim 1 wherein the recorded events are recorded in the respective event category in order of severity and where the number of recorded events is above the predefined limit, the least severest event in the particular event category is deleted until the predefined recorded event number is reached.

3. A vehicle dynamic reporting system as claimed in claim 2 wherein the total number of recorded events is 150 and each event is recorded in substantially 20 second segments.

4. A vehicle dynamic reporting system as claimed in any one of the preceding claims wherein the recorded events and data is downloadable to a

laptop computer, to a remote computer through wireless LAN equipment and or via SMS messaging.

5. A vehicle dynamic reporting system as claimed in any one of the preceding claims wherein the input means includes determinations with respect to vertical wheel force on all wheels, lateral bogie force on both bogies, vertical coupler force, lateral coupler force, lateral coupler force, lateral coupler swing, longitudinal draft-gear displacement, bogie yaw, brake cylinder pressure for both bogies, brake pipe pressure, longitudinal wagon body acceleration, enclosure temperature, speed, GPS location, time, date, bogie weight, wagon weight, and track classification.

6. A vehicle dynamic reporting system as claimed in claim 5 wherein wheel and bogie force measurements are made using strain gauges positioned on the side frame with use of brake cylinder pressure measurement and longitudinal acceleration measurement to calculate an thus remove the strain component due to the effect of braking and longitudinal wheelset inertia.

7. A vehicle dynamic reporting system as claimed in any one of the preceding claims wherein the vehicle dynamic reporting system will automatically record and analyse data whenever the wagon is moving.

8. A vehicle dynamic reporting system as claimed in any one of the preceding claims wherein the detection of an extremely severe event based

on set limits of the dynamic wagon data, an SMS text message is sent to the railway operator, said message includes the location and magnitude of the event.

9. A vehicle dynamic systems as substantially described herein with reference to and as illustrated by the accompanying drawings.

DATED THIS ELEVENTH DAY OF FEBRUARY 2004

CENTRAL QUEENSLAND UNIVERSITY AND QUEENSLAND RAILWAYS

By their Patent Attorneys
WYNNES PATENT AND TRADE MARK ATTORNEYS

Fig. 1

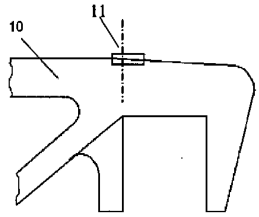


Fig. 2

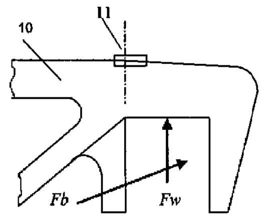


Fig. 3

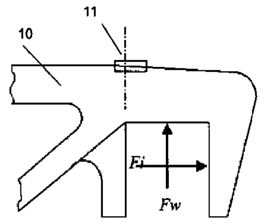


Fig. 4

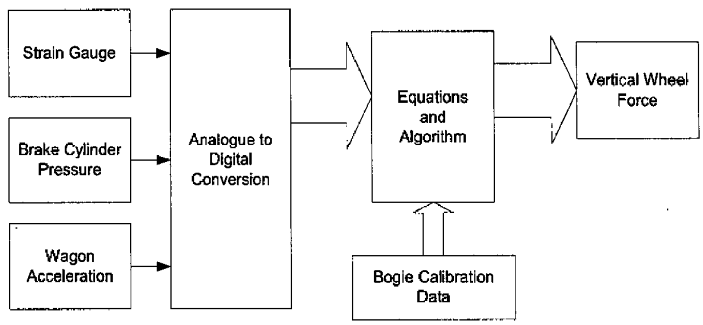

Strain Gauge
Brake Cylinder Pressure
Wagon Acceleration
Analogue to Digital Conversion
Equations and Algorithm
Bogie Calibration Data
Vertical Wheel Force

Fig. 5

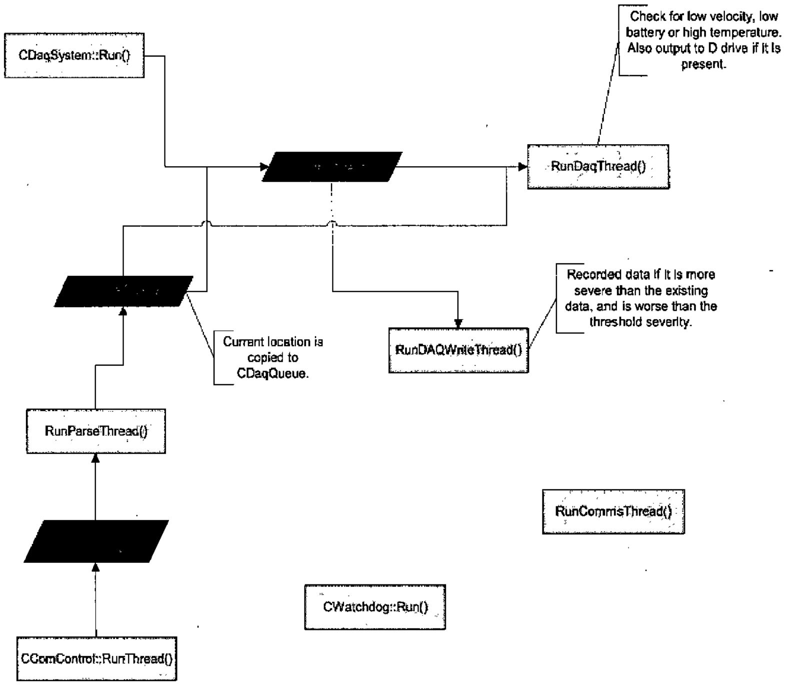
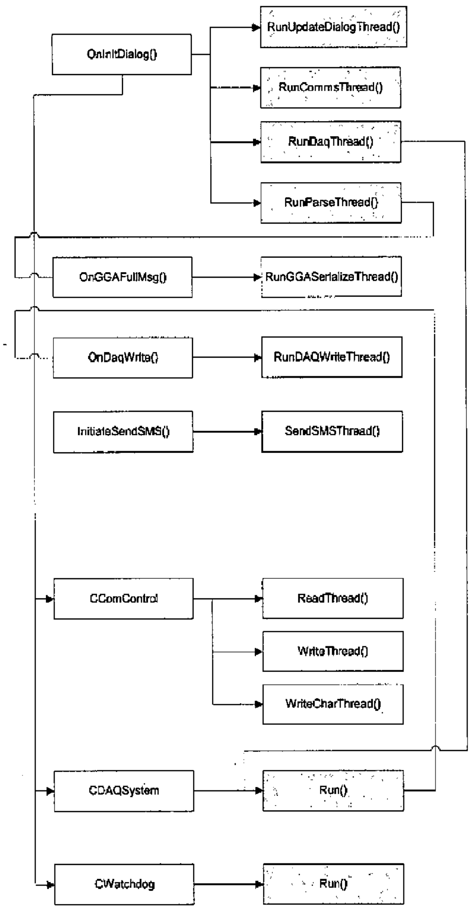

CDaqSystem::Run()
Check for low velocity, low battery or high temperature. Also output to D drive if it is present.
RunDaqThread()
Recorded data if it is more severe than the existing data, and is worse than the threshold severity.
Current location is copied to CDaqQueue.
RunDAQWriteThread()
RunParseThread()
RunCommsThread()
CWatchdog::Run()
CComControl::RunThread()

Fig. 6



Note: Shaded boxes donote persistant threads

Fig. 7

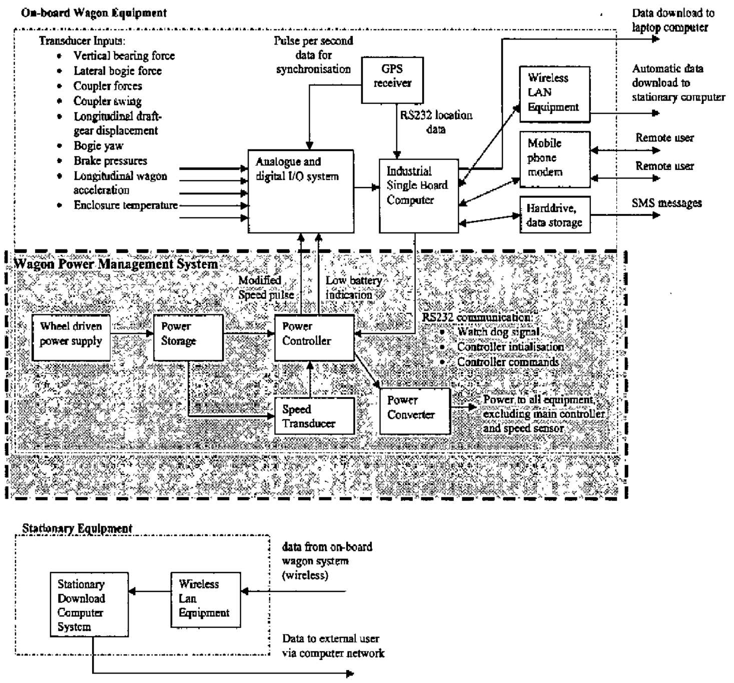
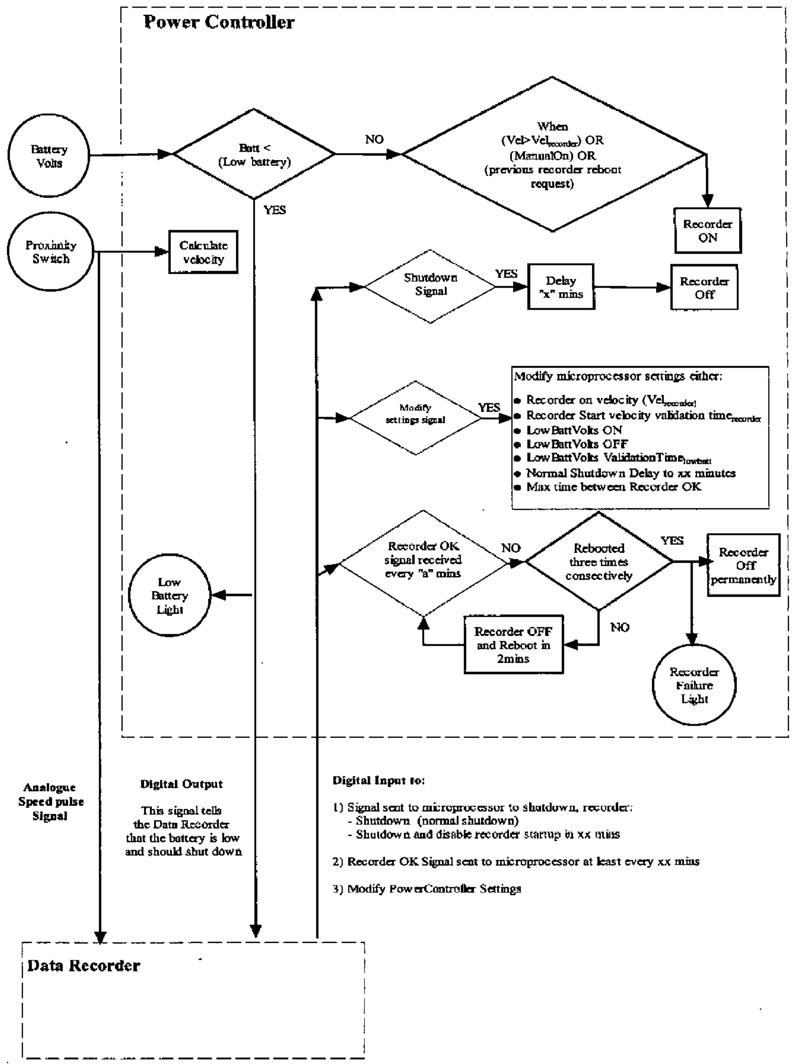

On-board Wagon Equipment
Transducer Inputs:
Vertical bearing force
Lateral bogie force
Coupler forces
Coupler swing
Longitudinal draft-gear displacement
Bogie yaw
Brake pressures
Longitudinal wagon acceleration
Enclosure temperature
Pulse per second data for synchronisation
GPS receiver
RS232 location data
Analogue and digital I/O system
Industrial Single Board Computer
Wireless LAN Equipment
Mobile phone modem
Harddrive, data storage
Data download to laptop computer
Automatic data download to stationary computer
Remote user
Remote user
SMS messages
Wagon Power Management System
Modified Speed pulse
Low battery indication
RS232 communication:
Watch dog signal
Controller intialisation
Controller commands
Wheel driven power supply
Power Storage
Power Controller
Speed Transducer
Power Converter
Power to all equipment, excluding main controller and speed sensor
Stationary Equipment
Stationary Download Computer System
Wireless Lan Equipment
data from on-board wagon system (wireless)
Data to external user via computer network

Fig. 8


Power Controller
Battery Volts
Batt < (Low battery)
NO
YES
When (Vel>Vel recorder) OR (ManualOn) OR (previous recorder reboot request)
Recorder ON
Proximity Switch
Calculate velocity
Shutdown Signal
YES
Delay "x" mins
Recorder Off
Modify settings signal
YES
Modify microprocessor settings either:
• Recorder on velocity (Vel recorder)
• Recorder Start velocity validation time recorder
• LowBattVolts ON
• LowBattVolts OFF
• LowBattVolts ValidationTime lowbatt
• Normal Shutdown Delay to xx minutes
• Max time between Recorder OK
Low Battery Light
Recorder OK signal received every "a" mins
NO
Rebooted three times consecutively
YES
Recorder Off permanently
NO
Recorder OFF and Reboot in 2mins
Recorder Failure Light
Analogue Speed pulse Signal
Digital Output
This signal tells the Data Recorder that the battery is low and should shut down
Digital Input to:
1) Signal sent to microprocessor to shutdown, recorder:
- Shutdown (normal shutdown)
- Shutdown and disable recorder startup in xx mins
2) Recorder OK Signal sent to microprocessor at least every xx mins
3) Modify PowerController Settings
Data Recorder

9/28
Fig. 9

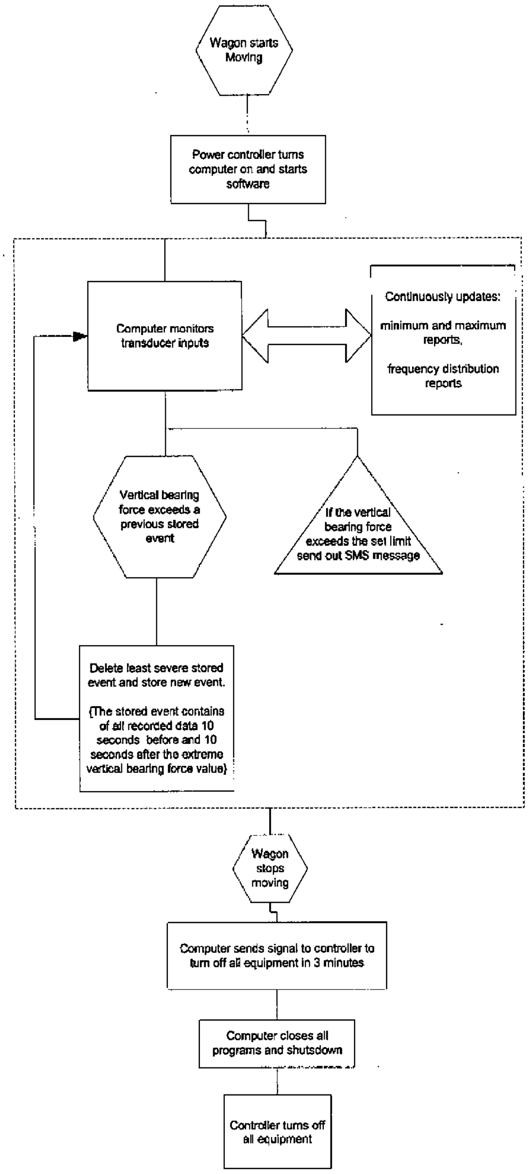

Wagon starts Moving
Power controller turns computer on and starts software
Computer monitors transducer inputs
Continuously updates:
minimum and maximum reports,
frequency distribution reports
Vertical bearing force exceeds a previous stored event
If the vertical bearing force exceeds the set limit send out SMS message
Delete least severe stored event and store new event.
(The stored event contains of all recorded data 10 seconds before and 10 seconds after the extreme vertical bearing force value)
Wagon stops moving
Computer sends signal to controller to turn off all equipment in 3 minutes
Computer closes all programs and shutsdown
Controller turns off all equipment

Fig. 10

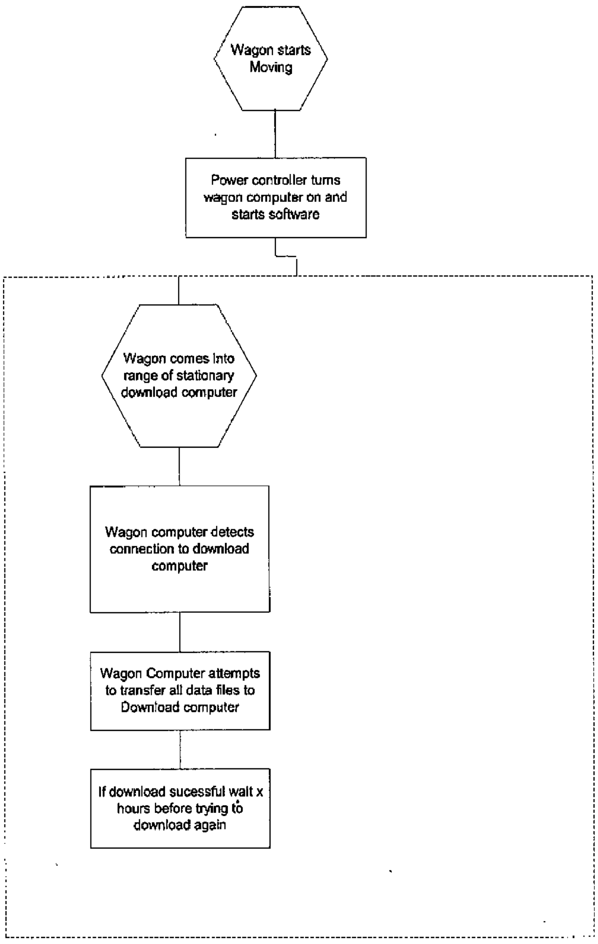

Wagon starts Moving
Power controller turns wagon computer on and starts software
Wagon comes into range of stationary download computer
Wagon computer detects connection to download computer
Wagon Computer attempts to transfer all data files to Download computer
If download sucessful wait x hours before trying to download again

Fig. 11

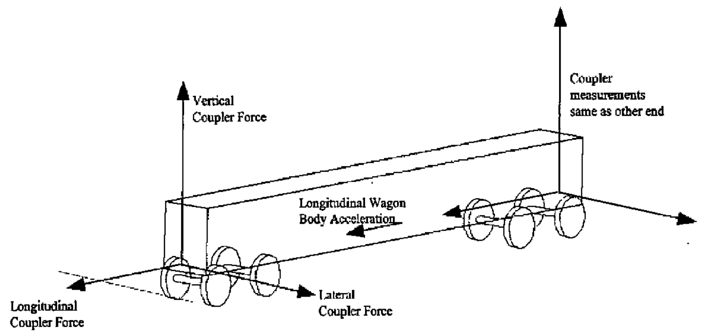

Vertical
Coupler Force
Coupler
measurements
same as other end
Longitudinal Wagon
Body Acceleration
Longitudinal
Coupler Force
Lateral
Coupler Force

Fig. 12

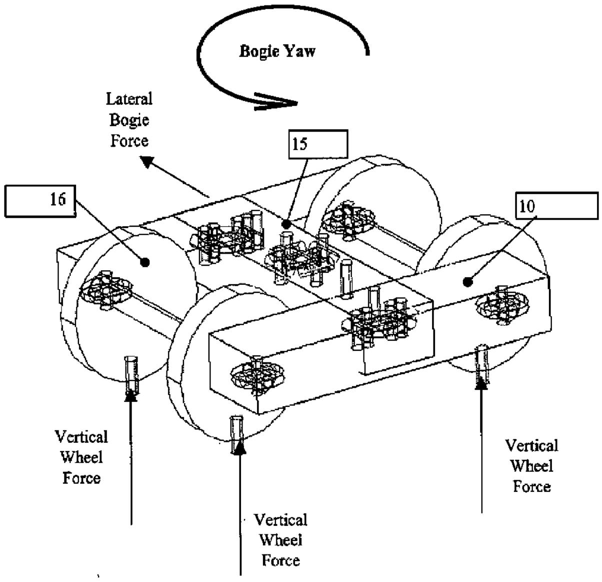

Bogie Yaw
Lateral
Bogie
Force
15
16
10
Vertical
Wheel
Force
Vertical
Wheel
Force
Vertical
Wheel
Force

Fig. 13

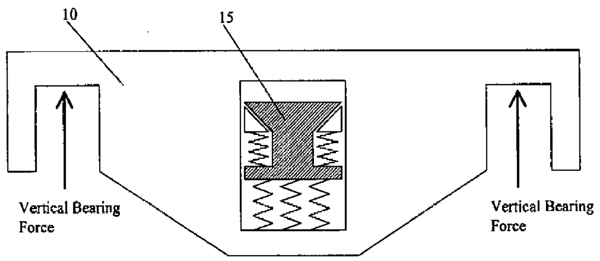


Fig. 14

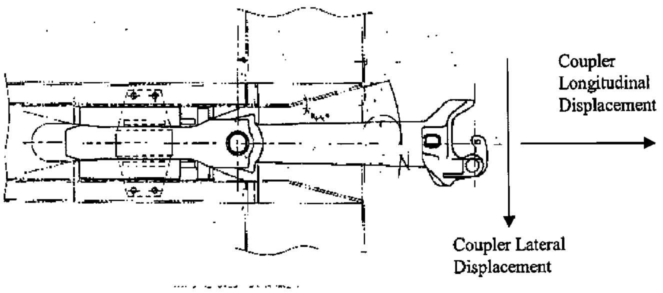

Coupler
Longitudinal
Displacement
Coupler Lateral
Displacement

Fig. 15

	Coal Infrastructure Wagon	Freight Infrastructure Wagon
Vertical bearing force	8	8
Longitudinal wagon body Acceleration	1	1
Front bogie yaw	1	1
Speed/Distance	1	1
GPS Location	1	1
Brake cylinder pressure - Front bogie - Rear bogie	2	2
Brake pipe pressure	-	1
Coupler displacement - longitudinal - lateral (swing)	-	4
Coupler Force - longitudinal - lateral - vertical	-	6
Lateral sideframe force (lateral bogie force calculated by summing two sideframes)	-	4
TOTAL	**14**	**29**

Fig. 16

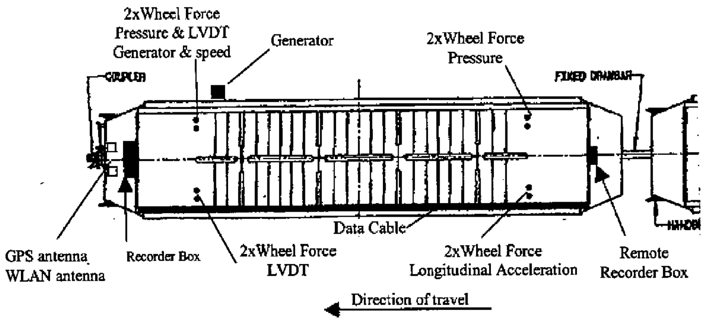

2xWheel Force
Pressure & LVDT
Generator & speed
Generator
2xWheel Force
Pressure
Data Cable
GPS antenna
WLAN antenna
Recorder Box
2xWheel Force
LVDT
2xWheel Force
Longitudinal Acceleration
Remote
Recorder Box
Direction of travel

Fig. 17

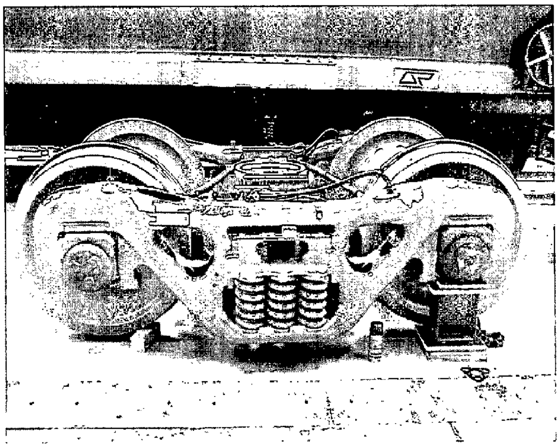
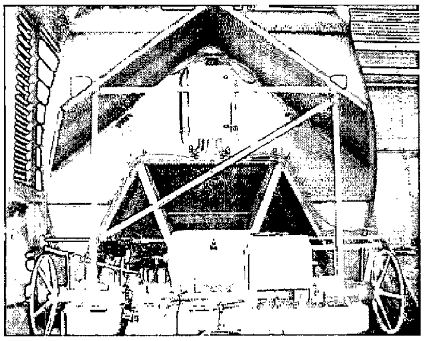


Fig. 18



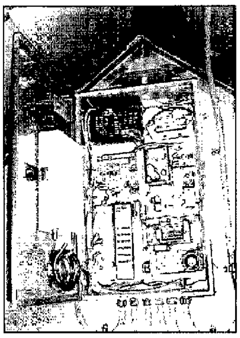


Fig. 19

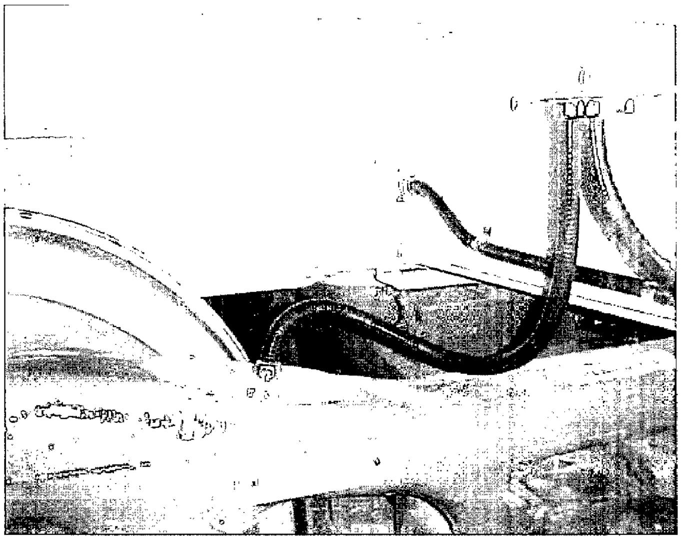


Fig. 20

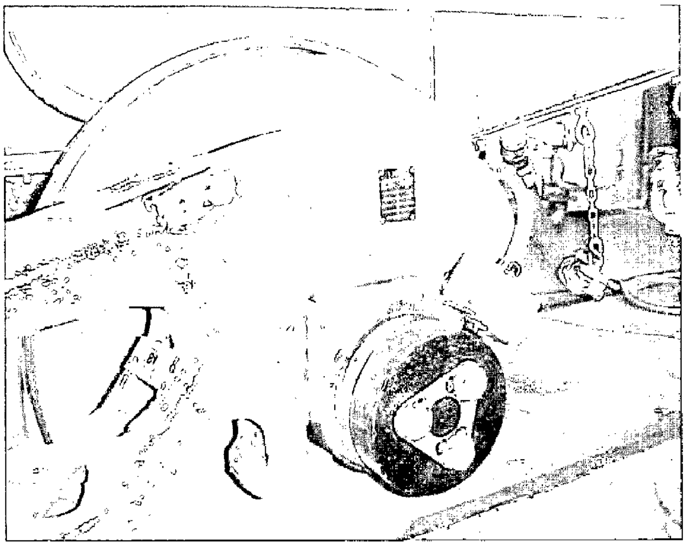


Fig. 21

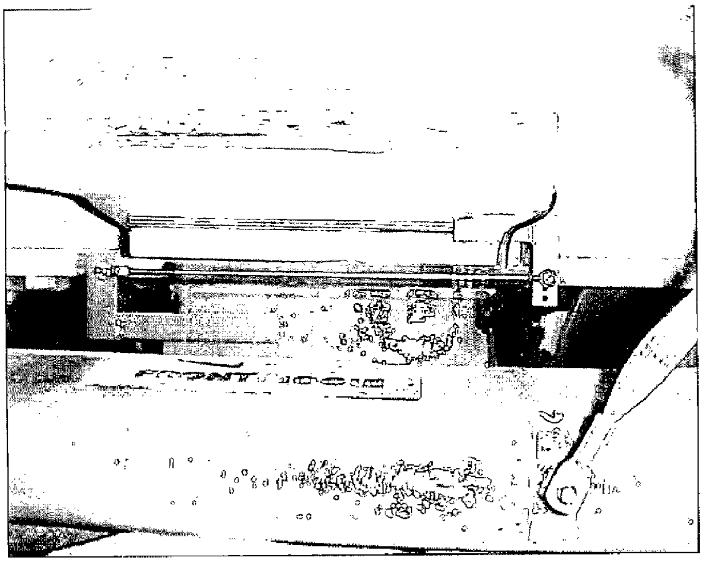


Fig. 22

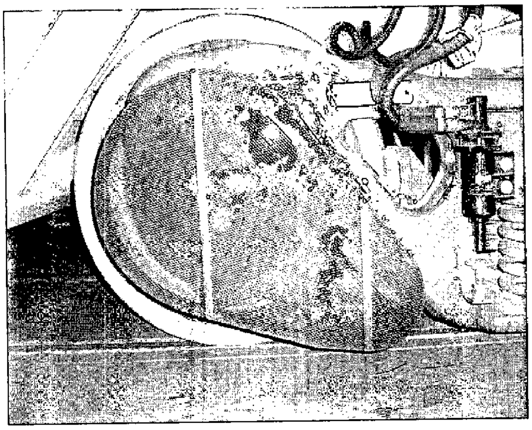
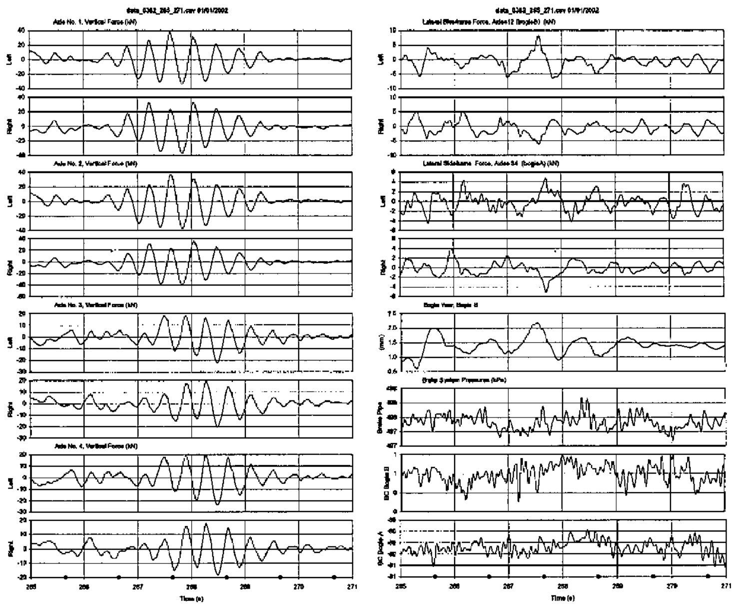


Fig. 23



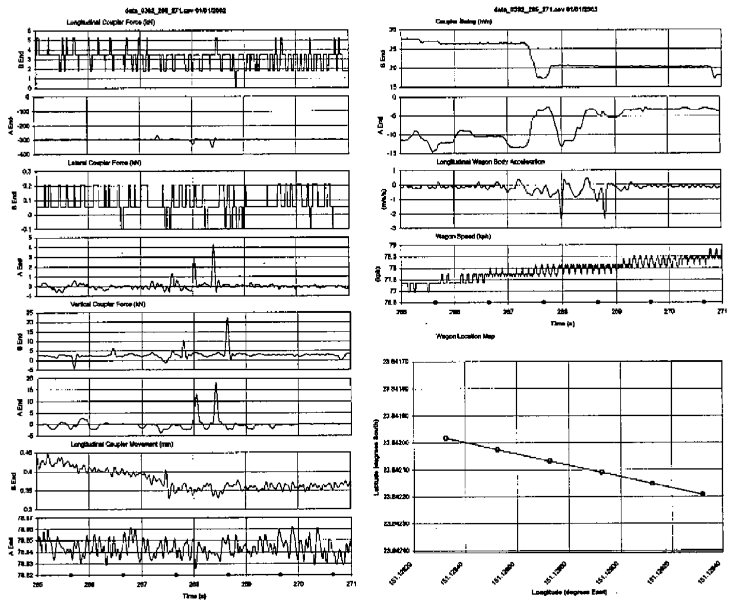


Fig. 24

Date	Time	GPS Location		Line	Load Case	Average Speed (km/h)	Brake Pressure (kPa)	Maximum Acceleration (m/s^2)	Maximum Wheel Force (% static)	Minimum Wheel Force (% static)
		Lat	Long.							
12/02/01	18:05	21.11	149.342	Down	Empty	80	0	0.5	130	30
12/02/01	13:01	21.02	149.023	Up	Loaded	70	0	0.2	160	50
12/02/01	15:34	21.05	149.134	Up	Loaded	35	50	0.1	140	65

Fig. 25

Parameter	Description	Units	Empty Wagon		Loaded Wagon	
			Minimum Value	Maximum Value	Minimum Value	Maximum Value
Acceleration	Longitudinal	m/s^2	-12.6	20.3	-5.6	4.2
Vertical Wheel Force	Axle 1, Left	% of static	13	220	23	226
	Axle 1, Right	% of static	21	219	31	232
...	Axle 2, Left	% of static	17	245	27	212

Fig. 26

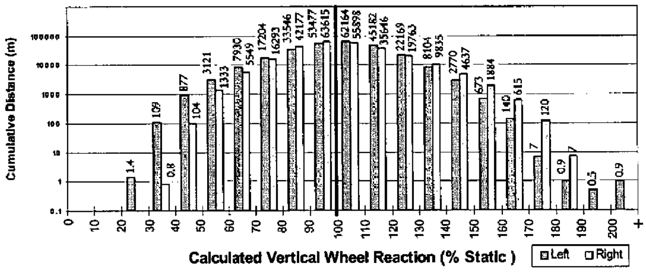
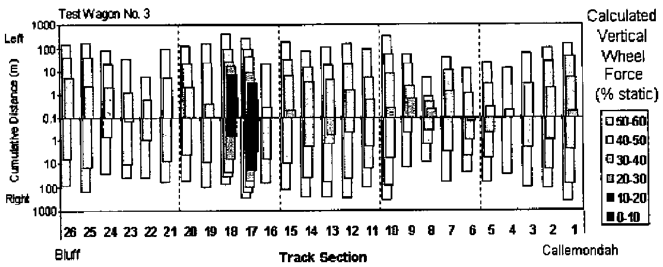

Cumulative Distance (m)
100000
10000
1000
100
10
1
0.1
1.4
109
0.8
877
104
3121
1333
7930
5549
17204
16293
33546
42177
53477
63615
62164
55898
45182
35646
22169
19763
8104
9835
2770
4637
673
1884
140
615
7
120
0.9
7
0.5
0.9
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
+
Calculated Vertical Wheel Reaction (% Static)
Left
Right

Fig. 27


Test Wagon No. 3
Left
Right
Cumulative Distance (m)
1000
100
10
1
0.1
1
10
100
1000
26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
Bluff
Track Section
Callemondah
Calculated Vertical Wheel Force (% static)
50-60
40-50
30-40
20-30
10-20
0-10