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सत्यमेव जयते

भारत सरकार – रेल मंत्रालय
अनुसंधान अभिकल्प और मानक संगठन
लखनऊ – 226011
Govt. of India - Ministry of Railways
Research, Designs & Standards Organization,
LUCKNOW - 226011

No. EL/3.1.35/26 Dated: As signed

Principal Chief Electrical Engineers;

- Central Railway, HQs Office, 2nd floor, Parcel Office Bldg., Mumbai – 400 001
- East Central Railway, Hajipur (Bihar) – 844 101
- Eastern Railway, Fairlie Place, Kolkata – 700 001
- East Coast Railway, Railway Complex, Bhuvneshwar – 751 023
- Northern Railway, Baroda House, New Delhi – 110 001
- North Central Railway, Allahabad – 211 001
- North Eastern Railway, Gorakhpur –273 001
- North Western Railway, near Jawahar Circle, Jaipur–302 017.
- North-East Frontier Railways, Maligaon, Guwahati – 781 011
- Southern Railway, Park Town, Chennai – 600 003
- South Central Railway, HQs Office, Rail Nilayam, Secunderabad – 500 071
- South Eastern Railway, Garden Reach, Kolkata – 700 043
- South East Central Railway, Bilaspur – 495 004
- South Western Railway, Hubli – 580020
- West Central Railway, HQs Office, Opp. Indira Market, Jabalpur – 482 001
- Western Railway, Churchgate, Mumbai – 400 020
- Banaras Locomotive Works, Varanasi – 221004
- Chittaranjan Locomotive Works, Chittaranjan – 713331 (WB)
- Patiala Locomotive Works, Patiala – 147 003

Technical Circular No. RDSO/2018/EL/TC/0145, Rev.1

1.0 Title:

Technical Circular for Interchangeability and Maintainability of Hall Effect Speed Sensors provided in IGBT based 3-phase electric locomotives.

2.0 Introduction:

Presently, Indian Railways is manufacturing four classes of 3-phase electric locomotives viz. WAG9, WAG9H, WAP7 andWAP5. Under the ToT from M/s ABB, Indian Railways received the technology to manufacture 3-Phase locomotives with GTO based traction and auxiliary converter and MICAS based VCU. Now CLW had discontinued the production of GTO based locomotive and have switched over to manufacturing of 3-Phase locomotives with IGBT based traction converter and auxiliary converter. Till now approximately 950 nos. of IGBT based locomotives have been turned out.

Slip/slide control is very important feature of the 3-phase locomotives which is implemented through complex algorithms in control software of traction converter. The rotational speed of the Traction Motor (TM) is accessed through speed sensor in 3-phase locomotives. The traction converter processes the speed signals received from the respective TM and detects the differentials between the speed signals from different TMs and calculates the slip/slide using complex slip/slide detection algorithm.

The OEM design was making use of the passive Wiegand based speed sensors. In this sensor, there was no need to give power supply to the Wiegand based sensors hence called passive speed sensor. The photograph of Wiegand based speed sensor is shown in Figure – 1.

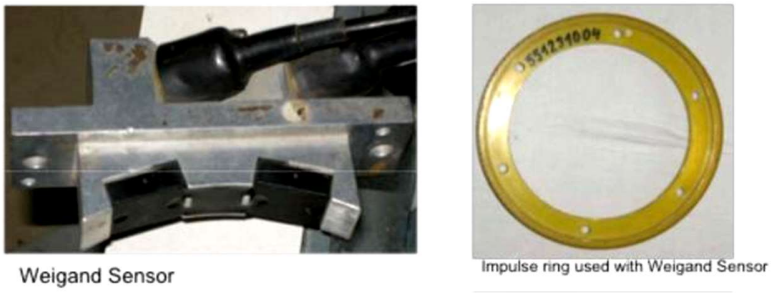


Figure – 1: Wiegand based passive speed sensor

These sensors had their own drawbacks, therefore, Indian Railways decided to switch over to Hall Effect based active speed sensors which have better and reliable signal characteristics. At present in GTO locomotives, mostly Hall Effect based active speed sensors of M/s Advance Rail Control (ARC) are being used however in IGBT based locos, Hall Effect speed sensors of M/s ARC, Jaquet, Leonard Bauer, Laxven, Baumer etc. makes are being used.

3.0 Objective:

Presently, IGBT based traction converters are being manufactured and supplied by M/s ABB, BHEL, BTIPL, CGL and Medha. Different manufacturers are providing different type and make of speed sensors in which they are providing different type of connectors, e.g., (5+3) pins, (5+5) pins and 8 pins.

The objective of this Technical Circular is to make the speed sensors interchangeable among the different make IGBT based traction converters and suggest maintenance practices to improve the reliability of speed sensors.

4.1 Working principle of Wiegand Speed Sensor:

Wiegand sensors are used as a pulse generator in multiple applications. The sensor needs no external power source and has no moving parts. Instead, it exploits the properties of a small Wiegand diameter wire.

When a magnetic field changes the magnetic state of the Wiegand wire within the sensor, a substantial output pulse is produced which can be used as a power source in an energy self-sufficient revolution counter.

Sensors are assembled using SMD mounting technology and can be used for revolution counters in absolute rotary encoders as well as in other applications, e.g. gas or water meters.

The Wiegand effect technology employs the unique magnetic property of specially processed, small ferromagnetic wire. John Wiegand discovered a way to cause the magnetic field of this specially processed wire to suddenly reverse. When the magnetic field of this wire, called a Wiegand Wire, is reversed a sharp uniform voltage pulse is generated. The pulse is referred to as a Wiegand Pulse and is used to measure the speed.

4.2 Working principle of Hall Effect Speed Sensors:

A typical Hall Effect Sensor has three wires or terminals – one for ground, one for supply or reference voltage and one for the output signal. To produce an output signal, a Hall Effect Sensor must be supplied with a reference voltage from the vehicle's on board computer (which may be 5 to 30 volts depending on the application). The supply voltage is necessary to create the switching effect that takes place inside the sensor. Hall Effect refers to the phenomenon that when an electric current is applied to a piece of metal inserted between two magnets, it creates a secondary voltage in the metal at a right angle to the applied voltage.

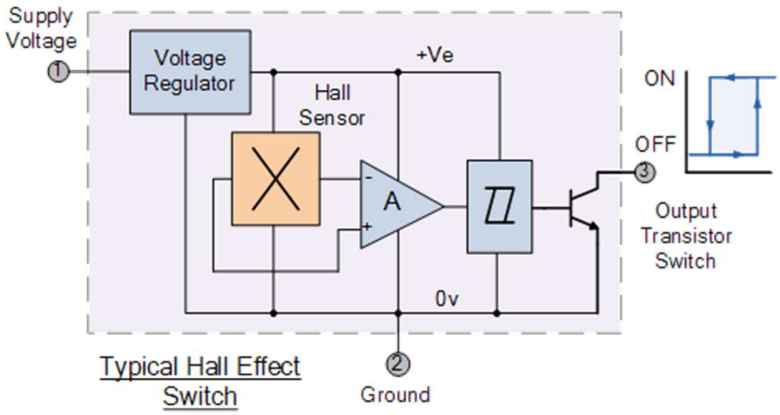


Figure – 2: Typical Hall Effect Sensor

A Hall Effect speed sensor produces an on-off square-wave voltage signal from a silicon chip (Hall Element) placed at a right angle to a magnetic field. When a metal gear wheel teeth passes through the air gap between the magnetic field and silicon chip, it blocks the magnetic field and causes the chip's output voltage to suddenly drop to zero. With additional circuitry, the sensor can be made to do just the opposite i.e. to produce a voltage signal when the teeth enter the magnetic field. Additional circuitry regulates the supply voltage to the chip and amplifies its voltage output.

A Hall Effect Sensor may be normally "on" or "off" depending on how its circuitry is designed. The normally "on" variety produces a steady voltage output when the magnetic window is unobstructed and no teeth are passing through it. The voltage output drops to near zero when a tooth enters the magnetic window and blocks the field. The normally "off" varieties work in the opposite manner. When the teeth passes through the window

and blocks the magnetic field, the sensor's internal electronics switch the sensor's output signal from near zero (off) to maximum voltage (on).

In 3-phase locomotive, the teeth gear wheel is mounted on the Non-Driving End (NDE) side of TM rotor and the speed sensor on the frame as shown in Figure-3 below.

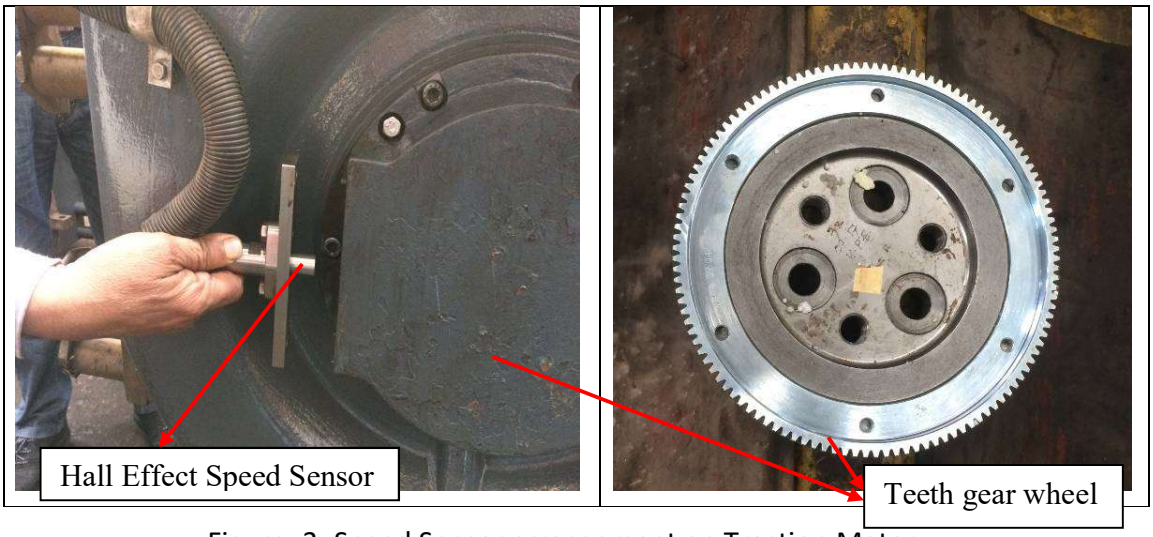


Figure -3: Speed Sensor arrangement on Traction Motor

In IGBT based 3-phase locomotives, the IGBT converter supplies 15 volt from Drive Control card of the converter. The schematic of the speed sensor is given below in Figure – 4:

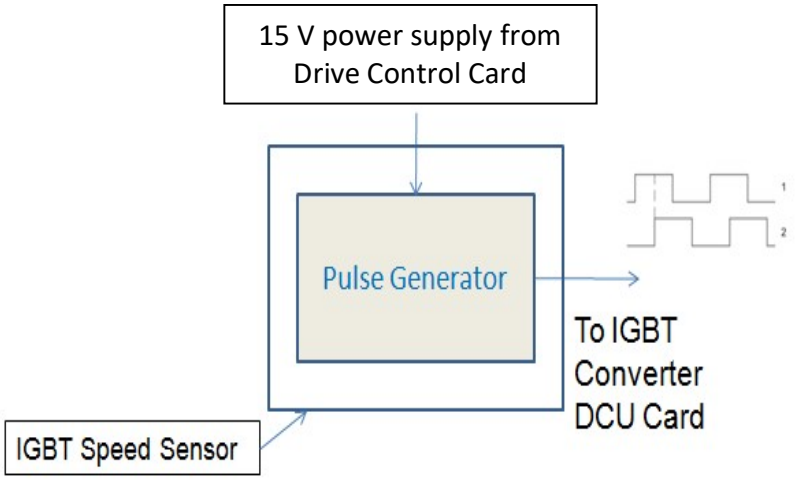


Figure – 4: Schematic of Speed Sensor

The speed sensor used in E-Loco project uses dual output for sensing the direction. These sensors produce two square wave outputs at 90º phase shift. Depending on which output signal is leading, the direction of rotation is determined. The speed of rotating is proportional to the frequency of output signal.

5.0 Different type of speed sensors used in locomotives:

5.1. The different types of speed sensor being used in 3-phase locomotives are shown below:

SN	Photograph of Speed Sensor	Details
1.		Type of loco - IGBT Make: Leonard Bauer Connectors: (5+3) pins Teeth gear wheel: 120 teeth 
2.		Type of loco - IGBT Make: Leonard Bauer Connectors: (5+5) pins Teeth gear wheel: 120 teeth (population is very low and not being used in new locos) 

3.		Type of loco - IGBT Make: ARC Connectors: (5+3) pins Teeth gear wheel: 120 teeth 
4.		Type of loco - IGBT Make: Lenord Bauer Connectors: (5+3) pins Teeth gear wheel: 200 teeth (BTIPL make) 
5.		Type of loco - GTO Make: ARC (Single Channel) Connectors: (5+5+3) pins Teeth gear wheel: 120 teeth (population is very low and not being used in new locos) 

6.		Type of loco - GTO Make: ARC (Dual Channel) Connectors: (5+5+3) pins Teeth gear wheel: 120 teeth 
7.		Type of loco - GTO Make: ARC (External Power Supply) Connectors: (5+5+3) pins Teeth gear wheel: 120 teeth 
8.		Type of loco - GTO Make: AAL Connectors: (5+5+3) pins Teeth gear wheel: 120 teeth 

9.		Type of loco – GTO Make: Laxven Connectors: (5+5+3) pins Teeth gear wheel: 120 teeth 

5.2. Speed sensors were not standardized initially, hence manufacturers had adopted different configuration such as M/s BTIPL has used one cable with 8 pin connector and M/s ABB and M/s BHEL have used two cables with 5, 5 pin connectors initially. The speed sensors (5, 5 pin connectors) were provided initially in approx. 30 locomotives.

5.3. Subsequently CLW has standardized the configuration as two cables with 5 & 3 pins connectors (Signal connector – 5 pins circular connector & power supply – 3 pin circular connector). Presently ARC, Lenord Bauer, Jaquet and Laxven make speed sensors are of two cables with 5, 3 pins connectors. The speed sensors have now been standardized in specification of IGBT based traction converter of CLW. Speed sensor shall be supplied as per CLW specification No. CLW/ES/03/0528 dated Nov'12.

5.4. Different type of speed sensors used in IGBT based 3-phase locos are summarized below:

SN	Make of Traction Converter	Sensor Make	No. of pin in connector	Nos. of teeth in Teeth gear wheel
1.	ABB	ARC	5 + 3	120
		Jaquet	5 + 3, 5 + 5	120
		Lenord Bauer	5 + 3	120
2.	BTIPL	Lenord Bauer	8, 5 + 3	200
3.	BHEL	ARC	5 + 3	120
		Jaquet	5 + 3	120
		Lenord Bauer	5 + 3	120
4.	CGL	Jaquet	5 + 3	120
5.	Medha	Jaquet	5 + 3	120

6.0 Interchangeability of Speed Sensors

6.1. All type of speed sensors used in IGBT based 3-phase locomotives is mounted on the Non-Driving End (NDE) side of TM rotor and the speed sensor on the frame as shown in Figure-3 above. Mainly there are two parts of the speed sensors which may be considered for interchangeability point of view. They are –

i) Types of Circular connectors:

Mostly (5+3) pins Circular connectors are being used by the traction converter manufacturers. 5 pins Circular connector is used for signal transmission (2 pins A, B for output signal and rest 3 pins C, D, E are spare), whereas another 3 pins Circular connector is used for power supply (pin A is +ve 10-30 volts, pin B is -ve and pin C is spare). Details are shown in annexure-1 which also indicates the sensor plate for (5+3) pin connector configuration.

Circular connectors are shown in Figure – 5 below:

Figure – 5: Circular connectors (5, 3) pins

However, some of the IGBT based traction converter manufacturers are also using Circular connectors having (5+5) pins which were used in a few locomotives prior to the standardization of speed sensor carried out in May 2013. BTIPL is using a different configuration which has 8 pins connector.

ii) Nos. of teeth in teeth gear wheel.

Except M/s BTIPL, all other IGBT based traction converter manufacturers are using Teeth gear wheel having 120 teeth however the teeth profiles are quite different in different makes. Only M/s BTIPL is using Teeth gear wheel having 200 teeth. Photographs of teeth gear wheel of 120 & 200 teeth are shown below:

120 Teeth gear wheel used by all manufacturer except M/s BTIPL

Figure – 6.1

200 Teeth gear wheel used by M/s BTIPL

Figure – 6.2

6.2. Recommendation:

a) Speed sensors having (5+3) pins Circular connectors along with Teeth gear wheel having 120 teeth are interchangeable in Traction Motor of 3-phase locomotives. However, it is

also recommended that make of speed sensor and Teeth wheel should be kept same as Teeth profile of different make can differ which may lead false data input/missing pulses at higher speed.

b) Locomotive equiped with BTIPL make traction converter shall only use BTIPL make speed sensors.

c) All speed sensors with 5+5 pins connectors to be converted to 5+3 pins connectors speed sensors as and when possible, scheme is indicated in para 6.1(i) of this TC.

7.0 Maintenance Practices followed by sheds

7.1 As far as the maintenance of the speed sensors by the shed are concerned, the shed do not have much role than to check the speed sensor tooth wheel direction on the test jig (when phase 2 lags, it should be anticlockwise and when phase 2 leads it should be clockwise) and to maintain the air gap between the sensor and the tooth wheel. It is recommended that the test jig should have VVVF drive so that the functionality of the speed sensors can be checked throughout the entire range of operation. A test jig of ELS/TKD for testing of speed sensor is shown in figure – 7 below.

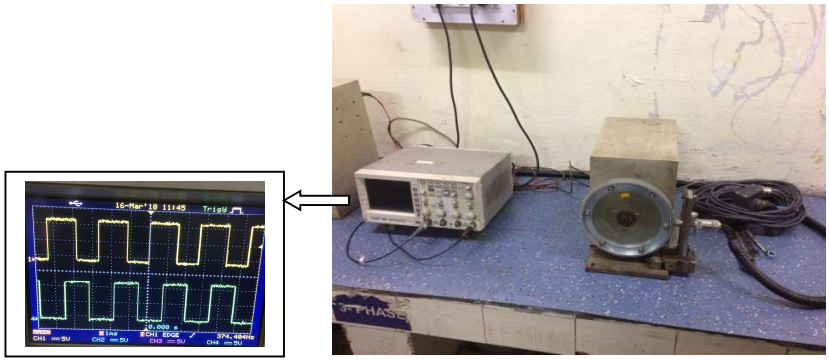


Figure – 7: Test jig for Speed Sensor

7.2 Pulse pattern of speed sensors received to IGBT based traction converer is shown in figure – 8 below. IGBT based Traction converter receives control power supply from the rack, and the speed signal is in the form of two, 90˚ phase shifted square pulses, mostly open collector type. The phase lag (90˚) between these pulses will determine the direction of rotation of the motor, which is resolved by the converter electronics. This means, in one direction, if pulse S1 lags pulse S2 by 90˚, in the opposite direction, pulse S2 will lag pulse S1 by 90˚. Also, it provides only one signal channel, as both the pulses together becomes one channel.

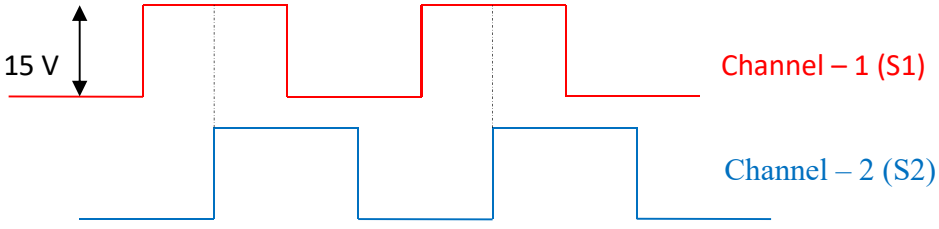


Figure – 8: Pulse Pattern of Speed Sensor

7.3 **Maintaining the air gap:** The Railways need to maintain the air gap not more than 1.8 mm (desirably 1.5 mm). However, it has been observed that speed sensors being provided in ALSTOM make propulsion system are highly sensitive and requires air gap in the range of 0.4 to 1.0 mm. Northern Railway vide letter No. 230-Elect/TRS/92/2/13 dtd. 06.05.2024 informed that ELS/GZB has developed a Digital Bore Gauge for maintaining desired air gap. The details of Digital Bore Gauge are as given below:

(i) Tool Overview:

Digital bore gauge consists of flat surface, a screw and depth meter which may be seen in Figure-9. The Technical Specification of digital bore gauge is as given below:

SN	Descriptions	Details
1.	Gauge Range	0-23 mm
2.	Resolution/least count	0.1 mm
3.	Weight	0.21 kg
4.	Tip width	10 mm
5.	Battery	3 Volt
6.	Dimensions	As per Annexure-1

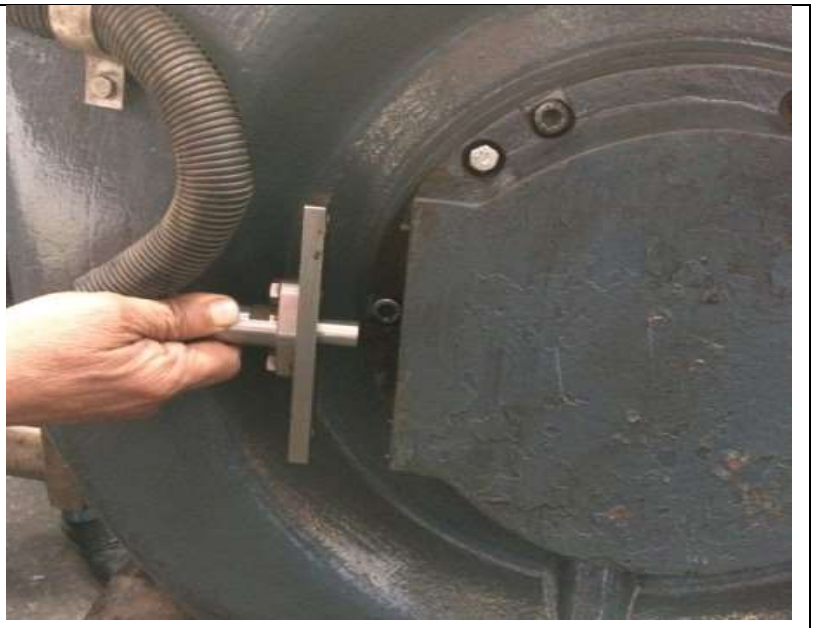


Figure – 9: Air gap measurement

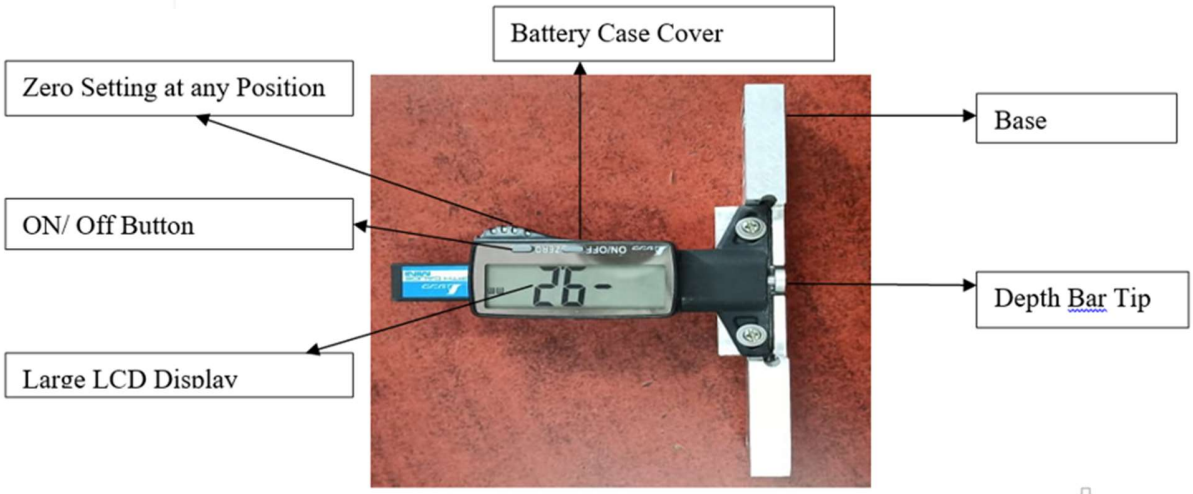


Figure – 9: Digital Bore Gauge

(ii) **Installation and Setup:**

- Place Digital Bore Gauge on a calibrated flat surface and set its reference to '0.0mm' which is displayed in Figure – 10 & 11 below:

Figure – 10: Digital Bore Gauge on a calibrated flat surface

Figure – 11: Calibrated flat surface

- Take speed sensor whose air gap is to be measured and place Digital Bore Gauge in such a way that Digital Bore Gauge base is rest on speed sensor probe and screw of Digital Bore Gauge matches with the speed sensor base by pressing movable part of Digital Bore Gauge displayed in Figure – 12.
- Now, set tip of sensor as reference by pressig 'Zero' button on gauge as shown in Figure – 13.

Figure – 12: Measuring the speed sensor probe.

Figure – 13: Set the tip of sensor as reference.

- Place Digital Bore Gauge on surface of grease cup where speed sensor is to be installed and tightened digital bore gauge meter properly with the help of screw.
- Slightly press movable part of Digital Bore Gauge meter, till it is not moving any further. In this step, note reading displayed on gauge screen. Reading shown on screen is the Measured Air Gap.

Figure – 14: Installed and Tightened Digital Bore Gauge.

Figure – 15: Reading shown on screen is 'Measured Air Gap'.

-sd-
for Director General/Elect.

Copy to:

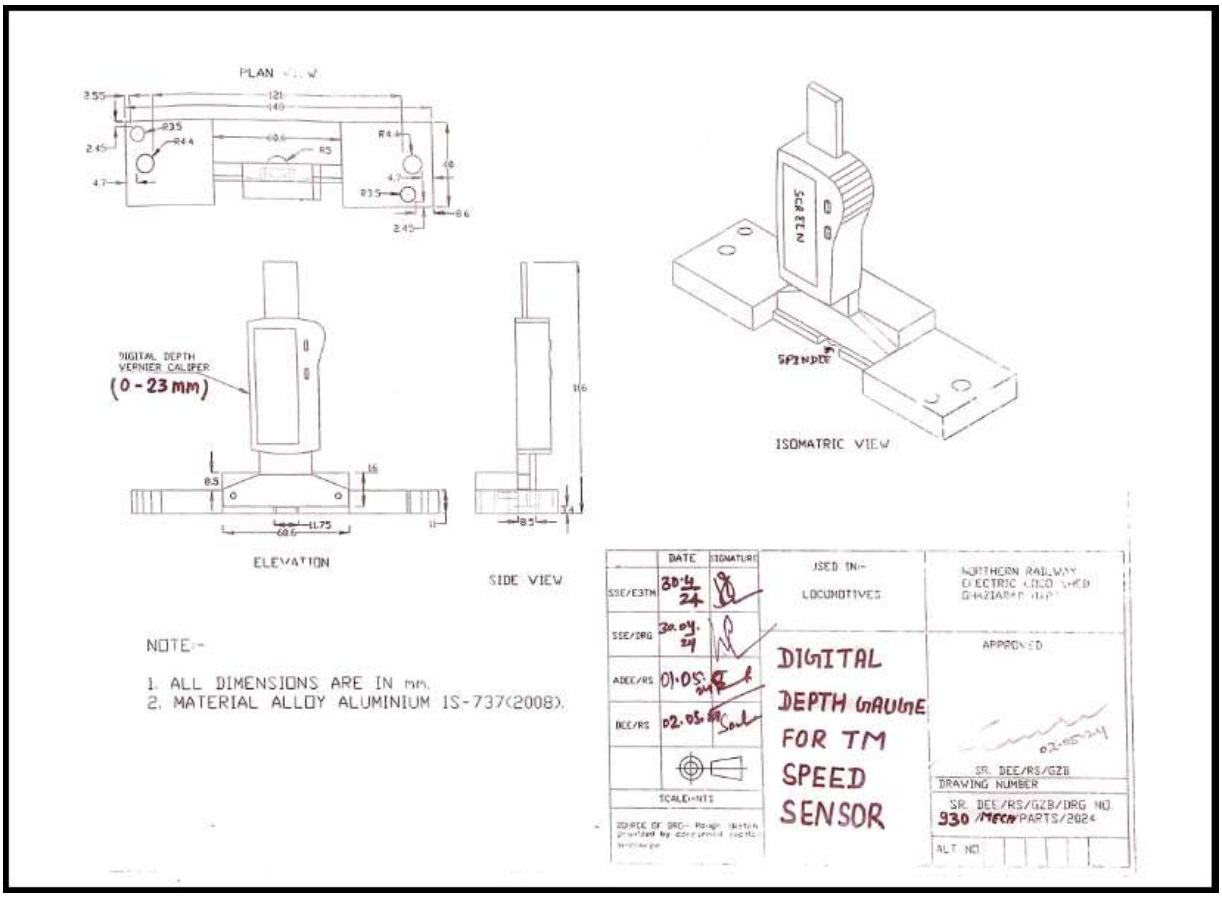
Secretary (Electrical), Railway Board, Rail Bhawan, New Delhi – 110001	: For kind information please.

Digitally Signed by Amit Kumar Saraf
Date: 21-08-2024 15:22:28
Reason: Approved

Encl: as above

for Director General (Elect.)

Annexure-1


PLAN
DIGITAL DEPTH VERNIER CALIPER (0-23 mm)
ELEVATION
SIDE VIEW
SPINDLE
ISOMATRIC VIEW
NOTE:-
1. ALL DIMENSIONS ARE IN mm.
2. MATERIAL ALLOY ALUMINIUM IS-737(2008).
DATE
SIGNATURE
SSE/E3TM
SSE/DRG
ADEE/RS
DEE/RS
USED IN:-
LOCOMOTIVES
NORTHERN RAILWAY
APPROVED
DIGITAL DEPTH GAUGE FOR TM SPEED SENSOR
SR. DEE/RS/GZB
DRAWING NUMBER
SR. DEE/RS/GZB/DRG NO.
930 /Mech PARTS/2024
SCALE=NIS
ALT NO