Chapter 13

Track Recording System

& Track Tolerances

Document History

Issue	Date	Description
0	May 2015	First Issue

Authorised By:	
Signature:	
Date:	

TABLE OF CONTENTS

13.1 GENERAL

13.1.1 Inspection on foot, and by trolleys, locomotives and rear vehicle, enable permanent way staff to monitor the condition of railway track. Such inspections, though important, are qualitative and the assessment is subjective, base mainly on individual experience. Objective assessment of track geometry is done by the track recording car. Portable accelerometers are also sometimes used to determine the riding quality of railway track.

13.1.2 Track geometry is an extremely good indicator of general track condition but it must be noted that it is not the only measure to monitor the track condition. Poor track geometry such as wide gauge indicates rail wear condition or loss of restraint of the fastenings. A large twist could be due to formation subsidence, poor ballast condition, dipped weld or a broken joint. As poor track geometry will lead to accelerated wear of all track components and poor ride quality, it is important that the track geometry condition is monitored and kept within acceptable limits.

13.1.3 This chapter describes the details of track parameters recorded by the track recording car for monitoring the track quality. It also prescribes the standards of tolerances for each class of line.

13.2 TRACK AND OVERHEAD LINE RECORDING CAR EM120 (TORC)

13.2.1 The Track and Overhead Line Recording car EM120 (TORC) is a heavy recording and inspection vehicle combining the measuring functions of track and overhead line measurements using three two-axle bogies out of which two bogies support the recording cabin and the third bogie is placed under the driving cabin. The TORC running at a speed of up to 120km/hr, measures and electronically records and analyses any faults of the track and overhead line geometry. Its helical coil spring suspension and hydraulic shock absorbers provide the car with an optimal damping system enabling it to record track geometry at speeds up to 120km/hr. The TORC is able to negotiate curves with a minimum radius of 100m or larger.

13.2.2 Optical gauge measuring sensors are installed between the axles of the bogies, where they are permanently fixed to the measuring frames that are supported on the axle bearing boxes of the bogie axles. They are positioned so that under any condition, they will not infringe the clearance gauge.

13.2.3 The recording car has a total weight of about 50.9 tonnes.

13.2.4 **Figure 13.1** gives a profile of the EM120 Track and Overhead Line Recording Car.

13.3 TRACK PARAMETERS RECORDED BY EM120 (TORC)

13.3.1 Parameters Recorded

13.3.1.1 The EM120 TORC gives a continuous record of the following track and rail parameters.

i. Surface (unevenness) of the left rail.

ii. Surface (unevenness) of the right rail.

iii. Twist.

iv. Gauge.

v. Superelevation/Cross Level

vi. Alignment of the left rail

vii. Alignment of the right rail

The EM120 TORC is also capable of measuring the following parameters:

- Horizontal and Vertical Rail Head Wear of both rails
- Rail Inclination of both rails

13.3.1.2 The EM120 TORC also measures the following Overhead Catenary System (OCS) parameters:

i. Contact wire height

ii. Contact wire stagger

iii. Rate of change of height of the contact wire

iv. Height difference of crossing contact wires

v. Horizontal and vertical accelerations of the pantograph

vi. Catenary pole position

13.3.1.3 It also gives a continuous record of the speed. The location of kilometre posts, bridges, switches and crossings and other objects/features can be marked on the recording chart during the run.

13.3.2 Method of Recording

The manner of recording of each parameter is as follows:

13.3.2.1 Surface (unevenness) of rail

The surface or the longitudinal unevenness of rail is measured as a deviation in the vertical plane (depression or rise) of the running axle with the rigid vehicle frame serving as basis of reference. The measurement is recorded over a base of 10m. The surface of each rail is recorded independently to the scale of 1:2.

13.3.2.2 Twist

Twist is measured as a change in the cross level of track under the running loaded axles. The measurement is recorded over a base of 1.75m. Thus a twist of 3mm per meter will show a deviation of 5.25mm on the chart. It is recorded to the scale of 1:2.

13.3.2.3 Gauge

The primary element used for gauge measurement consists of three non-contact laser measuring systems, which will be fitted on all three bogies. Its deviations are recorded to the scale of 1:1.

13.3.2.4 Superelevation/Cross Level

Superelevation or Cross Level is measured as the angle between the machine's floor and a loaded running axle. The superelevation measurement consists of the difference between a signal from a gyroscope mounted in the centre of the car and a signal coming via a transducer mounted between the floor and the axle. It is recorded to a scale of 1:4.

13.3.2.5 Alignment

The alignment is measured over a base of 10m. The measurement consists of three non-contact optical laser measuring systems, fitted on all three bogies. The alignment of each rail is recorded independently to the scale of 1:2.

13.3.2.6 Rail Head Wear and Rail Inclination

Rail head wear and rail inclination are measured using an optical measuring system, which are fitted to one of the bogies.

13.3.2.7 Contact Wire Height and Stagger

For Contact wire height and Stagger measurements, a roof mounted Laser Scanner is used together with linear transducers arranged between a bogie and the vehicle frame. The pole position will automatically be determined by the roof mounted laser reflection detectors.

13.3.3 Summary and Typical Chart

The following table summarises the EM120 TORC method of measurement of track geometry parameters and the abbreviation used.

Parameter	Description	Measurement Base	Method of Measurement
L.SFCr	Profile Left Rail, i.e. Vertical surfacing	10m	Contact-transducer
R.SFCr	Profile Right Rail, i.e. Vertical surfacing	10m	
TWS	Twist	1.75m	Contact-transducer & Inclinometer
GAUGE	Track Gauge	Continuous	Contactless-Laser
SUP	Super elevation, i.e. Cross level	Continuous	Contact-transducer & Inclinometer
ALL	Alignment Left Rail, i.e. Lateral alignment	10m	Contactless-Laser
ALR	Alignment Right Rail, i.e. Lateral alignment	10m	

A typical recording chart for the various track parameters is shown in **Figure 13.2**.

13.3.4 Track Analysing System

13.3.4.1 In addition to bringing out the various track parameters in analogue form on continuous sheet of paper, the EM120 is equipped with a computerized track analysing system. This system calculates a Track Quality Index (TQI) for every measured and recorded track geometry parameter. From the TQI of individual track geometry parameters, an overall track quality index (TQI-O), is calculated, giving an assessment of the overall track condition.

13.3.4.2 The individual TQIs and the overall TQI-O are calculated for each kilometre of track recorded. A combined value for a section of track can also be computed. The following table shows a typical reading:

Typical Readings										
FROM	**TO**	**LENGTH**	***L.SFCr***	***R.SFCr***	***TWS***	***GAUGE***	***SUP***	***ALL***	***ALR***	**TOTAL TQI-O**
181.001	182.000	999	***4.73***	***4.64***	***3.52***	***5.16***	***3.19***	***9.70***	***9.35***	40.29
182.000	183.000	1000	***2.80***	***2.65***	***3.58***	***3.34***	***3.06***	***4.67***	***3.33***	23.43
183.000	184.000	1000	***2.26***	***2.35***	***3.20***	***2.37***	***2.63***	***3.56***	***2.56***	18.93

13.3.4.3 As can be seen in the last column above, Track Quality Index Overall (TQI-O) of these track-kilometre locations is the sum of all the seven individual track indices. In general, a smooth track will have a smaller value of TQI indicating a superior track geometry quality whereas a track with rough riding quality will have a high TQI.

Important Notes:

Each track parameter value printed in the seven yellow highlighted columns is 3 times standard deviation [i.e. 3σ] of the parameter variation measured over the concerned stretch of track of one km length.

±3σ value will cover 99.73% of the variations, or practically all the variations occurring in the concerned kilometre.

±2σ represents 95% coverage

±1σ represents 68% coverage of variations.

If 3σ is within the tolerance prescribed for the parameter, it means that the concerned parameter satisfies the stipulation entirely over the kilometre.

13.4 TRACK TOLERANCES

13.4.1 Requirements

Track newly constructed shall be installed within the dimensions and tolerances given in **Table T-13.1 a, b and c**. Track that is at or below the maintenance limits or maintenance tolerances stipulated shall not require any maintenance input. Track maintenance shall aim at keeping the track parameters so as not to cross the intervention limit.

If, in exceptional circumstances, the intervention limit is reached action shall be taken as quickly as practicable or in accordance to the specified timescale to restore the track to be within the maintenance tolerance. When the intervention limit is exceeded and until rectified, imposition of Speed Restriction is required as a means of precaution. The imposition of speed restrictions shall be guided by clause 13.6.6 and **Table T-13.5**. Any closure of lines, if deemed necessary by the PWI due to track geometry defects, must be informed immediately to the Regional Engineer for further action.

Track conditions shall be monitored so that deterioration trends can be analysed and ascertained for the purpose of track maintenance planning. For each site, the most compliant and practical track geometry shall be maintained.

13.4.2 Types of Track Irregularity Tolerances

Tolerances for each track parameter have been laid down for various classes of lines. For each class, tolerances have been fixed for different track conditions i.e. on installation of new tracks (installation or construction tolerance), for maintenance (maintenance tolerance) and for immediate action and emergency repairs (intervention tolerance), as described below:

13.4.2.1 **Installation (Construction) Tolerances** These tolerances relate to all newly laid track sections which will include new construction and rehabilitation or renewals. Spot renewals will not come in this category.

13.4.2.2 Maintenance Tolerances

These give the limits to which track may be allowed to deteriorate before a planned maintenance action is undertaken.

13.4.2.3 Intervention Tolerances

When these limits are reached, action shall be taken as quickly as practicable or in accordance to the specified timescale to restore the track to be within the maintenance tolerance.

These limits, if exceeded, may lead to an uncomfortable ride condition, when in combination with rolling stock defects. When the intervention limit is exceeded and until rectified, the line might require imposition of Temporary Speed Restriction or immediate closure as a means of safety protection.

13.4.2.4 **Immediate Action Limit tolerances**

This is the value, which, if exceeded, requires taking measures to reduce the risk of derailment to an acceptable level. This can be done either by reducing speed, by correction of track geometry or by closing the line.

13.4.3 Limits of Tolerances

13.4.3.1 The table at **T-13.1 a, b & c** gives the tolerances currently specified. They have been prescribed both for static measurements and dynamic measurements. An integrated summary of the tolerances for all classes of lines and the Immediate Action Limits is given in **Annexure 13.1** for easy use by field staff.

13.4.3.2 Static measurements are those which are taken when no vehicle is standing over the track (as against dynamic measurements which are recorded under moving loads). The dynamic measurements are always more than the static measurements as the rail and other track components do undergo a certain amount of displacement under load.

13.4.3.3 The track measurements recorded by EM120 TORC shall be considered dynamic measurements for taking further follow up action by senior Permanent Way Officers and the PWI.

13.4.3.4 For twist measurements on transitions of curves, the twist recorded need to be compared against the designed cant gradient for the transition portion in order to determine how much the actual twist readings are beyond the stipulated tolerance. For this purpose, the designed cant gradient must be deducted from the actual twist readings obtained from the measurements made in order to check conformance to the twist tolerances.

Table T-13.1a

TOLERANCES FOR TRACK LAYING AND MAINTENANCE

Class of Line (Ref: Chap. 10)	**Class 1** (High Speed Route, Max Passenger Train Speed 140km/hr) (All dimensions in mm, except where stated)		
Track Geometry Parameter	Limit for New Track Commencement Construction Rehabilitation	Maintenance	Intervention
1.(a) Track Gauge (static)-	± 2**	± 3	+6,-4
(b) Track Gauge (dynamic)	± 2**	+4,-3	+8,-5
(c) Variation between adjacent sleepers	2	3	4
2.(a) Cross Level (static)	2	3	6
(b) Cross Level (dynamic)	3	4	7
3.(a) Vertical Alignment (Static)	3	4	10
(b) Vertical Alignment (dynamic) (over a 10m Chord)	4	5	11
4.(a) Lateral Alignment (Static)	2	4	11
(b) Lateral Alignment (dynamic) (over a 10m chord)	4	5	10
5.(a) Twist (static) mm/m ❖	1	1.7	2.5
(b) Twist (dynamic)mm/m ❖	1.5	2.5	3.0

Legend: ** Shall be complied with regard no worn out in side wear of rail head, even during train operation.

❖ For twist tolerance, the measurement is recorded in TRC over a base of 1.75m. Thus a twist of 3mm per meter will show a deviation of 5.25mm on the EM120 chart.(3x1.75=5.25)

Table T-13.1b

TOLERANCES FOR TRACK LAYING AND MAINTENANCE

Class of Line (Ref: Chap. 10)	**Class 2** Max Passenger Train Speed 120km/hr (All dimensions in mm, except where stated)			**Class 3** Max Passenger Train Speed 100km/hr (All dimensions in mm, except where stated)		
Track Geometry Parameter	Limit for New Track Commencement Construction Rehabilitation	Maintenance	Intervention	Limit for New Track Commencement Construction Rehabilitation	Maintenance	Intervention
1.(a) Track Gauge (Static)	+2, -2 **	+6, -4	+10, -4	+2, -2 **	+6, -4	+14, -6
(b) Track Gauge (dynamic)	+2, -2 **	+10, -5	+12, -5	+2, -2 **	+10, -5	+18, -6
(c) Variation between adjacent sleepers	2	3	4	2	3	4
2.(a) Cross Level (static)	2	8	12	2	9	14
(b) Cross Level (dynamic)	3	12	16	3	13	18
3.(a) Vertical Alignment (Static)	3	8	12	3	9	14
(b) Vertical Alignment (Dynamic) (Over a 10m Chord)	6	14	18	6	16	20
4.(a) Lateral Alignment (Static)	2	8	12	3	9	14
(b) Lateral Alignment (dynamic) (Over a 10m chord)	4	14	18	6	15	20
5.(a) Twist (static) mm/m ❖	1	2	3	1	2.5	3.5
(b) Twist (dynamic) mm/m ❖	2	3	4	2	3.5	4.5

Legend:

** Shall be complied with regard no worn out in side wear of rail head, even during train operation.

❖ For twist tolerance, the measurement is recorded in TRC over a base of 1.75.Thus a twist of 3mm per meter will show a deviation of 5.25 on the EM120 chart.(3x1.75=5.25mm)

Note:

- Gauge variation shall be measured with respect to design value of Gauge; not nominal value for sharp curves and turnouts.
- Cross level difference shall be measured with respect to Level in straight track and with respect to design value of cant in curved track.
- Lateral misalignment shall be measured with respect to the base line versine on 10m chord, on curved track.
- Twist measured on transition portion of curve shall exclude the design cant gradient provided in the transition length. For twist, the measurement is recorded by the EM120 Track Recording Car over a base of 1.75m. Thus a twist of 5.25mm in the EM120 chart is equivalent to a twist of 3mm/m.

Table T - 13.1c

TOLERANCES FOR TRACK LAYING AND MAINTENANCE

(For 50km/hr Loops and 25km/hr Loops and Sidings)

Static Tolerances For Track Parameters

Parameter	Tolerance in mm		
	Installation	Maintenance (use IAL 70km/hr)	Intervention *(use IAL 30km/hr)*
Gauge (i) For new PSC sleepers (ii) For recovered PSC sleepers	(i) ± 2 (ii) ± 3	+ 15, - 6	+16, -7
Superelevation (Cross level / Cant)	± 2.5	± 15	± 16
Vertical Surfacing, over 10m chord, for each rail	± 6	± 15	± 16
Lateral Alignment, over 10m chord, for each rail	± 4	± 15	± 16
Twist, over 3.0m long base	5 (1:600)	16.5 (1:182)	18.5 (1:162)

13.5 TRACK CONTROL BY TRACK QUALITY INDEX (TQI)

13.5.1 In order to examine the general condition of track maintenance, particularly to monitor the trend of change in track geometry for maintenance planning and operation, the system of determining the track quality index (TQI) is used.

13.5.2 In the EM120 TORC recording system, the TQI for each track parameter and the overall Track Quality Index TQI-O are computed for every kilometre of track recorded, by the on-board computer. These indices indicate the condition of each individual track parameter and of the overall track, after taking into account the importance of each parameter in influencing the overall quality of track.

13.5.3 In theory, track with a TQI-O of zero indicates that the track geometrical quality in all respects is in an ideal or perfect condition.

13.5.4 Successive measurements of the overall TQI over track or route segments provide trends for diagnosis of any deterioration in track geometry. The extent of a TQI exceeding a threshold is a means to monitor the overall condition of the track. The main focus in successive track recordings is to observe whether there is an adverse or increasing trend in TQI readings above the threshold value, which indicates a general decline in overall track geometry condition. Track with a TQI exceeding the intervention limits and an adverse trend requires immediate attention by the Regional Engineer, CPWI and the PWI. An analysis of the TQI trend and the track characteristics need to be carried out to identify the underlying root cause of the trend. Rectification of the immediate causes of the deteriorating TQI trend may not result in a long term sustainment of track condition. As an example, poor track geometry due to mud pumping issues need to be addressed by improvement to the drainage and formation together with replacement of the dirty ballast with good quality ballast of adequate depth.

13.5.5 For **Class 1 line**, track quality and maintenance standard are classified for the purpose of planning maintenance work as indicated in **Table T-13.2** as follows:

Table T-13.2

Track Quality Standard for Class 1 Line

TQI-O	Track Quality
< 24	Excellent
25-32	Very Good
33-45	Good
46-60	Fair
>61	Poor

13.5.6 For **Class 2 and Class 3 line,** the classification is as shown in **Table T-13.3** as follows:

Table T-13.3

Track Quality Standard for Class 2 and Class 3 Line

TQI-O	Track Quality
< 30	Excellent
31-50	Very Good
51-70	Good
71-110	Fair
>111	Poor

13.5.7 The above classification of track quality standard is only indicative and meant to be used for judging the standards of maintenance in terms of track quality for the various PWI

sections or segments of track and for the purpose of track resources planning and maintenance management within the Permanent Way Division. Actual maintenance work to be carried out shall be based on the actual track geometry parameters as well as TQI as measured by the Track Recording Car with respect to the tolerances stated in **Table T-13.1 a, b and c** above and **Table T-13.4** below.

13.5.8 Limit for TQI of track parameters and TQI-O

The TQI for each track parameter and TQI-O for the overall track geometry are measured for each segment of track, the segment being of normally one km length. Limiting values of TQI and TQI-O are worked out as follows, based on the tolerances stipulated in **Table T–13.4** below:

Table T-13.4: TQI limit for each parameter

Track Geometry Parameter	Installation	Maintenance	Intervention
Gauge	**2**	**3.5**	**6.5**
Superelevation (Cross level/Cant)	**3**	**4**	**7**
Surfacing - right rail	**4**	**5**	**11**
Surfacing - left rail	**4**	**5**	**11**
Alignment - right rail	**4**	**5**	**10**
Alignment - left rail	**4**	**5**	**10**
Twist (on a base of 1.75m)	**2.6**	**4.4**	**5.25**
TQI-O (Sum)	**23.6**	**31.9**	**60.75**

13.5.9 In the example readings below, for km 11.0-13.0, the TQI-O is within limit of track standard. Most of the TQI parameters are in between the maintenance and intervention limits. Thus the track need to be planned for maintenance as they have exceeded the Maintenance Tolerances. Intervention action in the form of immediate rectification works or imposition of speed restriction is not yet required

Example**:**

Typical Readings										
FROM	**TO**	**LENGTH**	**GAUGE**	**L.SFCr**	**R.SFCr**	**ALL**	**ALR**	**SUP**	**TWS 1.75m**	**TOTAL TQI-O**
11.000	10.004	996	**3.44**	**6.01**	**5.55**	**6.67**	4.96	**5.16**	**5.85**	37.60
12.000	11.000	1000	**4.18**	**7.45**	**7.06**	**7.21**	**5.71**	**5.67**	**6.02**	43.27
13.000	12.000	1000	**3.32**	**5.38**	**5.58**	**6.13**	4.59	**5.69**	**5.85**	36.51

13.6 MONITORING TRACK QUALITY WITH EM 120 RECORDING CAR AND FOLLOW UP ACTION

For monitoring track quality with EM120 recording car, the following guidelines have been laid down:

13.6.1 The EM120 recording car is programmed to traverse on the track once in 3 months for Double Track Electrified Lines and 3 to 4 months for non-electrified lines. The Regional

Engineer and the section PWI shall note down the readings of the parameter TQIs and the TQI-Os of the track under their charge for every measuring run.

13.6.2 During the measuring run, the Regional Engineer, CPWI and PWI accompanying the recording car will also note the locations, where track defects exceed the intervention limits. Immediate remedial action shall be taken to rectify such track defects. Otherwise speed restrictions shall be imposed to ensure safe running. This rule applies to all classes of tracks mentioned in **Table T-13.1 a, b and c.**

13.6.3 If turnouts are located in the segment concerned, the turnout lengths may be excluded for the purpose of reckoning TQI for the segment. Further guidance are given in the High Speed Turnout (HSTo) Maintenance Manual for the purpose of monitoring and control of the quality of HSTo turnouts.

13.6.4 Repetition of track defects recorded at the same location in successive runs of TRC will indicate the need for investigation and implementation of remedial action.

13.6.5 The application of Oscillation Monitoring System (OMS) as a supplementary tool to take decision for track attention shall be in force once the Permanent Way Division has acquired the equipment.

13.6.6 **For Class 1 Line**, the following procedure shall be adhered to by Permanent Way officers in the region:

13.6.6.1 For commissioning of newly constructed track, installation tolerances shall be complied with for each of the track parameters.

13.6.6.2 The Maintenance Limit in **Table T - 13.4** signifies the standard which does not require through tie-tamping. It is the limit allowed for deterioration of track geometry before maintenance input is needed. If TQI-O exceeds this limit, through tie-tamping shall be planned to be done within **6 months (m6)** or before the track geometry reaches the **Intervention** Limit, whichever is earlier.

13.6.6.3 However, if the next track recording (carried out not later than 3 months) shows TQI-O is less than the maintenance limit, then this apparent improvement is just noted as 'scatter effect'. In this case, through tie-tamping shall be rescheduled to be carried out within **6 months (m6)** of the next recording run and the schedule to attend to the track with through tie-tamping shall be subject to the result of the next recording run.

13.6.6.4 If the track gauge exceeds the Maintenance Limit, through tie-tamping is not required and only local correction of gauge needs to be carried out.

13.6.6.5 For short stretches of track that needs levelling and lining attention, usage of heavy on-track machines may not be economical. The PWI shall arrange for spot tamping using portable hand tampers to rectify the track alignment deterioration.

13.6.6.6 However, if the density of locations that requires spot maintenance adds up to more than 10 locations per kilometre length, the PWI shall make a request to the Regional Engineer who shall make arrangement for the work to be carried out with On-track Tamper/Regulator.

13.6.6.7 When the TQI-O reading exceeds the value 61, (refer **Table T-13.4**) corresponding to Intervention limit, over a segment as recorded by the EM120 run, a maximum seven days (d7) time will be permitted to plan and attend the track over this entire segment by way of through lining and levelling by on-track tie tamper. **A speed restriction of 120km/h shall be imposed immediately**. This is not due to reason of safety but to ensure that the ride comfort limit is within an acceptable range.

13.6.6.8 If the **Intervention** tolerance for any parameter is exceeded in any isolated location as recorded in Exception Report generated by EM120 run, action shall be taken to rectify such track defect within **seven days (d7). Otherwise suitable speed restriction shall be imposed till rectification.** The quantum of speed restriction to be imposed is explained under the clauses 13.7.2, 13.7.3, 13.7.4, below, depending on whether the exceedence is beyond the **Intervention tolerance** of Class 1,Class 2 or Class 3 line. For such spot attention, off-track tampers may be used if this can serve the purpose. Depending on the spacing between the spots requiring attention and the nature of work required to rectify the parameters, through lining and levelling by on-track tie tampers may also be resorted to.

13.6.6.9 If the **Immediate Action Limits** (IAL) for any parameter are exceeded in any isolated location as recorded in Exception Report generated by EM120 TORC run, a speed restriction shall be imposed immediately and action shall be taken to rectify such track defect. Refer to **Table T-13.5** for various limits and associated speed restrictions.

13.6.6.10 The Immediate Action Limit tolerance parameters will also serve as the limiting values for permitting traffic, with the specified speed restriction when a track is restored after being damaged by a derailment.

13.6.7 Classes 2 and 3 Track

For classes 2 and 3 tracks with **TQI-O of value 51-70**, the track defects (even though they may fall within the intervention limits), shall be rectified as early as possible but not exceeding a period of 3 months **(m3)** from the date of recording**.**

13.6.8 For track with **TQI-O** of value **71-110**, immediate plan of action shall be taken by the Regional Engineer to rectify the track. An analysis of the individual track parameters that exceeds the intervention limits shall be carried out and the causes ascertained to enable appropriate remedial action to be taken. The Regional Engineer shall discuss with the Permanent Way Headquarters office regarding his proposed remedial action.

13.6.9 For track with **TQI-O** of value **111** and above, the Regional Engineer shall **impose a speed restriction of 70km/hr** for Class 2 & 3 track until the track is rectified subject to individual parameters that may warrant a lower speed restriction. The Permanent Way Headquarters office shall plan and issue instructions for the rectification work such that speed restrictions imposed may be withdrawn as soon as practicable.

13.7 TRACK PARAMETER QUALITY INDICES

13.7.1 The TQI value for each parameter shall also be considered in order to ensure total safety of the track, and the following guidelines have been laid down.

13.7.2 If the value of any of the parameter recorded in the **exception report** exceed the intervention tolerance of **Class 1 line, but not exceeding Class 2 line**, action shall be taken to rectify such track defects within **7 days (d7).** A speed restriction of **120km/h** (appropriate for Class 2 line) shall be imposed to ensure safe running until rectification of the defects is completed.

13.7.3 If the value of any of the parameter recorded in the **exception report** exceed the intervention tolerance of **Class 2 line, but not exceeding Class 3 line,** action shall be taken to rectify such track defects within **7 days (d7).** A speed restriction of **100km/h** (appropriate for Class 3 line) shall be imposed to ensure safe running until rectification of the defects is completed.

13.7.4 If the value of any of the parameter recorded in the **exception report exceed the intervention tolerance** of **Class 3 line**, **Immediate Action (IA)** shall be taken by imposing speed restriction to ensure safe running of trains. Speed restriction to be imposed shall be in accordance with the provision in **Table T-13.5.**Rectification of such track defect shall be carried out **within 24hrs to enable speed restriction to be normalized.**The track parameters to be achieved shall comply with **Immediate Actian Limet** laid down in **Table T-13.5** for the various speed.

Table T-13.5 IMMEDIATE ACTION LIMIT TOLERANCES

Track Geometry Parameter	Immediate Action Limit			
	For 100km/hr	For 70km/hr	For 30km/hr	For 10km/hr
	T_{IAL100}	T_{IAL70}	T_{IAL30}	T_{IAL10}
1.(a) Track Gauge (static)	+14, -6	+15, -6	+16, -7	+17, -8
(b) Track Gauge (dynamic)	+18, -6	+19, -7	+20, -8	+21, -9
(c) Variation between adjacent sleepers	4	5	6	7
2.(a) Cross Level (static)	14	15	16	17
(b) Cross Level (dynamic)	18	19	20	21
3.(a) Vertical Alignment (Static)	14	15	16	17
(b) Vertical Alignment (dynamic) (over a 10m Chord)	20	22	24	26
4.(a) Lateral Alignment (Static)	14	15	16	17
(b) Lateral Alignment (dynamic) (over a 10m chord)	20	22	24	26
5.(a) Twist (static) mm/3m	10.5	16.5	18.6	21
(b) Twist (dynamic) mm/1.75m	7.875	12.25	14	15.75

13.7.4.1 For track with readings that exceed maintenance limits but have not exceeded intervention limits, the track shall be planned for maintenance work to be carried out based on the rate of deterioration of the track quality. If the result of the next TORC recording (carried out not any longer than 90 days after the last TORC recording) shows no deterioration, the planned maintenance may be deferred further. Monitoring of the track quality shall however be continued. Intervention action in the form of immediate rectification works or imposition of speed restriction is not yet required.

13.8 TRACK MONITORING WITH OSCILLATION MEASURING SYSTEM (OMS)

13.8.1 Ride Quality

Ride quality can be interpreted as the capability of rail road suspension in combination with the track geometry to maintain the motion within the range of human comfort, while running at the desired/designed speed. There are several methods of determining the ride quality based on international practices and standards as described below:

1. Sperling's ride index Wz: This is a frequency weighted root mean square (r.m.s) value of accelerations evaluated over defined time intervals or over a defined track section

Sperling's Ride Index W_z	Ride Quality	Duration of Journey (Max.)
1.0	VERY GOOD	OVER 24 Hours
1.5	ALMOST GOOD	
2.0	GOOD	
2.5	NEARLY GOOD	10.0 Hours
3.0	PASSABLE	5.0 Hours
3.5	STILL PASSABLE	2.8 Hours
4.0	ABLE TO RUN	1.5 Hours
4.5	NOT ABLE TO RUN	45 minutes
5.0	DANGEROUS	15 minutes

A Wz value of 2.5 is often compared to ISO weighted r.m.s. acceleration value of 0.25m/s2. This value is often considered as acceptable for ride comfort on trains with respect to motions and vibrations.

2. Based on European standard EN- 12999: 1999 by the following:

i) A simplified method based on measurement of acceleration on the floor termed as NMV.

ii) A complete method based on measurement of acceleration at the interface between passengers and the vehicle (termed as N_{VA}, N_{VD}).

Based on the simplified method, the lateral and vertical mean comfort index (N_{MV}) is used to categorise ride comfort levels as follows:

N_{MV}	Ride Comfort
$N_{MV} < 1.5$	Very comfortable
$1.5 \leq N_{MV} < 2.5$	Comfortable
$2.5 \leq N_{MV} < 3.5$	Medium
$3.5 \leq N_{MV} < 4.5$	Uncomfortable
$4.5 \leq N_{MV}$	Very uncomfortable

3. Based on **ISO 2631**, ride comfort levels for individual lateral and vertical directions are described in the following table. The levels are the same for the lateral as well as the vertical directions.

α^{wrms} = *rms* values of frequency-weighted accelerations on the vehicle floor.

α^{wrms} (m/s^2)	Ride Comfort
$\alpha^{wrms} < 0.2$	Very comfortable
$0.2 \leq \alpha^{wrms} < 0.3$	Comfortable
$0.3 \leq \alpha^{wrms} < 0.4$	Medium
$0.4 \leq \alpha^{wrms}$	Less comfortable

13.8.2 Considering the above, the following table may be adopted for KTMB use:

Vehicle	Preferable	Limit
Coach/Train-set	0.25 m/s^2	0.30 m/s^2
Locomotive	0.30 m/s^2	0.35 m/s^2

13.8.3 Portable Oscillation Measuring System (OMS) recorder shall be used as a supplementary tool for measuring the riding quality of track on a **3-month interval** and to take decisions on maintenance actions. The portable Oscillation Measuring System recorder is kept on the floor of a locomotive cabin or as far as practicable placed in the last coach of a fast train as close to the pivot of the bogie, as much as possible. It is preferable that same coach or locomotive is used in the successive runs to enable comparison with previous recordings. The monitoring of the accelerations is done at the floor level but the acceleration values will be higher at the seat level although the level of comfort also depends on the seat design as well as extent and type of restraint to the passengers. The perception of ride comfort will also be different for standing passengers.

13.8.4 The OMS recorder measures track ride quality by measuring the vehicle response to vibrations in terms of the accelerations both in vertical and lateral directions. The real time output is in terms of value of peaks exceeding a predefined limiting value of acceleration that can be translated into degree of passenger comfort.

13.8.5 During recordings by the OMS recorder, the CPWI/PWI responsible for the section of track shall accompany the recording run to identify locations of high priority defects and to arrange the necessary maintenance actions. In the absence of the Track Recording Car, the frequency of OMS recordings may be suitably increased.

13.8.6 Rating of Track Quality based on OMS readings:

The track in the Region or a PWI section is rated as “Very good”, “Good” or “Average” based on the peaks of accelerations exceeding 0.25m/s2 as per criteria below.

Rating	Reading
Very Good	No. of peaks exceeding 0.25m/s^2 is less than 1 per Km
Good	No. of peaks are between 1 and 2 per Km
Average	No. of peaks are more than 2 per Km

13.8.7 Action required

If the number of peaks of vertical and lateral accelerations exceeding 0.25m/s^2 are more than 1 in any Km or an average of 0.25 per Km in any section, the track requires maintenance action to be done no longer than 30 days after the recording. If the peaks at any location exceed 0.30m/s^2 the same shall be attended urgently (Priority 1) in not more than 24 hrs after the recording.

13.9 PRIORITIES FOR MAINTENANCE

(Refer to Ch. 38: Track Maintenance Operations)

Priorities for maintenance are defined in accordance to the Track Quality Indices and the track parameters measured, as follows:

CLASS 1 LINE	
Category of Priority	**Track Condition**
Priority 1	I. Where safety is endangered and/or Immediate Action Limits are reached. II. Portions of track that falls with TQI-O exceeding 60 and/or Vertical and Lateral Acceleration exceeds 0.3 m/s^2 and / or Ride Index exceeding 3.0. III. Locations of track where individual track parameters exceeded the Intervention Limits for their Class of Line.
Priority 2	I. Portions of track that falls with TQI-O exceeding 31 and up to 60. II. Locations of track where track parameters exceeded the Maintenance Limits for their Class of Line and / or Vertical and Lateral Acceleration between 0.25 m/s^2 and 0.3 m/s^2 and/or Ride Index between 2.5 and 3.0. III. Track segments requiring repeated attention.
Priority 3	I. Portions of track that falls with TQI-O of 30 or less. Locations of track where track parameters exceeded the Maintenance Limits and/or Vertical and Lateral Accelerations are less than 0.25 m/s^2 and/or Ride Index less than 2.5.

Note: Any condition I, II or III may apply.

CLASS 2 LINE AND LOWER	
Category of Priority	**Track Condition**
Priority 1	I. Where safety is endangered/Immediate Action Limits are reached. II. Portions of track that falls with TQI-O exceeding 100 and/or Vertical and Lateral Acceleration exceed 0.3 m/s^2 and/or Ride Index exceeding 3.0. III. Locations of track where track parameters exceeded the Intervention Limits for their Class of Line.
Priority 2	I. Portions of track that falls with TQI-O exceeding 71 and up to 100. II. Locations of track where track parameters exceeded the Maintenance Limits for their Class of Line and/or Vertical and Lateral Acceleration between 0.25 m/s^2 and 0.3 m/s^2 and/or Ride Index between 2.5 and 3.0. III. Track segments requiring repeated attention.
Priority 3	I. Portions of track that falls with TQI-O exceeding 61 and up to 70. II. Locations of track where track parameters exceeded the Maintenance Limits for their Class of Line and/or Vertical and Lateral Accelerations are less than 0.25 m/s^2 and/or Ride Index less than 2.5.

Note: Any condition I, II or III may apply.

13.10 LIST OF FIGURES

13.11 LIST OF ANNEXURES

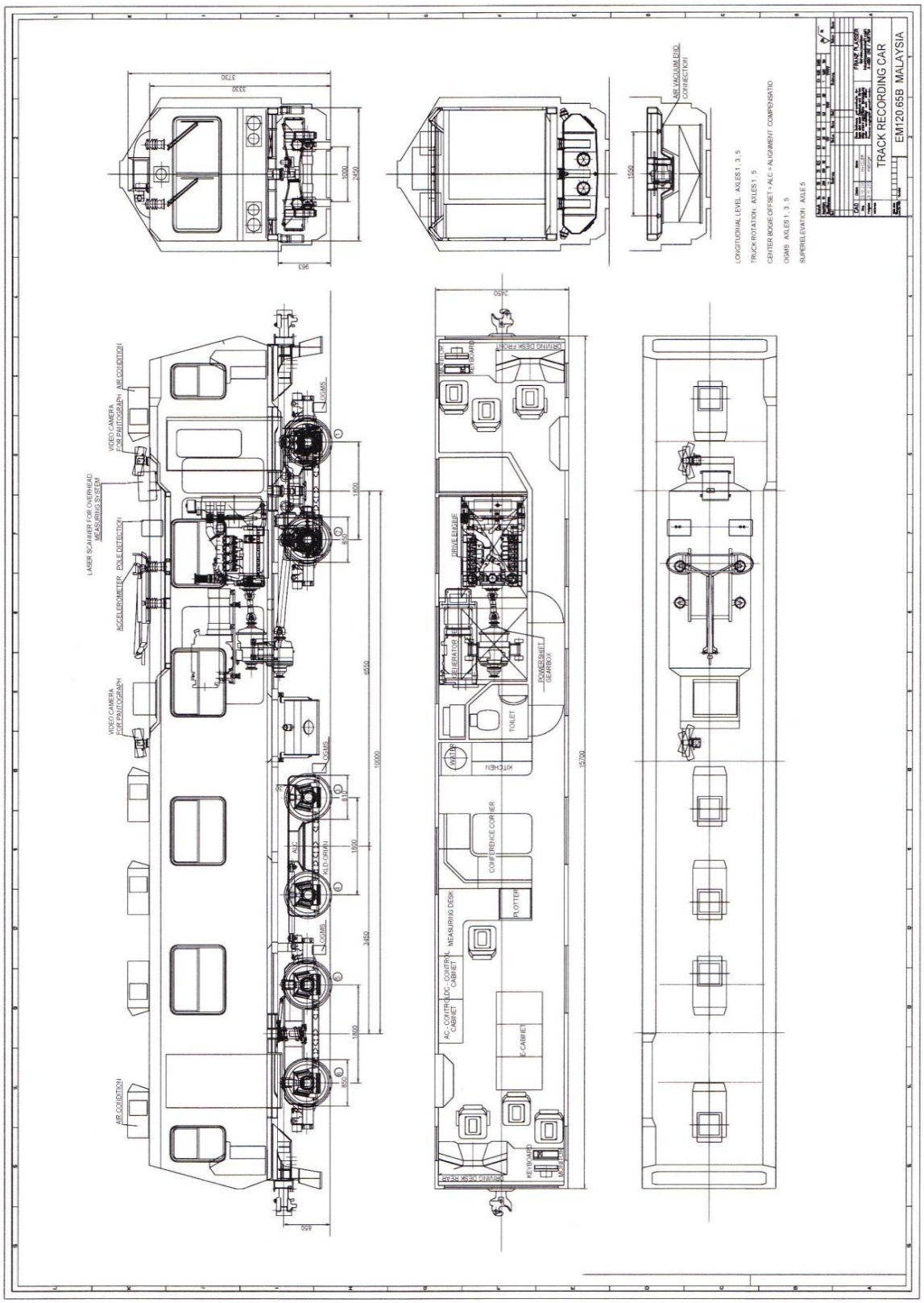
TRACK RECORDING CAR
EM120.65B MALAYSIA
AIR VACUUM EXH. CONNECTION
LONGITUDINAL LEVEL : AXLES 1, 3, 5
TRUCK ROTATION : AXLES 1, 5
CENTER BOGIE OFFSET + ALC + ALIGNMENT COMPENSATIO
OGMS : AXLES 1, 3, 5
SUPERELEVATION : AXLE 5
VIDEO CAMERA FOR PANTOGRAPH
AIR CONDITION
LASER SCANNER FOR OVERHEAD MEASURING SYSTEM
POLE DETECTION
ACCELEROMETER
VIDEO CAMERA FOR PANTOGRAPH
OGMS
ALC
AIR CONDITION
OPERATORS DESK FRONT
DRIVE ENGINE
TRANSMISSION
POWERSHIFT GEARBOX
TOILET
KITCHEN
CONFERENCE CORNER
PLOTTER
MEASURING DESK
AC - CONTROL CABINET
LDC - CONTROL CABINET
E-CABINET
KEYBOARD
OPERATORS DESK REAR

Figure 13.1 - Schematic View of the Track and Overhead Recording Car EM 120

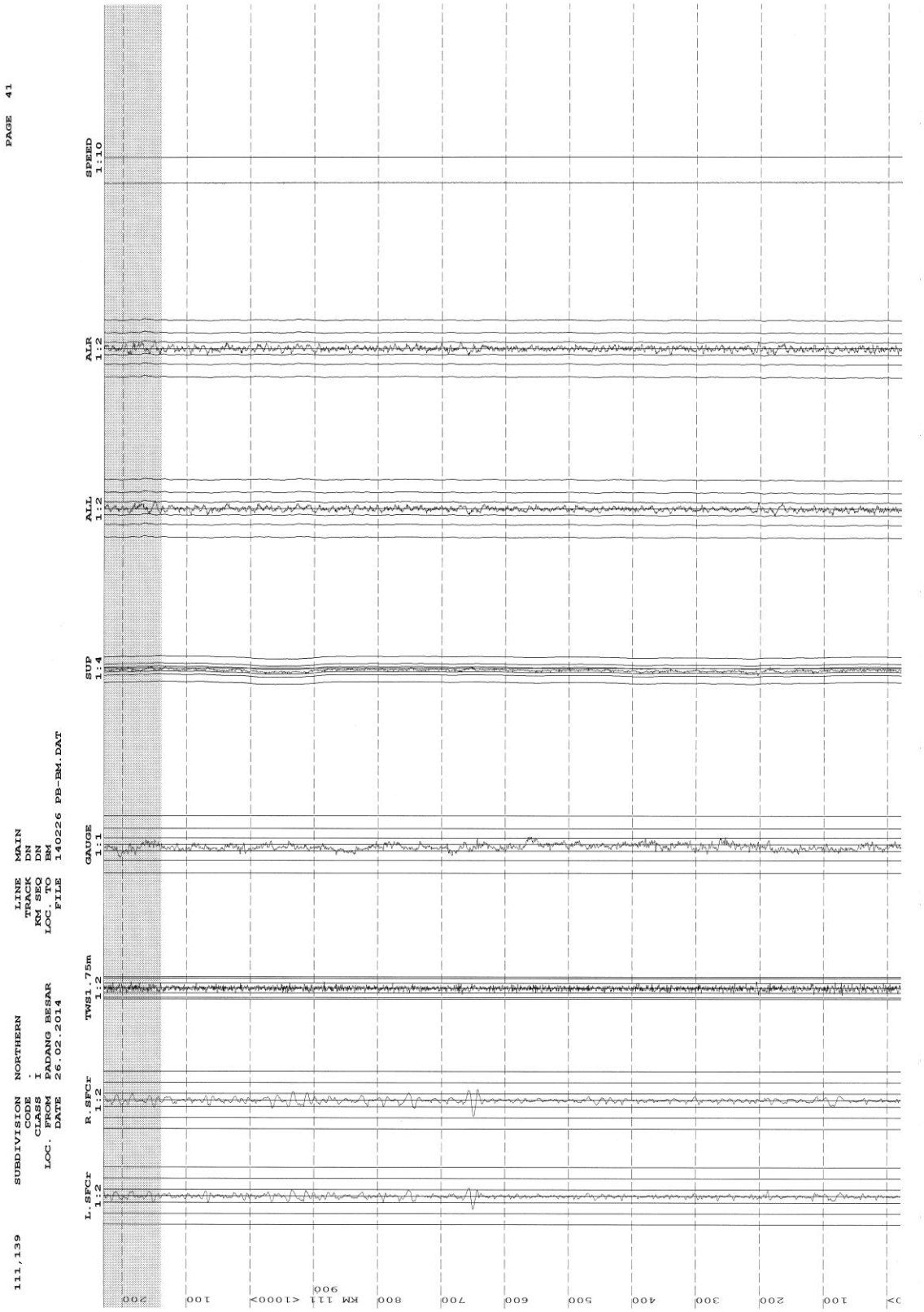

Figure 13.2 - Typical chart Recording Chart

EXCEPTION REPORT PAGE 99

112,147 SUBDIVISION NORTHERN LINE MAIN
CODE . TRACK DN
CLASS I KM SEQ DN
LOC. FROM PADANG BESAR LOC. TO BM
DATE 26.02.2014 FILE 140226 PB-BM.DAT

TRK	--FROM-- KM M	--TO-- KM M	LENGTH M	PARAMETER	MAXIMUM EXCEPTION VALUE	LOCATION	CLASS EXC	SEV	SUBCLASS
DN	112,149	112,148	1	TIGHT GAUGE	-3	112,149	I	N/A	A
DN	112,145	112,142	2	WIDE GAUGE	3	112,144	I	N/A	A
DN	112,139	112,135	4	WIDE GAUGE	3	112,138	I	N/A	A
DN	112,134	112,127	7	WIDE GAUGE	4	112,131	I	N/A	A
DN	112,113	112,111	2	WIDE GAUGE	3	112,112	I	N/A	A
DN	112,82	112,81	1	WIDE GAUGE	3	112,81	I	N/A	A
DN	112,74	112,72	2	WIDE GAUGE	2	112,73	I	N/A	A
DN	112,72	112,71	2	PROFILE LEFT	5	112,71	I	II	A
DN	112,72	112,71	2	PROFILE RIGHT	5	112,71	I	II	A
DN	112,66	112,64	1	PROFILE RIGHT	-4	112,65	I	II	A
DN	112,37	112,35	2	WIDE GAUGE	2	112,36	I	N/A	A
DN	112,16	112,14	2	WIDE GAUGE	2	112,15	I	N/A	A
DN	112,5	112,1	3	WIDE GAUGE	2	112,4	I	N/A	A
DN		112,0		KM 112 <1000>					
**T3.0*	113,0	112,0	1000	(GAUGE 2.58)(L.SFCr 2.82)(R.SFCr 3.44)(ALLr 3.66)(ALRr 4.25)(SUPr 2.71) (TOTAL 22.26)					
**M **				(GAUGE 0.29)					

SUMMARY TRACK	*--FROM-- KM M*	*--TO-- KM M*	*LENG*	*CLASS=I LENGTH'COUNT*	*LENGTH'COUNT*	*LENGTH'COUNT*
DN	*113,0*	*112,0*	*1000*	*A*	*B*	*C*
		WIDE GAUGE		*30'13*	*0'0*	*0'0*
		TIGHT GAUGE		*3'2*	*0'0*	*0'0*
		ALIGNMENT LEFT		*4'3*	*0'0*	*0'0*
		ALIGNMENT RIGHT		*10'4*	*0'0*	*0'0*
		PROFILE LEFT		*2'1*	*0'0*	*0'0*
		PROFILE RIGHT		*3'2*	*0'0*	*0'0*
		SUPERELEVATION		*5'1*	*0'0*	*0'0*
		TWIST 1.75		*0'0*	*0'0*	*0'0*

DN	111,922	111,920	1	WIDE GAUGE	3	111,921	I	N/A	A
DN	111,919	111,896	23	WIDE GAUGE	4	111,913	I	N/A	A
DN	111,895	111,893	2	WIDE GAUGE	2	111,894	I	N/A	A
DN	111,555	111,553	2	WIDE GAUGE	2	111,555	I	N/A	A
DN	111,482	111,481	1	WIDE GAUGE	2	111,481	I	N/A	A
DN	111,413	111,412	1	TIGHT GAUGE	-3	111,413	I	N/A	A
DN	111,383	111,380	3	WIDE GAUGE	3	111,381	I	N/A	A
DN	111,375	111,373	2	WIDE GAUGE	3	111,374	I	N/A	A
DN	111,346	111,343	2	WIDE GAUGE	2	111,344	I	N/A	A
DN	111,337	111,333	5	WIDE GAUGE	3	111,337	I	N/A	A
DN	111,324	111,322	3	WIDE GAUGE	3	111,323	I	N/A	A
DN	111,293	111,291	2	WIDE GAUGE	3	111,292	I	N/A	A
DN	111,207	111,196	11	WIDE GAUGE	4	111,202	I	N/A	A
DN	111,193	111,191	2	WIDE GAUGE	3	111,191	I	N/A	A
DN	111,187	111,186	1	ALIGNMENT RIGHT	4	111,186	I	II	A
DN	111,181	111,179	2	WIDE GAUGE	3	111,180	I	N/A	A
DN	111,150	111,149	2	ALIGNMENT LEFT	-5	111,150	I	II	A
DN	111,151	111,148	3	ALIGNMENT RIGHT	-6	111,150	I	II	A
DN	111,51	111,50	1	WIDE GAUGE	2	111,50	I	N/A	A
DN	111,48	111,47	1	WIDE GAUGE	2	111,48	I	N/A	A
DN	111,17	111,15	1	WIDE GAUGE	3	111,16	I	N/A	A
DN	111,9	111,6	3	WIDE GAUGE	3	111,8	I	N/A	A
DN		111,0		KM 111 <1000>					
**T3.0*	112,0	111,0	1000	(GAUGE 2.64)(L.SFCr 3.08)(R.SFCr 3.65)(ALLr 3.05)(ALRr 3.71)(SUPr 2.49) (TOTAL 21.30)					
**M **				(GAUGE 0.76)					

Figure 13.3 - Exception Report

KEY:

DN	Dn Line
112,149 112,148	Defects at KM 112,149 to 112,148
1	Defects length = 1 meter
TIGHT GAUGE	Tight Gauge (Parameter)
-3	Defect Value
112,149	KM at maximum value
I	Class of Line (Class I)
N/A	Not Applicable (exceeded all classes I, II and III)
A	Maintenance Tolerance
SEV	Severity

Figure 13.4 – Understanding The Exception Report
(First row reading of Fig.13.3)

13.12 Annexure 13.1 – Extract of Tolerances for PWI Action and Intervention

Class of Line (Ref: Chap. 10)	**Class 1** (High Speed Route, Max Passenger Train Speed 140km/hr) (All dimensions in mm, except where stated)			**Class 2** Max Passenger Train Speed 120km/hr (All dimensions in mm, except where stated)			**Class 3** Max Passenger Train Speed 100km/hr (All dimensions in mm, except where stated)			**IMMEDIATE ACTION LIMITS**			
Source	**Table T-13.1a**			**Table T-13.1b**			**Table T- 3.1c**			**Table T-13.5**			
Track Geometry Parameter	New Track Commencement Construction Rehabilitation	Limit for Maintenance	Intervention	New Track Commencement Construction Rehabilitation	Limit for Maintenance	Intervention	New Track Commencement Construction Rehabilitation	Limit for Maintenance	Intervention	**For 100km/hr**	**For 70km/hr**	**For 30km/hr**	**For 10km/hr**
	T_{NC}	T_{MP}	T_{IV}	T_{NC}	T_{MP}	T_{IV}	T_{NC}	T_{MP}	T_{IV}	T_{IAL100}	T_{IAL70}	T_{IAL30}	T_{IAL10}
1.(a) Track Gauge (static)	±2	±3	+6,-4	+2, -2	+6, -4	+10, -4	+2, -2	+6, -4	+14, -6	+14, -6	+15, -6	+16, -7	+17, -8
(b) Track Gauge (dynamic)	±2	+4,-3	+8,-5	+2, -2	+10, -5	+12, -5	+2, -2	+10, -5	+18, -6	+18, -6	+19, -7	+20, -8	+21, -9
(c) Variation between adjacent sleepers	2	3	4	2	3	4	2	3	4	4	5	6	7
2.(a) Cross Level (static)	±2	±3	±6	2	8	12	2	9	14	14	15	16	17
(b) Cross Level (dynamic)	±3	±4	±7	3	12	16	3	13	18	18	19	20	21
3.(a) Vertical Alignment (Static)	3	4	10	3	8	12	3	9	14	14	15	16	17
(b) Vertical Alignment (dynamic) (over a 10m Chord)	4	5	11	6	14	18	6	16	20	20	22	24	26
4.(a) Lateral Alignment (Static)	2	4	11	2	8	12	3	9	14	14	15	16	17
(b) Lateral Alignment (dynamic) (over a 10m chord)	4	5	10	4	14	18	6	15	20	20	22	24	26
5.(a) Twist (static) mm/3m	3	5.1	7.5	3	6	9	3	7.5	10.5	10.5	16.5	18.5	21
(b) Twist (dynamic) mm/1.75m	2.625	4.375	5.25	3.5	5.25	7	2	6.125	7.875	7.875	12.25	14	15.75

Notes:
1. For values exceeding T_{IAL10}, action is at the discretion of the Regional Engineer.
2. Measurement base for Twist in section 5 are shown to the standard field measurement base or EM120 measurement base as a factor of the mm/m values shown in **Table T-13.1** for the convenience of field staff and ready application.
3. The table is for use when attending individual TQI parameter readings and not for overall reckoning of TQI-O.
4. For value $\mathbf{T_{NC}}$, Gauge reading Class1, Class 2 and Class 3, shall be complied with regard no worn out in side wear of rail head, even during train operation.

13.13 Annexure 13.2 Track Maintenance instructions based on the TORC chart and the derived data - summarized in the following table for easy comprehension at a glance.

Class 1 line				
I. Instructions Based on TQI value for individual parameter over a segment (1km length)				
Condition warranting action	Speed restriction to be imposed	Time set for rectification	Action to be taken	Objective & ref to the clause in the Manual
TQI > Maintenance tolerance, <intervention tolerance	Not specified	Not specified	Plan for maintenance work based on rate of deterioration .If next recording shows no deterioration defer planned maintenance	Good Riding quality Clause 13.7.4.1
II. Instructions Based on TQI-O value over a segment (1km)				
TQI-O>32 & < 61 (Exceeding Maintenance limit & within Intervention limit)	Nil	6 months or before TQI-O exceeds 61 (Intervention limit)	Through tamping planned to be done in 6 months. If next recording within 3 months shows the TQI-O within maintenance limit reschedule tie tamping work	Good Riding quality Clauses 13.6.6.2 13.6.6.3, 13.6.6.4
Only Gauge tolerance exceeding Maintenance limit	Not specified		Regauging . through tamping not required	Good Riding quality Clause 13.6.6.4
TQI-O>61 i.e. Intervention limit	120kph	7 days	Through lining and leveling of entire segment	clause 13.6.6.7
III.. Based on Exception Report on individual track parameter values at isolated locations				
Intervention tolerance of Class1 exceeded but not of Class 2	120 km/ hr	7 days	Action as appropriate at the identified locations	Safety clause 13.6.6.8
Intervention tolerance of Class2 exceeded but not of Class 3	100 km/ hr	7 days		Safety clause 13.7.3
Intervention tolerance of Class 3 exceeded	Speed Restriction As per Table T-13.5	24 hrs		Safety clause 13.7.4
Immediate action tolerance exceeded				Safety clause 13.6.6.9

> means *exceeding* , < means *less than or falling within*

13.14 Annexure 13.3 – Track Maintenance instructions based on the TORC chart and the derived data - summarized in the following table for easy comprehension at a glance

Class 2 & Class 3 lines				
Condition warranting action	Speed restriction to be imposed	Time set for rectification	Action to be taken	Objective & ref clause in Manual
I Instructions Based on TQI value of individual parameter over a segment (1km length)				
TQI > Maintenance tolerance < intervention tolerance	Not specified	Not specified	Plan for maintenance work based on rate of deterioration .If next recording shows no deterioration defer planned maintenance	Riding quality clause 13.7.4.1
II. Instructions Based on TQI-O value over a segment (1km)				
TQI-O 51-70 Values Less than Intervention limit	nil	3 months	Track defects to be rectified	Safety clause 13.6.7
TQI-O -71 to110	nil	Immediate plan of action	Individual track parameters exceeding Intervention limits to be attended to	Safety clause 13.6.8
>111	70 km/hr individual parameters may need lower speed restriction	Not specified	HQ office shall plan and issue instructions	Safety clause 13.6.9
III. Based on Exception report on individual track parameter values at isolated locations.				
Intervention tolerance of Class2 exceeded but not of Class 3	100 km/ hr	7 days	Rectify defects	Safety clause 13.7.3
Intervention tolerance of Class 3 exceeded Immediate action tolerance exceeded	Speed restriction As per Table T-13.5	24 hrs	Immediate rectification of defects	Safety clause 13.7.4

> means *exceeding*, < means *less than or falling within*