WHEEL IMPACT LOAD DETECTOR (WILD)

Development of WILD with IIT/K

Introduction

- With the increase in axle load, Indian Railways decided to put in safety checks that will provide automated information to officials about health of Rolling Stock.
- It was decided to develop an indigenous system instead of importing technology to gain cost benefit.
- RDSO partnered IIT-Kanpur in the development of the prototype of the system.

Introduction

- Extensive Studies were conducted with various technologies such as vibration sensors and load sensors
- Based on quality of wheel signature detected it was decided to build a prototype using strain gauge technology to measure the impact load
- Further algorithms were developed to identify defects

Introduction – Wheel Flat Detection

- Initially it was believed that high impact loads were caused only by wheel flats.
- Wheel flats were formed on the wheel tread due to unintentional sliding of the wheel on rails.
- Metal deposits in lump form caused due to brake binding result in out-of-round wheels and have the same effect as wheel flat.
- Isolated wheel-flats, molten metal deposition on wheel tread, out of roundness of a wheel etc. cause repeated impact loads.
- Heavier trains and higher speeds accentuate the influence of imperfections causing distress to both track and vehicle.
- A fresh wheel-flat has the shape of a geometric chord at the wheel circumference. However, when the brake unlocks, the corners of the flat profile soon become rounded due to running.

Development Need

- Wheel flats are formed on the wheel tread due to unintentional sliding of the wheel on rails or due to brake binding.
- Isolated wheel-flats/metal deposits cause repeated, extremely short duration impact loads.
- Defects beyond certain sizes may produce impact loads to cause failure of already defective rails and welds.

Development Need

- Indian Railways till date were trying to identify the wheels with flats manually by listening to the sound produced by running wheel at entrance of major yards.
- This method is purely subjective and may escape notice.
- Wheel Flat Detection System which gives output in terms of impact load has therefore been developed.

Wheel Impact Load Detector (WILD) developed indigenously

The project was taken up jointly by RDSO and IIT/Kanpur in April 2001 under Railway Technology Cell, at IIT Kanpur Established in January 2001

……..Wheel Impact Load Detector (WILD) developed indigenously

- It was found by trials that the signature of normal wheel and defective wheels were different.
- An algorithm based on the following principle was developed to isolate the defective wheel from normal wheel:
  - The signature of impact load on time scale for each passing wheel
  - Value of impact load due to passing of each wheel over instrumented zone

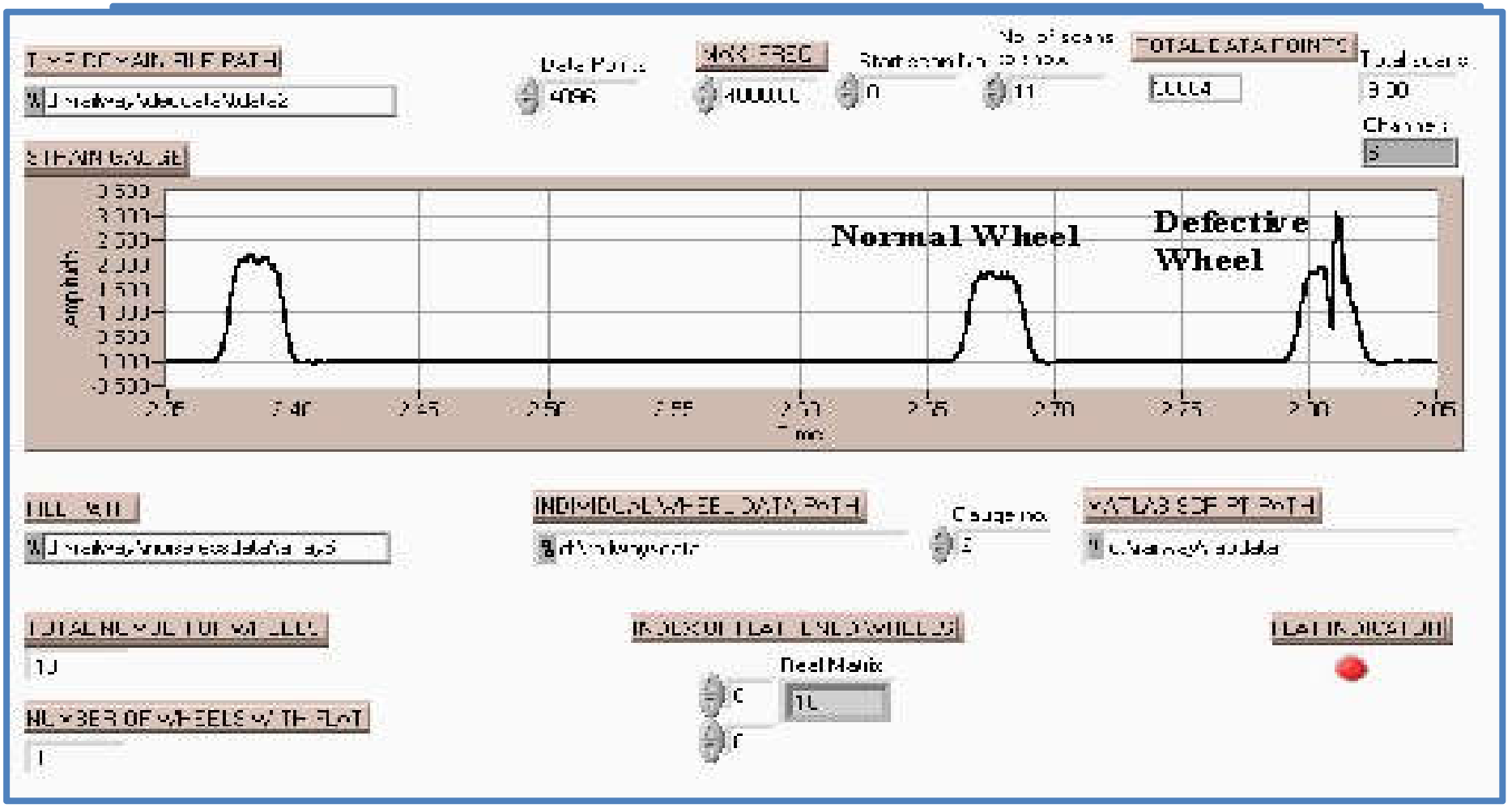
……..Wheel Impact Load Detector (WILD) developed indigenously

- Based on above algorithm, RDSO with the help of I.I.T/Kanpur developed software on LabVIEW platform. Analysis of data was done by using Mat Lab which was interfaced with LabVIEW.
- The system consists of 12 channels.
- Each channel consists of 4 Rosette type strain gauges fixed on neutral axis of rail (both sides) with wheat stone bridge configuration for each channel.
- It was found that to cover two revolutions of wheel 12 channels are sufficient with a sleeper spacing of 60 cm.

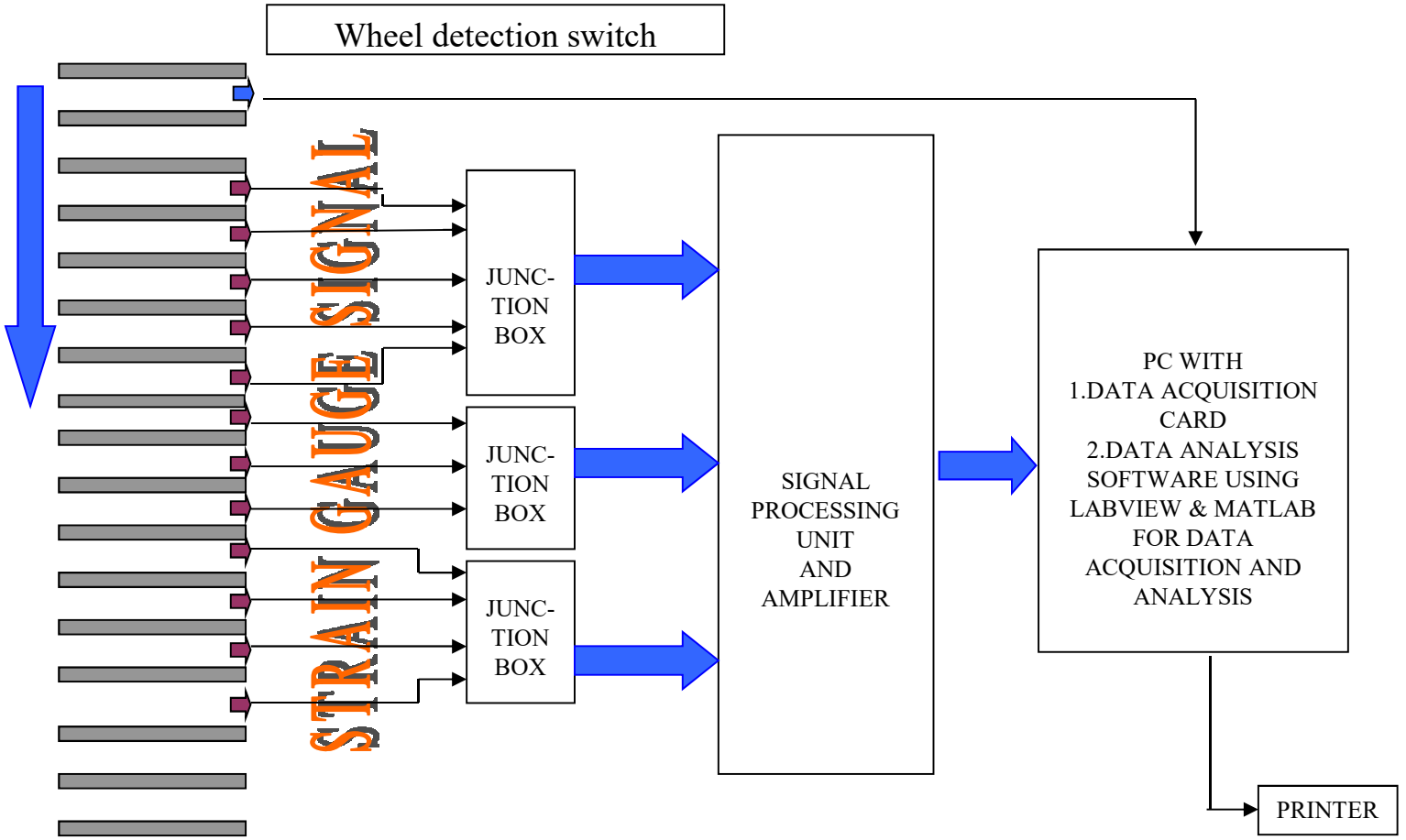
……..Wheel Impact Load Detector (WILD) developed indigenously

Based on the studies & research done by RDSO along with IIT/Kanpur , the Wheel Impact Load Detector (WILD) was installed on the left rail of the track with a 12 channel instrumented rail at Ajgain station and field trial was started on 21/6/02. These 12 channels were fixed on one side rail only (i.e. L/S)

……..Wheel Impact Load Detector (WILD) developed indigenously



Schematic Layout of Wheel Impact Load Detector was installed at Ajgain



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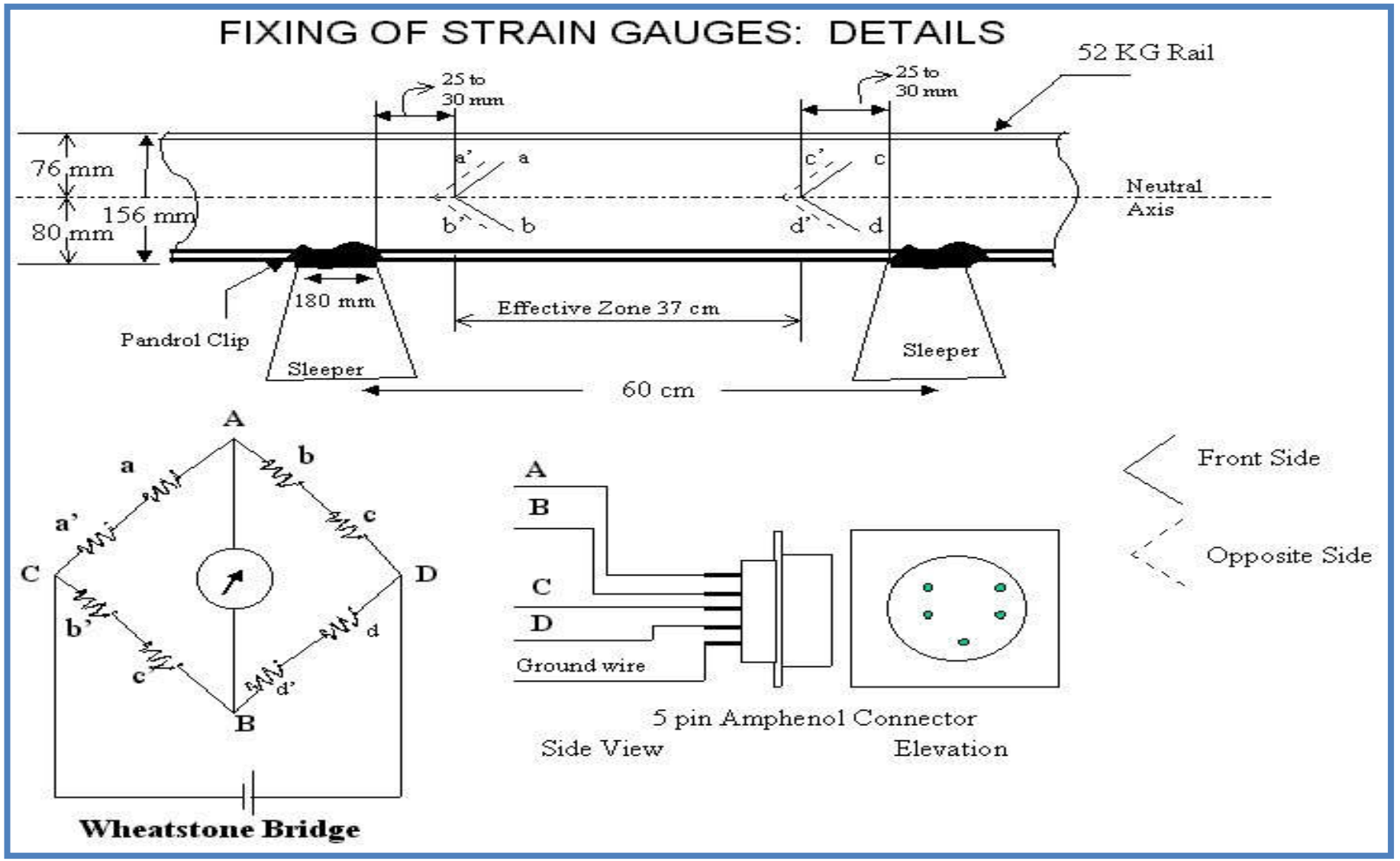
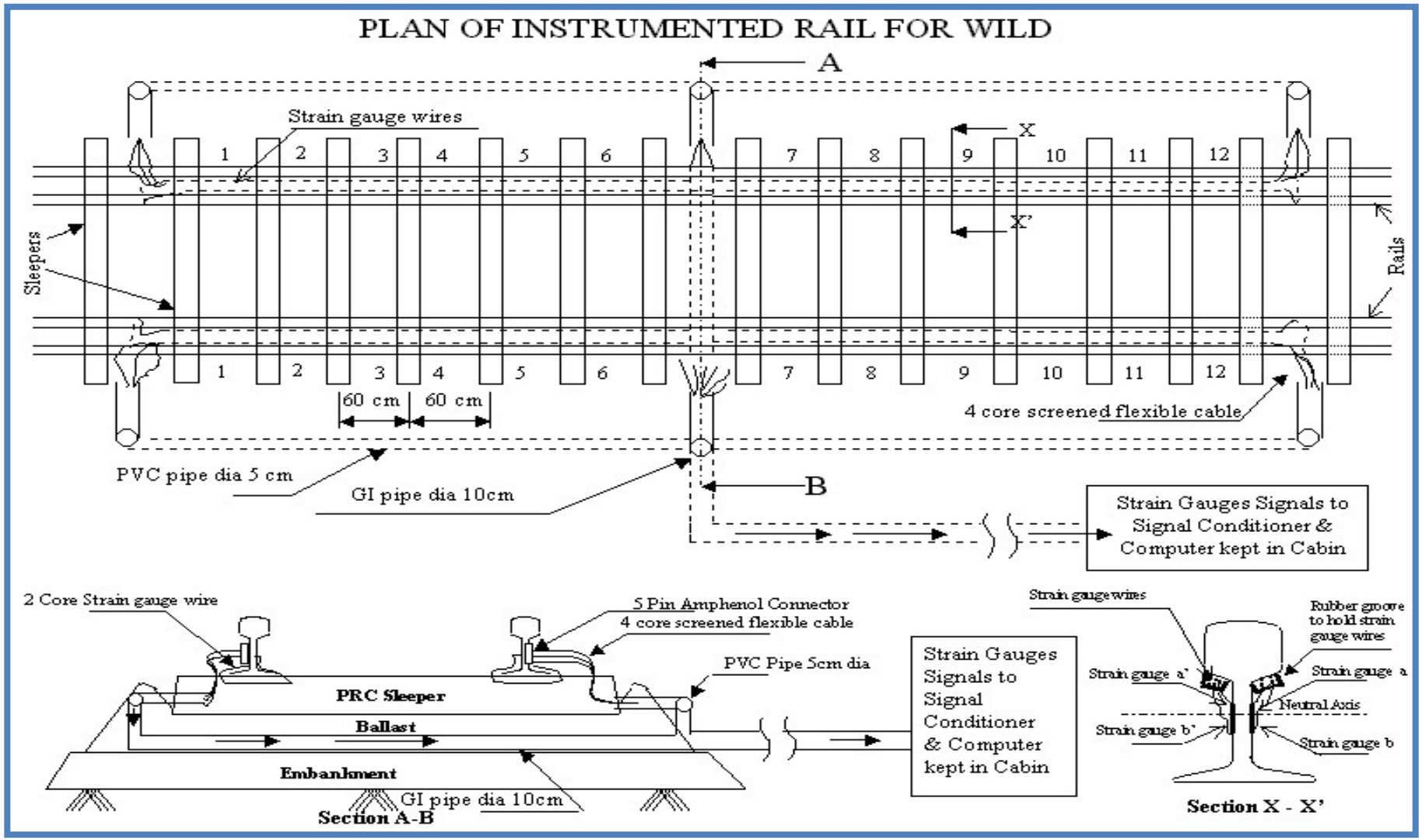
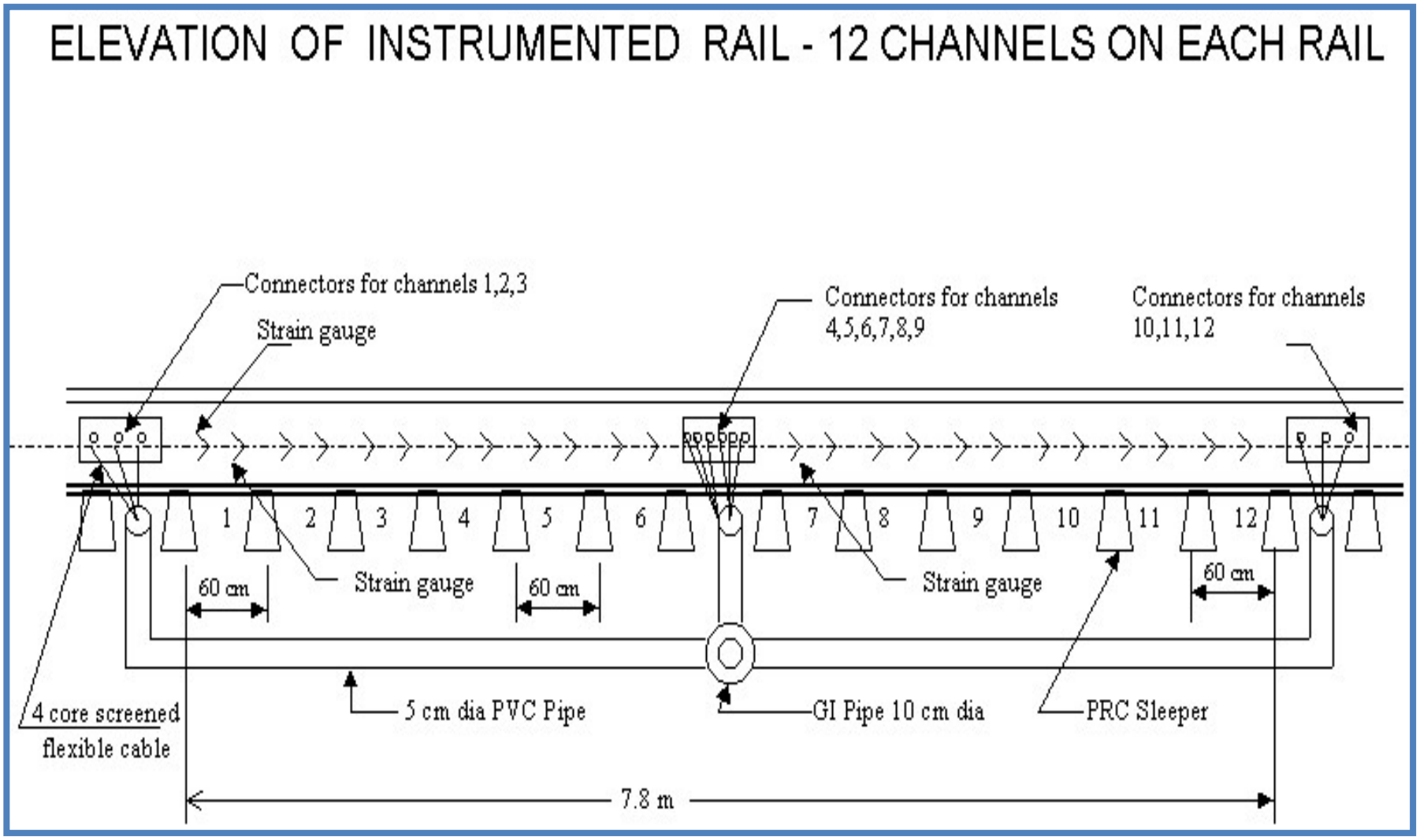


Schematic Layout of Wheel Impact Load Detector



Schematic Layout of Wheel Impact Load Detector



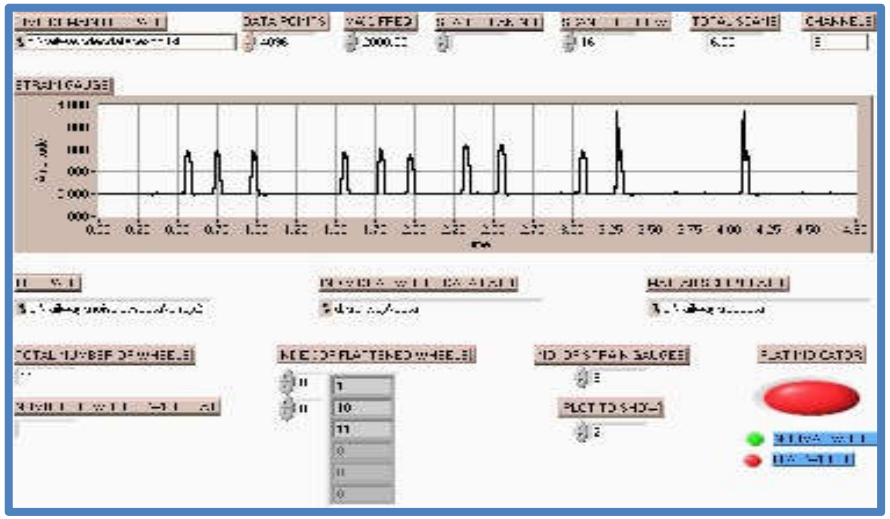
View of Instrumented Rail

A View of Instrumented rail indicating Active Zone (in white) and Non-active Zone (in red)

……Wheel Impact Load Detector (WILD) developed indigenously

The following indications were captured on the monitor after passing the defective wheel :

- Date and time
- An audio alarm indicating that wheel having defect has passed.
- A visual indication with the lighting of a red indication.



- The count of axle of the defective wheels in the train taking locomotive front axle as No.1 for the exact location of the defective wheel.
- The total number of defective wheels.
- Total no. of wheels in the train passing the instrumented zone.

…..Wheel Impact Load Detector (WILD) developed indigenously

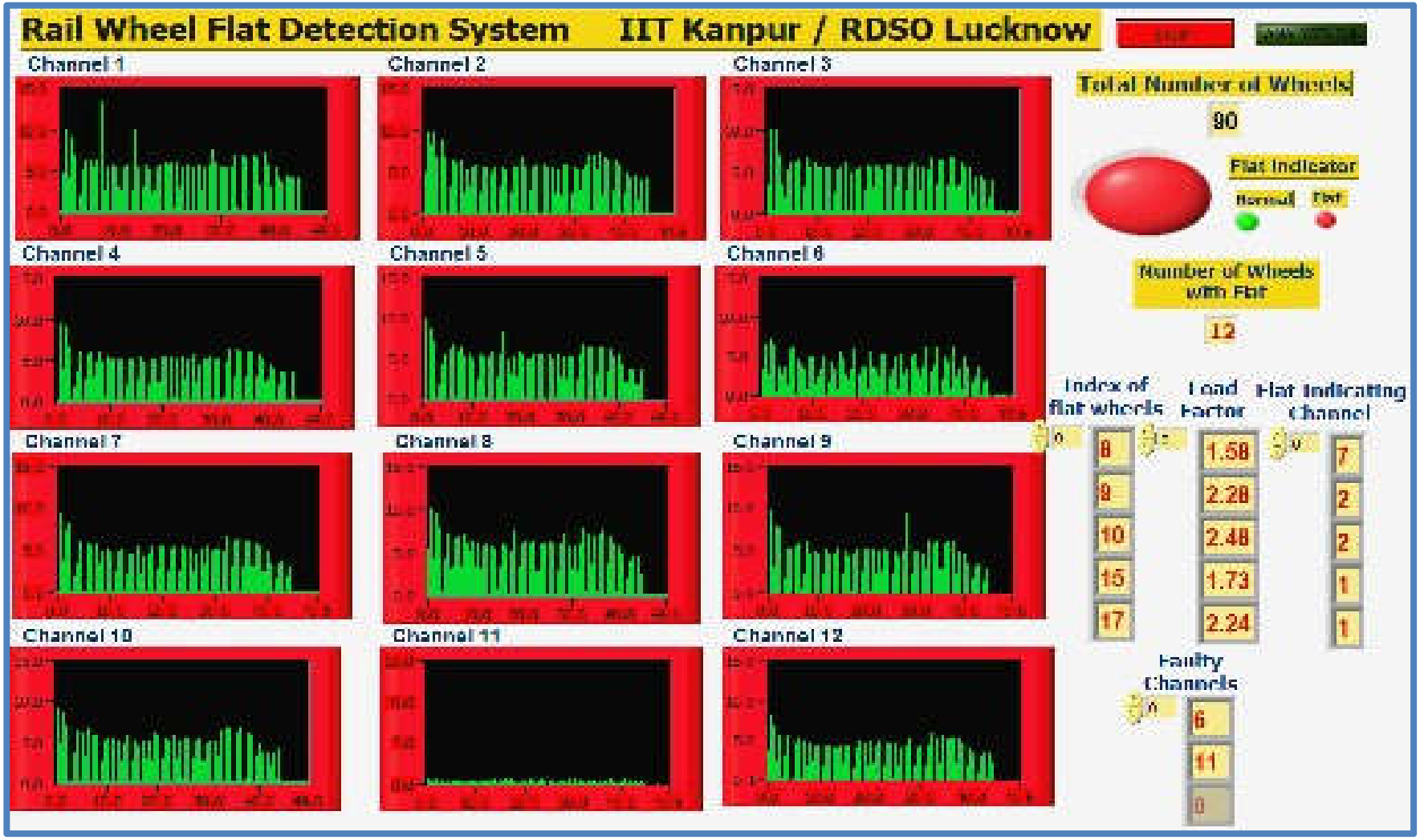
➢The features of the system was working at Ajgain are :

- Automatic data capturing & analysis
- Report Generation
- Self-Diagnostic feature
- Detection of overloaded wagons

- On-line data transfer to control office
- On-line data transfer has also been connected to RDSO's website on RailNet.

➢ **The cost of indigenous WILD system was Rs 19 lakhs approx. as against Rs 75 lakhs of imported system.**

…..Wheel Impact Load Detector (WILD) developed indigenously



Report Generated by WILD was installed at Ajgain

DATE : 27/08/2003 TIME : 9.14 Hrs.

Research Directorate

Research Designs & Standards Organisation

WHEEL-FLAT IMPACT LOAD DETECTION (WILD) REPORT

'WILD' System At Ajgain Station in Kanpur-Lucknow Section of Northern Railway

RUN No.: 27080303 TRAIN NO./NAME : **5009 Chitrakoot Express**

Axle No. (from front)	Average Normal Dynamic Wheel Load 'WN' *(Tonnes)*	Maximum Dynamic Wheel Load 'WA' Recorded *(Tonnes)*	Ratio of Maximum to Nominal Wheel Load of 12.5t	Ratio of Maximum to Average Normal Dynamic Wheel Load **(Impact Load Factor)**	Speed of Axle (Kmph)	Overloaded Wheel for Wagons : Col.(b) recording >11.5t per wheel
(a)	(b)	(c)	(d)=c/12.5	(e)=c/b		
1	10.16	13.17	1.05	1.30	97	
2	11.19	13.90	1.11	1.24	96	
3	10.47	12.74	1.02	1.22	87	
4	8.94	11.70	0.94	1.31	93	
5	8.96	11.29	0.90	1.26	88	
6	7.87	10.55	0.84	1.34	88	
7	6.80	8.26	0.66	1.22	90	
8	6.62	8.38	0.67	1.27	86	

.....Report Generated by WILD was installed at Ajgain

SUMMARISED REPORT FOR ACTION

TRAIN INFORMATION - Total Axles : 58

Engine : 1 Coach/Wagon *(8 Wheeler)* : 13 Brake Van *(4 Wheeler)* : 0

SPEED : 1st Axle : 97 kmph Last Axle : 90 kmph Average : 89 kmph

Total Number of Recorded Defective Axles (Wheels) : 1 *(Details mentioned Below)*

SL	*Alarm Label*	*Serial No. of Defective Axle*	*Wagon/ Coach position from Engine*	*Axle No. of Coach/ Wagon*	*Impact Load Factor (ILF) >1.5*	*Maximum Dynamic Impact Load/Wheel (Tonnes)*
1	*	14	2	4	1.54	10.43

Notes :	*1 :*	** or ** or *** denote defective wheels having abnormal signatures.*	
	2 :	*WA is the maximum dynamic load of wheel having abnormal signatures (Column-c).*	
	3 :	*WN is the normal dynamic load of wheel with normal signatures (Column-b).*	
	4 :	*Impact Load Factor (ILF) is the ratio of WA & WN (Column-c/Column-b).*	
	5 :	*ILF > 1.5*	*Wheel is reportedly abnormal and needs to be examined.*

.....Report Generated by WILD was installed at Ajgain

DEFECTIVE WHEEL HAVING IMPACT LOAD MORE THAN 15t

SL	*Position of wheel from engine*	*Load of defective wheel(tonnes)*
1	17	16.04
2	39	25.44

REPORT FOR OVERLOADED ROLLING STOCKS

Recorded Average Load of One Coach/Wagon = 52.72 tonne

SL	*Position of overloaded Wagon/coach from engine*	*Load of overloaded Wagon/Coach (tonnes)*
1	2	60.76
2	9	63.42

Notes:		*Overloaded Vehicle - Wagon/Coach recording more than 15 percent extra load than the average load 'WA' of each Wagon/coach of full train has been reported as overloaded wagon/coach.*

Working Channels = 11 Nos. (2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,)

Site Condition

- The system has to be installed on straight and leveled track of minimum 250m length including approaches to the site .
- There should not be any fish plated joint within 13m on either side of the instrumented portion of the track.
- There should not be any welded joint in the instrumented portion of the rail.
- Track condition should be as close to new-condition as possible.
- Rail head profile should be relatively new and sleeper/ballast interface should be stable.

…..Site Condition

- Rail used for instrumentation should be ultrasonically tested and defect free. The rail should be 52kg/m / 60kg/m with flat foot, 67mm to 74.3 mm width at head laid on Pre-stressed concrete sleepers 60-65 cm spacing with elastic fastening viz. pandrol clips on rubber grooved sole and ballast up to 300 mm deep.
- The site should not be near to any station or at the approach of a signal to avoid acceleration or braking over the instrumented rails.

Technical Details

Hardware:

The system comprises of following units :

- Two full length 52 kg/60 kg rail for instrumentation.
- Train sensor for automatic switching on&off of the system.
- Signal conditioners and amplifiers.
- 32 channel High Speed Data Acquisition System.
- 2 nos. of Pentium IV Computer with MODEM
- Reliable & dedicated telecommunication link capable of handling data transfer up to 64 KBPS.
- Uninterrupted stabilized power supply of 230 volts 50 Hz.
- 100 nos. of Rosette type strain gauges & associated wiring
- Hut at the site for installing the system

Software

- Window based software on LAB VIEW and MATLAB plat form for data acquisition, analysis and transfer.

Fixing of Threshold Limits For Wheel Detection

Recommendations Of The Committee

of

Sr.ED/Wagon, ED/Track, ED/Traffic & ED/Research

At RDSO

31st March 2005

Recommendations Of The Committee

a) Medium Alarm Level (**) :

Impact Load Factor in the range of 3.0 – 3.5 or, Wheel Impact Load 20t – 25t

- Vehicle shall be examined at the nearest major C&W examination depot/station for identification of culprit wheel and vehicle for taking any remedial action and intimation to the destination station/base for taking any remedial action by the C&W staff.

  The vehicle shall be permitted to run up to destination without any speed restriction, if nothing unusual has been noticed.

…..Recommendations Of The Committee

b) High Alarm Level (***) :

Impact Load Factor in the range of 3.5 – 4.0 or, Wheel Impact Load 25t – 30t

- In case of a **passenger vehicle** the train shall be examined at the next passenger convenient station/halt by Driver, Guard, SM/ASM and C&W staff (if available) for taking corrective action, if necessary and thereafter permit the train to move at normal speed.
- In case of **loaded goods train**, it shall be stopped at the next station and the vehicle examined by Driver, Guard, SM/ASM for physical verification of the defect and taking remedial action, if any. The loaded goods train will, however, be permitted to move up to the destination station at a suitable speed not exceeding 50 kmph and the wagon after unloading shall be examined & attended to by C&W staff.
- In case of **empty wagons**, the train will be stopped at next station for identification of culprit wheel & vehicle; communicating the same to control & base maintenance depot/nearest ROH depot enroute and would be permitted to move up to destination at a suitable speed not exceeding 50 kmph.

Recommendations Of The Committee

c) **Emergency Alarm Level (****) :**

Impact Load Factor greater than 4.0 or,

Wheel Impact Load greater than 30t

- In case of a **passenger vehicle** it shall be stopped at the next station, examined by Driver, Guard, SM/ASM and will be permitted to move at a suitable speed not exceeding 75 kmph up to next passenger convenient station for detachment.
- In case of a **loaded goods train**, it shall be stopped at the next station and examined by Driver, Guard and SM/ASM. The vehicle may be detached, if after examination any evident defect which can contribute to the high load is found, otherwise the train be permitted to move at 30 kmph maximum up to next major C&W depot for examination and repair.
- In case of **empty goods vehicle** the train may be permitted to move up to next C&W maintenance depot at a suitable speed not exceeding 50 kmph where the vehicle shall be detached for repairs.

The above mentioned alarm levels will be reviewed after two years after gaining more experience from 'WILD' System at Ajgain and new such systems to be installed on IR.

Wheel Flats permitted by various Railways

Railway	Report	Flat Length (mm)	Flat Depth (mm)
UIC	UIC 510-(2) January 1978	60mm for 630< wheel dia< 1000mm for Speeds < 160 km/h	0.9-1.4 mm
British Rail	ORE D161.1 September 1986	For bogie stock with Gross above 70t: If flat is 60-70mm, attend after completion of journey If flat is >70mm, detach stock & attend immediately	1.3 mm
MAV(Hungary)	ERRI S 1079/RP1 May 1995	If flat is 50-70 mm, test and attend subsequently If flat is > 70mm, detach &attend immediately	
BV-(Sweden)	----,,----	60mm	
CFF(Swiss)	----,,----	60mm	
PKP(Poland)	----,,----		2.0 mm

Wheel Flats permitted on Indian Railways

	Flat size	Authority
Locomotives	50mm	Clause 4.3.8.7 of MI for Co-Co bogies No. MP MI-71/78 dated July,'92
Coaches	50mm	Clause 3.2.2 of IRCA Pt IV
Wagons	60mm	Board's letter No. 86/M(N)/204/9 dated 4/3/92

Wheel flat Lengths (mm)	Corresponding depths (versions in mm)					
	Wagon		Coach		Locomotive	
	Max dia 1000mm	Min dia 906 mm	Max dia 915 mm	Min dia 813mm	Max dia 1092 mm	Min dia 1016 mm
50	0.63	0.69	0.68	0.77	0.57	0.62
60	0.90	0.99	0.98	1.11	0.82	0.89

…Wheel Flats permitted on Indian Railways

The limits laid down by Indian Railways are not only in line with international practices but are more stringent since:

- The minimum wheel diameters on IR are 915-813 mm , whereas most UIC Railways have coaching wheel diameter of 840-780mm.Thus the impact forces for wheel flats of equal length would be lower on IR Wheels.
- The axle loads are higher on these Railways leading to a correspondingly high impact force.
- Operating speeds are significantly higher as compared to IR.

Product Protyping

Prototype Details

- A prototype automated system for On-Line estimation of Wheel Impact Loads and detection of Wheel Flats of running trains was developed.
- The Instrumentation System consisting of both Hardware and Software components was then rigorously field tested at Ajgain Railway Station, between Lucknow and Kanpur for more than two years.
- Strain-Guage Technology had been employed and data was collected over 24-channels along a rail length of five meters. Intelligent software algorithms and codes have been developed and embedded into the hardware processors.

System Description - Transducers

- Rosette type Strain gauges were fixed on the two rails for measurement of vertical wheel loads.
- They were fixed on the neutral axis on the web of rails between sleeper cribs with full Wheatstone bridge configuration for each channel.
- 12 such circuits*(channels)* on each rail were used to detect the impact loads due to any portion of the defective wheel by covering two revolutions of each wheel on the instrumented *(strain gauges)* portion of the rails.
- A triggering switch was provided on the rail for triggering the system to begin data acquisition on arrival of the train over the instrumented rail.
- The Data acquisition and was done on LabVIEW platform. Signal analysis was done using MATLAB code embedded in LabVIEW.

System Description – Data Acquisition System

- The pulse from triggering switch was employed to trigger the digital recording system and the signals from transducers were sent to Data Acquisition System (DAQ) through signal conditioning cards. The system components included:
- Data Acquisition System
- Signal Conditioning System
- Triggering Switch
- Power Supply
- Other Accessories

System Description – Data Acquisition System

- System controller: Pentium-IV PC with standard/latest peripherals including modems
- Operating System: Window XP
- Application Software: NI LabVIEW 8.0, MATLAB 6.5 on Windows Platform
- Data Acquisition Card: NI PCI 6220 M, 2 DAQ cards were installed on the PC. The first DAQ card was for receiving signals from the trigger and the second one was for controlling signal conditioning module.

System Description – Data Acquisition System

- Signal Conditioning System: NI SCXI-1000 Chassis (4 Slot)
- Signal Conditioning Card: NI SCXI-1520:
  - 4 cards of 8 channels each (total 24 channels used)
  - universal strain/bridge module with mounting terminal block (4 units of NI SCXI 1314) & chassis

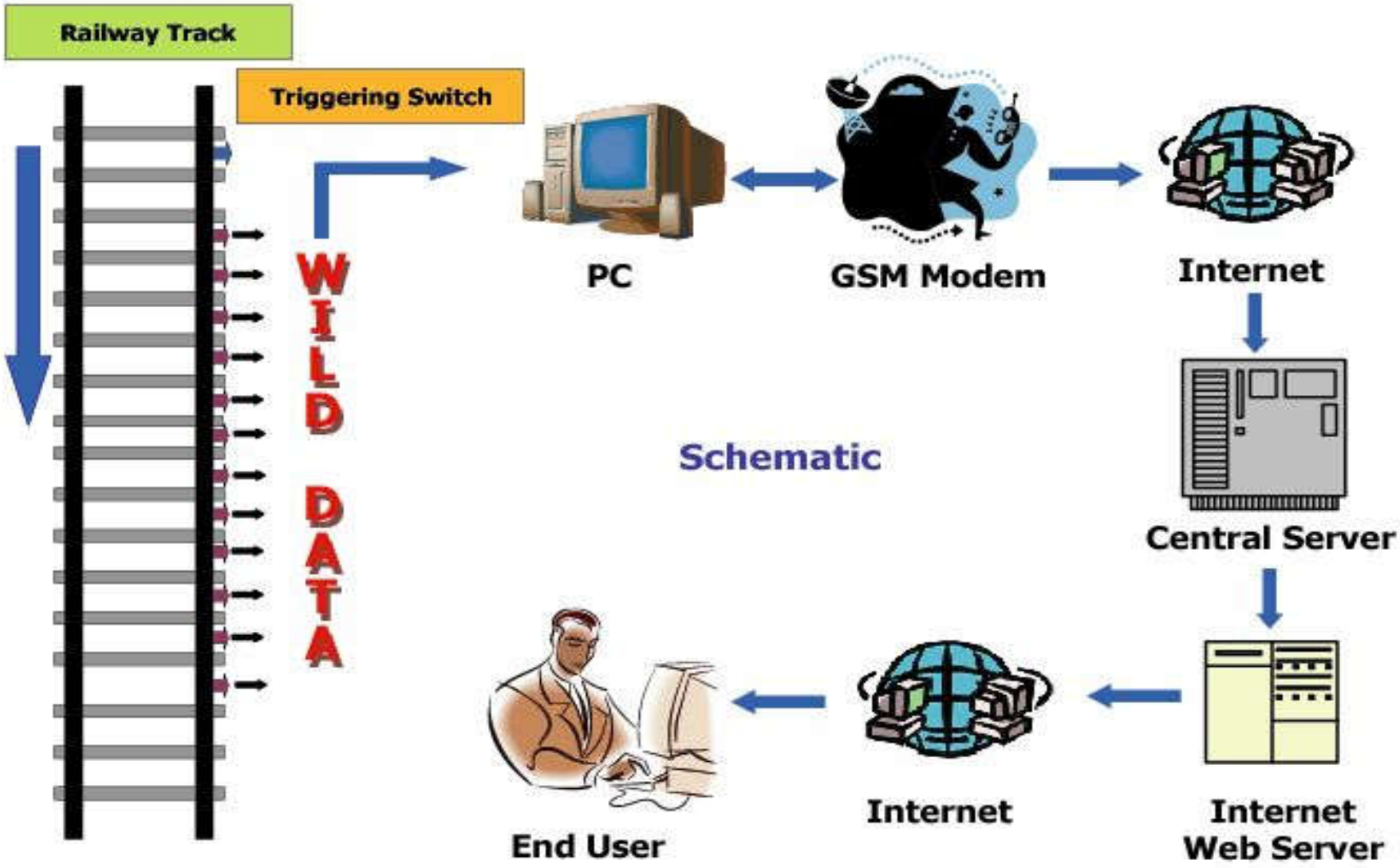
Data Acquisition Card

Signal Conditioning Card

System Description – Other Components

- Triggering Switch: A switch was used for automatic starting of the system for data acquisition when the train approaches the instrumented rail.
- Power Supply: The system will be able to operate on AC 230 V nominal, 50 Hz Single phase supply.
- Other Accessories: NI SCB Junction Box, NI SHC68-68 Cable, NI SXCI-1349 Connector, NI CB 68LP

Report Generation



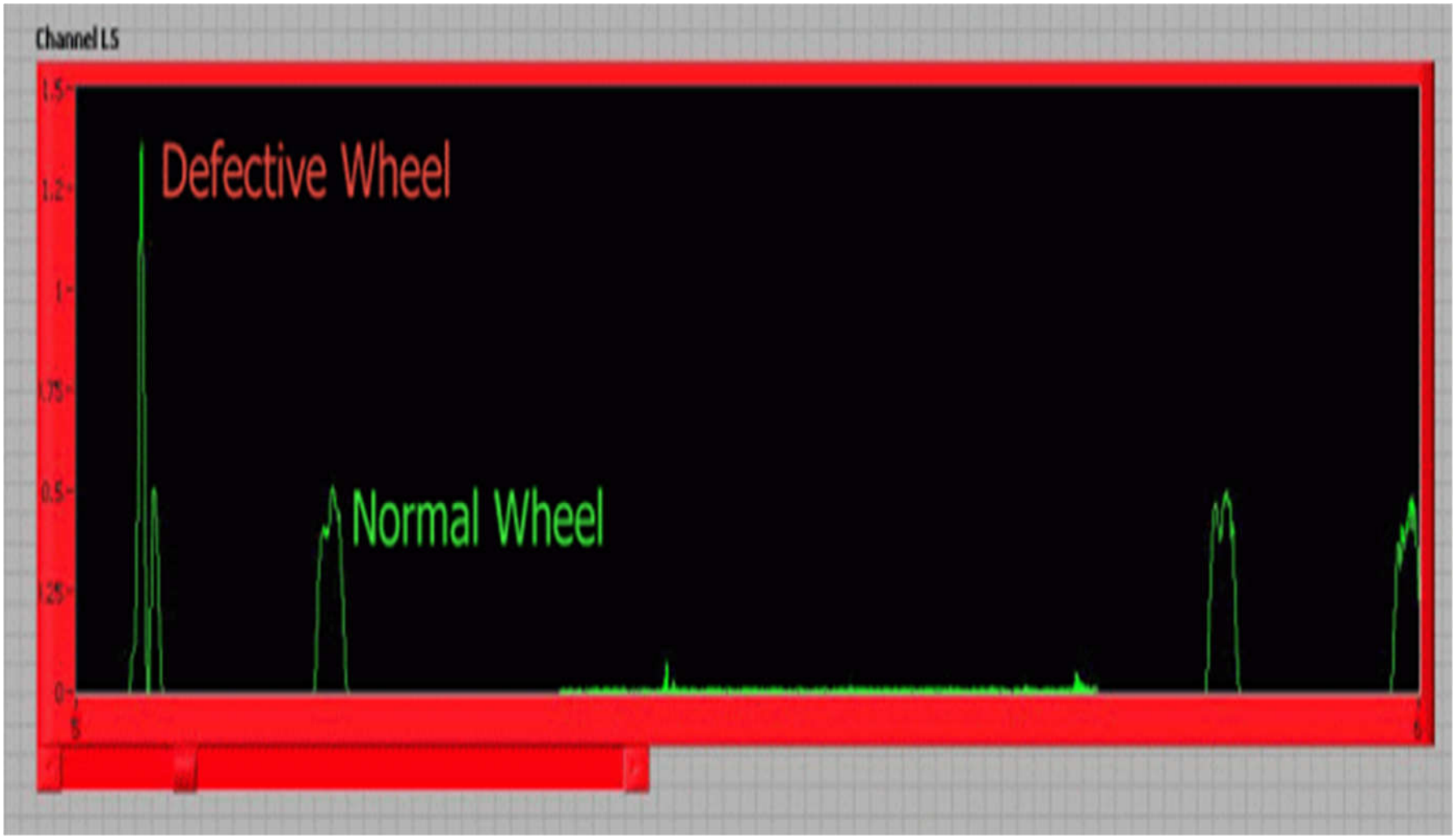
Report Generation

- The entire data of the train, after acquisition, gets processed through the sophisticated software developed indigenously on LabVIEW and MATLAB platform and the report for each train run gets generated on the PC at the WILD site with a unique run number through the computerized identification protocol.
- For on-line communication of the report of WILD system through GPRS, personal computers (PCs) with Internet connection were required in the Control Office or at the field electrical/mechanical maintenance units.
- Subsequently, the communication link from WILD site PC to control office PC could be established through railway's telephone line using dial-up mode (manually)
- Report file for the train with unique identification number was transferred from WILD PC to the Control PC or to the PCs available with the field electrical/mechanical maintenance units for examining the identified defective wheels and taking further necessary action for safe train operation.

Measuring Principle

- The WILD system developed by IIT Kanpur and RDSO employs strain-gauge technology for measurement of dynamic vertical wheel load.
- It was found that a flat wheel was indicated by an abnormal signature displaying various combinations of rail-load reduction, loss of contact and impact phenomenon within milliseconds.
- Accordingly, an algorithm based on this principle has been developed to isolate defective wheels from normal wheels.

Measuring Principle



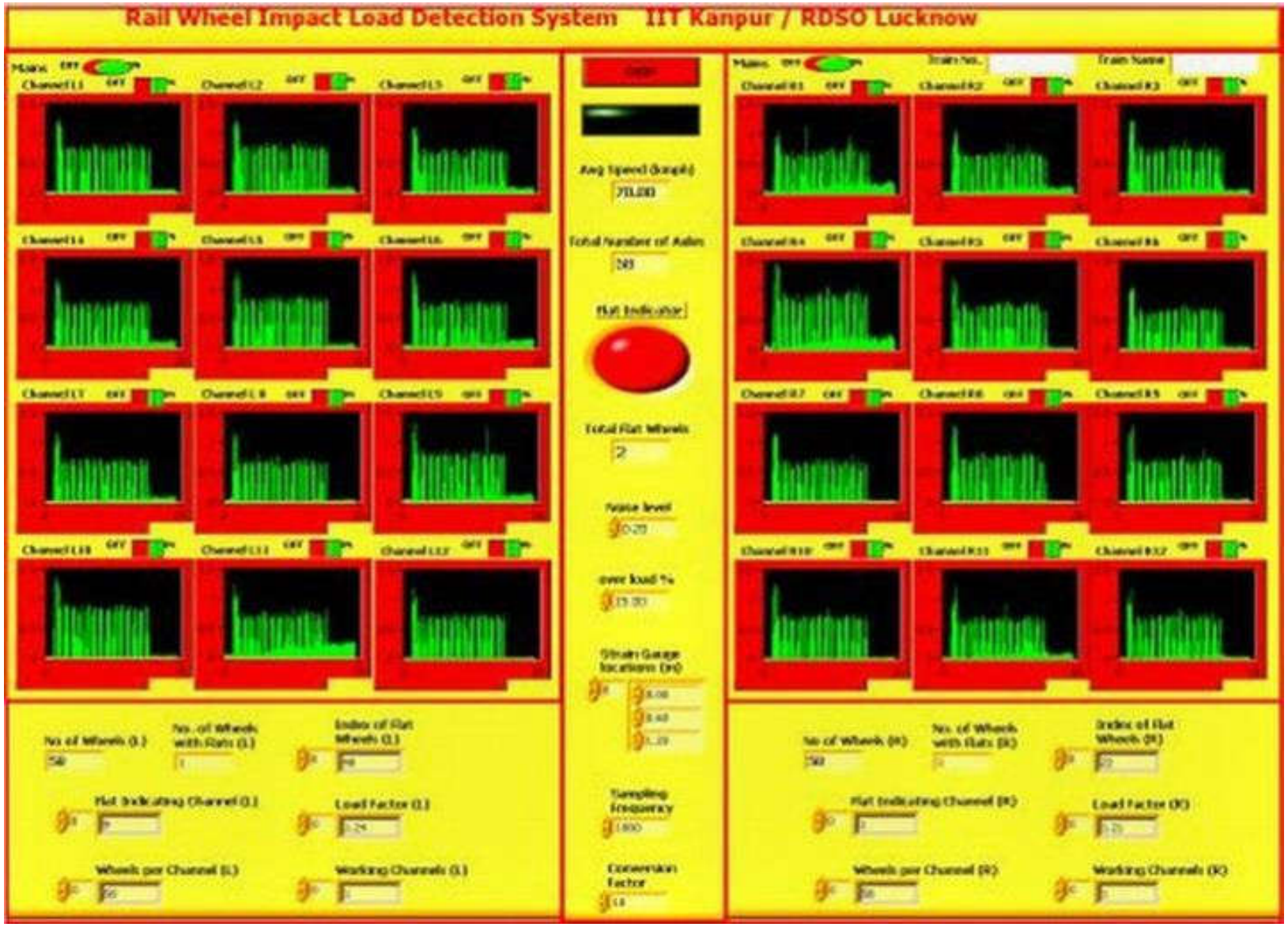
System Details - Instrumentation

Instrumented Rail

Junction Box

- The system consists of 24 channels with 12 such channels on either rail formed between consecutive sleepers lie over a rail span of about 8 meters.
- These 24 channels on the system ensure that every wheel makes at least two revolutions on the instrumented rail and the defective wheel was detected by the WILD system

Software Screenshot



Features and Facilities

- Automation of System: The system (PC) at WILD site remains in ON condition and the data acquisition begins automatically on arrival of the train as detected by the start trigger switch.
- Detection of overloaded wagons: The report was generated automatically identifies the overloaded wagons. Overloaded Wagons have been defined by RDSO as Overloaded Vehicle' - Wagon / Coach recording more than 15% extra load than the average load. 'WA' of each Wagon / Coach of full train has been reported as overloaded wagon/coach.
- On-line data transfer to control office: The communication link between computers at site and the control office/field maintenance units was established through GSM modem and the reports generated by WILD site computer were transferred on-line.

Conclusion

- The prototype testing in Ajgain provided satisfactory results to prove that Automated Defect Detection Systems such as WILD could be implemented on Indian Railways and used for improved maintenance regimes and health monitoring of Rolling Stock
- Over the past 4 years of use Indian Railways has learnt more about the utility of the system
- It has been observed in various WILD sites that the critical alarm was caused by defects other than in the wheel flats.

  – RDSO has released a list of defects on 23rd March

Thank You