METROLOGY

User Manual

EZSPEED CALIBRATOR

Transforming the World of Metrology one Device at a Time

Document version control

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Legal

From time to time we may present updated versions of this document in order to make corrections, clarifications, or other changes. These updated versions will supersede any earlier versions of the document.

METROLOGY

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1. Getting Started

Before using the device please go through the user manual instructions carefully.

The EZSpeed Calibrator is used to calibrate the EZSpeed device to confirm repeatability, reproducibility, accuracy, and precision of the EZSpeed device.

1.1. Precautions:

i) Always place the calibrator on a firm, level surface for easier use.
ii) Do not operate without correctly leveling the calibrator using the level gauge and height adjustment feet.
iii) Do not obstruct the motion of moving parts as it will affect the speed readings taken.

***CAUTION!!!** Do not attempt to open/loosen any part of the calibrator unless instructed by supplier to do so. Doing this may cause the loss of nominal calibrator readings.*

iv) Do not bend the rebound breaking clip too much or too frequently. This will weaken the clip and cause loss of functionality.

1.2. Component Description:

The following image shows the calibrator along with its various components:

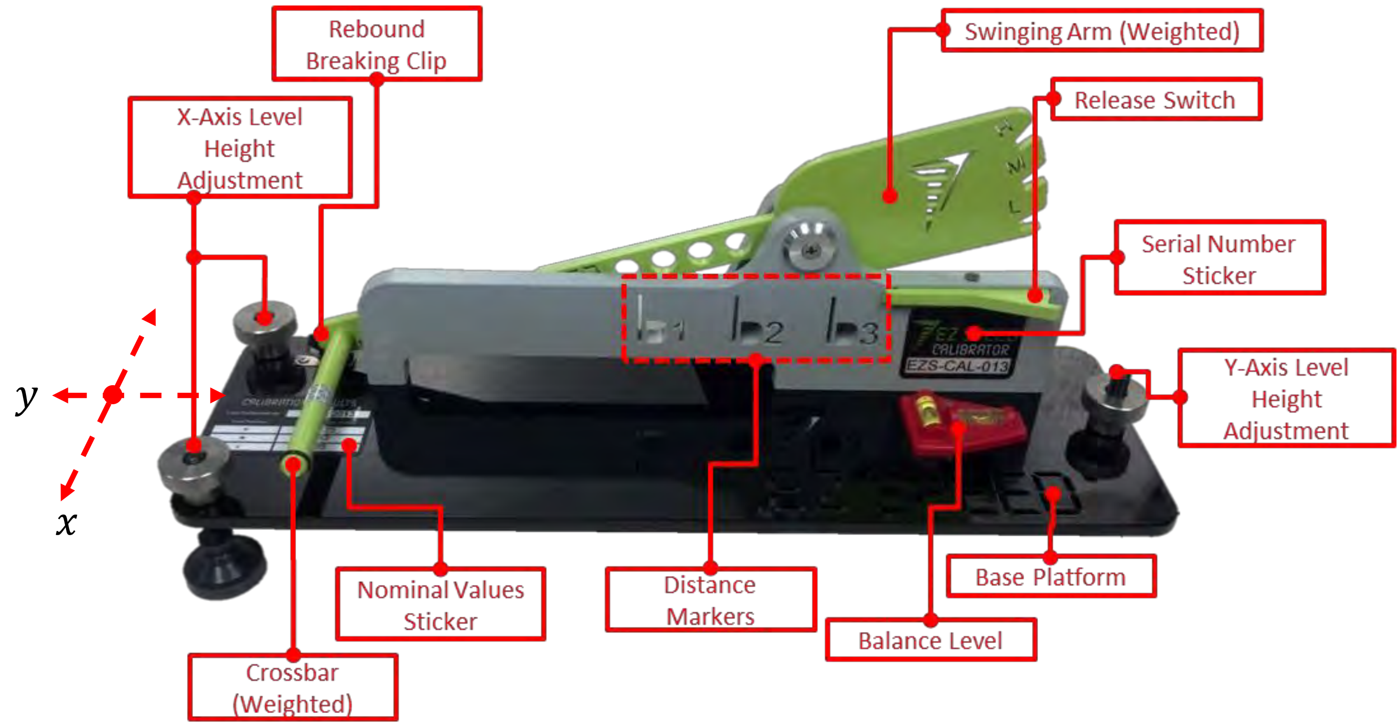

Figure 1: Calibrator – Full Assembly

a.	**Base Platform**	**Mounting surface for components**
b.	**X-Axis Level Height Adjustment**	**For leveling along the x-axis**
c.	**Y-Axis Level Height Adjustment**	**For leveling along the y-axis**
d.	**Swinging Arm**	**Weighted arm for measurement**
e.	**Crossbar**	**Crosses EZSpeed lasers**
f.	**Release Switch**	**Locks arm into starting position**
g.	**Rebound Breaking Clip**	**Prevents arm from bouncing back**
h.	**Balance Level**	**Shows the calibrator levelness**
i.	**Distance Markers**	**Placement of EZSpeed**
j.	**Serial Number Sticker**	**Designated serial number**
k.	**Nominal Values Sticker**	**Nominal speeds shown in mm/s**

2. Operation

2.1. Leveling:

1) Place the calibrator on a leveled firm surface that does not wobble and does not have a steep gradient.

2) Adjust the two feet at the left of the calibrator by loosening the silver adjustment knob and raising or lowering the loose adjustment nut until the bubble along the x-axis is between the two black lines as shown.

3) Adjust the foot at the right of the calibrator in the same manor until the bubble along the y-axis is between the two black lines as shown.

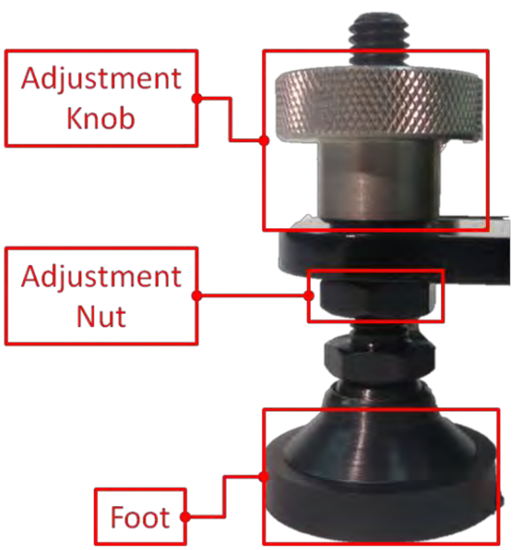

Figure 2: Height Adjustment Assembly

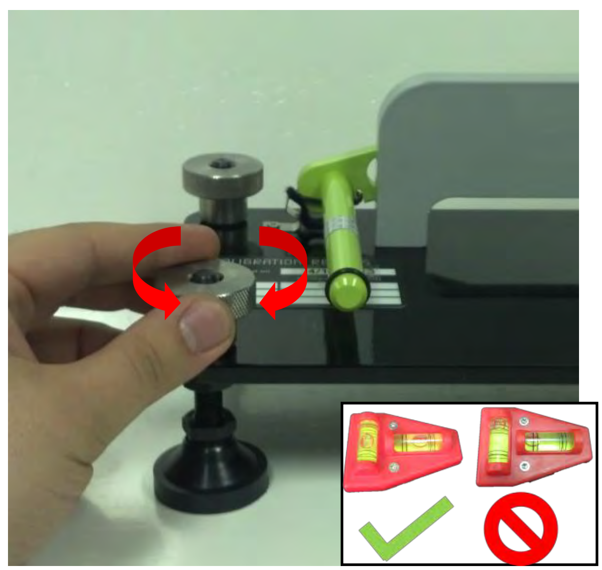

Figure 3: How to Adjust Height

2.2. Taking Measurements

1) Mount the EZSpeed such that the rear of the device is lined up with the desired distance marker (D1, D2, D3). See the EZSpeed Manual for mounting instructions.

Figure 4: Positioning for D1 (left) and 3 Positions of EZSpeed on Calibrator (right)

2) Lift the arm out of the cradle by the crossbar.

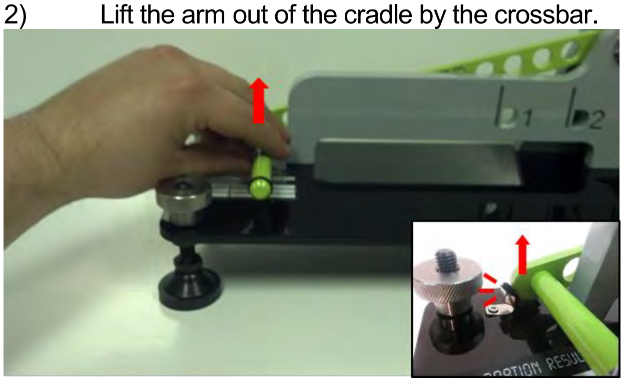

Figure 5: Proper Crossbar Release

3) Lock the arm into the desired position (high, medium, low) using the release switch.

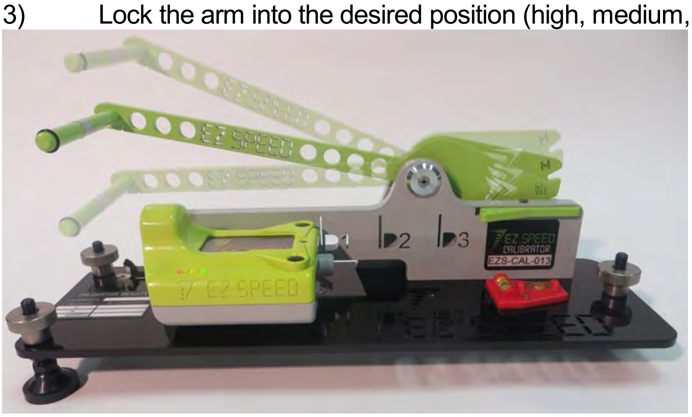

Figure 6: Various Arm Positions

4) Press the release lever firmly to drop the measurement arm.

Figure 7: Pressing release switch

5) The speed measurement will appear on the EZSpeed display.

Figure 8: Measurement displayed

3. Technical Information

3.1. Principle of Calibration:

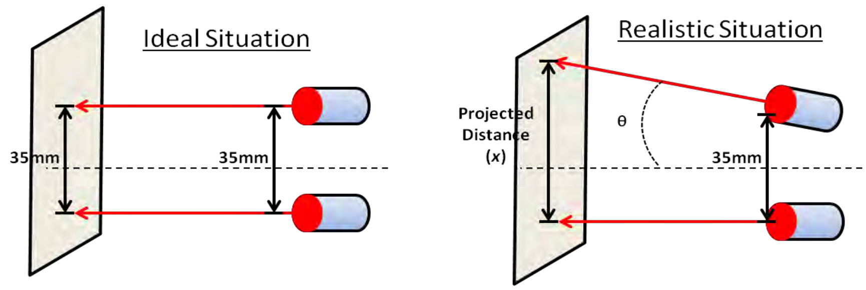

Figure 9: Laser projection in actual and ideal situation

The main principle of operation of the EZSpeed is based on the measurement of velocity by dividing distance over time. When a surface moves perpendicular to the lasers, it will trigger each one at different times. When it crosses the first laser, its light is reflected back at the object. When this light falls on a light dependent resistance (LDR) diode, this circuit starts an internal timer. A similar signal is generated when the object crosses the second laser and the timer is stopped. Thus the timer calculates the time difference between the two incidences which is the time taken for the object to cross the second laser after the first laser is triggered.

In an ideal situation If this time = t in seconds, and the distance between the laser (which is a constant of 35mm) = d, the velocity in mm/s is given by:

$$v = \frac{d}{t}$$

In a realistic situation however, since the projected distance is$\neq d$, there is an error in the velocity calculation. Hence if time take is now t' and the projected distance is x, the measured velocity will be

$$v' = \frac{d}{t'} \ instead\ of\ \ v = \frac{x'}{t'}$$

This is because the EZSpeed cannot measure the projected distance and assumes it to be same as in case of a realistic situation. Thus to adjust this to get back the correct value of velocity, we use the above 2 equations to get

$$t' = \frac{d}{v'} = \frac{x'}{v}\ , so\ v = v' \times \frac{x'}{d}$$

Here the factor (x'/d) is known as the calibration factor.

<u>Theoretical method for estimation</u>:

The calibration factor can be estimated by using simple principles of geometry and newton's laws applied to free fall motion. Assuming the calibrator arm to fall freely under gravity in a straight line (neglecting frictional and rotational factors), let the arm fall from a designated height 'h' from the initial release point to the point where it crosses the second laser (see fig below).

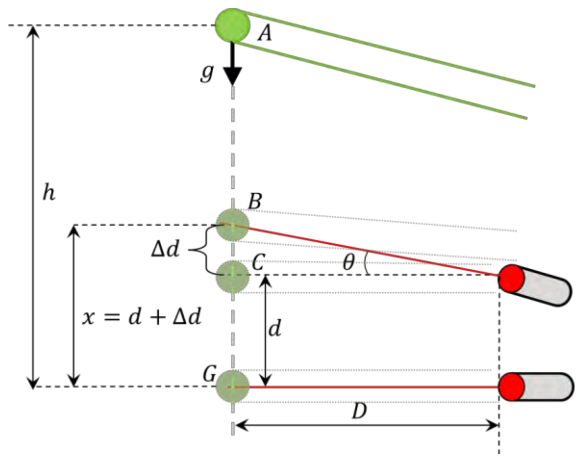

Figure 10: Geometry of motion of calibrator arm and laser projection

Since the EZ speed uses a time calculation for velocity reference, we calculate that time taken to fall from height 'h' is given by:

$$t = \sqrt{\frac{2h}{g}} \ldots\ldots\ldots\ldots\ldots.(i)$$

where 'g' is acceleration due to gravity. The above equation will give time taken to fall from pt. 'A' to pt. 'G'. the time take to fall to pt. 'C' can be calculated by subtracting height 'd' from 'h' and will be given by:

$$t_{AC} = \sqrt{\frac{2(h-d)}{g}} \ldots\ldots\ldots\ldots\ldots\ldots(ii)$$

Hence the total time taken to move from pt. 'C' to pt. 'G' can be calculated by subtracting (ii) fro (i):

$$t_{CG} = t_{AG} - t_{AC} = \sqrt{\frac{2h}{g}} - \sqrt{\frac{2(h-d)}{g}} \ldots\ldots\ldots\ldots\ldots\ldots(iii)$$

Hence the nominal velocity that the EZ speed would calculate in an **ideal** situation would be:

$$v = \frac{d}{\sqrt{\frac{2h}{g}} - \sqrt{\frac{2(h-d)}{g}}} = \frac{d}{\sqrt{\frac{2h}{g}}\left(1 - \sqrt{1 - \frac{d}{h}}\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(iv)$$

Substituting for 't' using eqn. (i), we get,

$$\frac{d}{vt} = 1 - \sqrt{1 - \frac{d}{h}} \ or\ 1 - \frac{d}{h} = \left(1 - \frac{d}{vt}\right)^2 \ or$$

$$d = h\left(1 - \left(1 - \frac{d}{vt}\right)^2\right) \ldots.(v)$$

Similarly for a non-ideal situation, the time measure by EZ speed will be the time taken from B to G can be calculated as:

$$t_{BG} = t_{AG} - t_{AB} = \sqrt{\frac{2h}{g}} - \sqrt{\frac{2(h-x)}{g}} \ldots\ldots\ldots\ldots\ldots\ldots(vi)$$

(Continued on next page)

Hence the velocity calculated by EZ speed will be given by:

$$v_c = \frac{d}{\sqrt{\frac{2h}{g}} - \sqrt{\frac{2(h-x)}{g}}} = \frac{d}{\sqrt{\frac{2h}{g}}\left(1 - \sqrt{1 - \frac{x}{h}}\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (vii)$$

Solving for 'x', we get

$$x = h\left(1 - \left(1 - \frac{d}{v_c t}\right)^2\right) \ldots . (viii)$$

We also know that

$$x = d + \Delta d \; and \; \frac{\Delta d}{D} = \tan\theta \, , so \; x = d + D\tan\theta \ldots \ldots . (ix)$$

From (viii) and (ix), we get

$$d + D\tan\theta = h\left(1 - \left(1 - \frac{d}{v_c t}\right)^2\right) \ldots . (x)$$

From (v) and (x) we get

$$h\left(1 - \left(1 - \frac{d}{vt}\right)^2\right) + D\tan\theta = h\left(1 - \left(1 - \frac{d}{v_c t}\right)^2\right) or \; \frac{D\tan\theta}{h} = \left(1 - \frac{d}{v_c t}\right)^2 - \left(1 - \frac{d}{vt}\right)^2$$

$$substituting \; \frac{d}{t} = v_o \; we \; get$$

$$\frac{D\tan\theta}{h} = \left(1 - \frac{v_o}{v_c}\right)^2 - \left(1 - \frac{v_o}{v}\right)^2 = 1 + \left(\frac{v_o}{v_c}\right)^2 - 2\left(\frac{v_o}{v_c}\right) - 1 - \left(\frac{v_o}{v}\right)^2 + 2\left(\frac{v_o}{v}\right) =$$

$$\left(\frac{v_o}{v_c}\right)^2 - \left(\frac{v_o}{v}\right)^2 - 2\left(\frac{v_o}{v_c} - \frac{v_o}{v}\right) = \left(\frac{v_o}{v_c} - \frac{v_o}{v}\right)\left(\frac{v_o}{v_c} + \frac{v_o}{v} - 2\right) = \left(\frac{d}{t}\right)^2\left(\frac{1}{v_c} - \frac{1}{v}\right)\left(\frac{1}{v_c} + \frac{1}{v} - \frac{2t}{d}\right)$$

Hence we get

$$\tan\theta = \frac{h}{D}\left(\frac{d}{t}\right)^2\left(\frac{1}{v_c} - \frac{1}{v}\right)\left(\frac{1}{v_c} + \frac{1}{v} - \frac{2t}{d}\right) \ldots \ldots . . (xi)$$

Substituting for t using (i), we get

$$\tan\theta = \frac{gd^2}{2D}\left(\frac{1}{v_c} - \frac{1}{v}\right)\left(\frac{1}{v_c} + \frac{1}{v} - \sqrt{\frac{8h}{d^2 g}}\right) \ldots \ldots . . (xii)$$

We can now use the above formula, put in value of calculated velocity v_c at any given distance 'D' and using nominal value of velocity v, we can calculate the skew angle θ.We can now simply use eqns. (ix), (vii) and (iv) to get

$$calibration \; factor \; f_{cal} = \frac{v_{actual}}{v_c} = \frac{\left(1 - \sqrt{1 - \frac{d}{h}}\right)}{\left(1 - \sqrt{1 - \frac{d + D\tan\theta}{h}}\right)}$$

This way, the calibration factor takes into account the natural skewing that occurs between the lasers. Realistically, they are not perfectly parallel and the actual projected distance between them at a certain distance away from the device could be greater or less than 35mm.

<u>Note:</u> The above theorem does not take into consideration factors due to friction and curvature of the path of the arm. In real situations, those factors will also have to be taken into account

3.2. Calculation of Calibration Factor and Error Checking:

The EZ Speed calibrator can be used to calculate the calibration factor and to check errors in actual measurements. By placing the EZSpeed at different distances and measuring and comparing the values measured by EZSpeed to the nominal value, we can calculate calibration factor for devices that are not calibrated or check error in calibrated devices.

3.2.1 Calibration Process:

1) Place the EZSpeed in any one of the locations D1, D2 and D3 (refer to topic 2.2 –taking measurements).
2) Starting with the lowest speed setting –take 10 readings at each distance and each speed and tabulate your results

Here is an example below:

		Distance Setting			
Speed setting	Serial number	D1	D2	D3	
Speed Setting 'L' (low speed) Nominal= 695mm/s	1	697	655	648	
	2	681	627	601	
	3	645	754	798	
	4	725	721	654	
	5	641	686	702	
	6	675	676	755	
	7	742	765	684	
	8	731	722	765	
	9	676	698	735	
	10	710	682	671	Net average
	Avg	692.3	698.6	701.3	697.4
d Setting 'M' (Medium speed) minal = 985mm/s	1	974	956	1015	
	2	983	974	125	
	3	995	988	227	
	4	974	922		
	5	998			
	6	1012			
	7				

Figure 11: Example Table for Calibration

3) Calculate the average of all readings at a particular speed and compare with the nominal.
4) Each speed setting will have different calibration factors based on the geometry of motion.
5) Once the data has been collected, you can share the data with the distributer / supplier who will calculate the calibration factor and give a code.
6) Input this code in the device to calibrate it.

***CAUTION!!!** Do not attempt to tune device by entering random codes. Doing this may lock the device permanently and may render it inoperable.*

3.2.2 Error Checking:

Simple error checking can be performed by using the calibration also.

1) Repeat Steps 1 and 2 as above.
2) Calculate the difference of 10 readings and take the maximum difference in reading (see example below:

Speed setting	Serial number	Distance Setting						
		D1		D2		D3		
		Speed (v)	Error (Δv)	Speed (v)	Error (Δv)	Speed (v)	Error (Δv)	
Speed Setting 'L' (low speed) Nominal = 695mm/s	1	697	2	663	32	665	30	
	2	681	14	695	0	687	8	
	3	696	1	701	6	706	11	
	4	725	30	721	26	687	8	
	5	687	8	686	9	702	7	
	6	675	20	676	19	709	14	
	7	715	20	714	19	684	11	
	8	731	36	722	27	721	26	
	9	676	19	698	3	729	34	
	10	710	15	682	13	671	24	Net Maximum
		Max	36	Max	32	Max	34	36
		Max error	% age =				4.89%	
ng 'M' (Medium ...eed) = 985mm/s	1	974	11	956	29	1015		
	2	983	2	974	11	125		
	3	995	10	988	3			
	4	974	11	922				
	5	998	13					

Figure 12: Example Table for Error Checking

3) Calculate you error using the formula:

$$\%age\ error\ \varepsilon = \left|\frac{\Delta v_{max}}{v_{nominal}}\right| \times 100\%$$

By calibration standards, a calibrated device should not have an error of more than 5% from the nominal

CAUTION!!! *In case device gives erratic reading, do not attempt to open/repair or tune the device, and contact the supplier immediately*

3.3. Specifications and Characteristics:

Physical Characteristics	
Dimensions	L480mm x H238mm x D150mm
Weight	3.094kg
Accuracy	99%
Units	mm/sec

4. Warranty Information

Each device is inclusive of a two year warranty. Some services and repairs are covered within the warranty period free of charge. To know about the detail of warranty terms and conditions, contact the supplier.

NOTES

CALIBRATION TABLE

		Distance Setting			
Speed setting	Serial number	D1	D2	D3	
Speed Setting 'L' (low speed) Nominal= ________mm/s	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				Net average
	Avg				
Speed Setting 'M' (Medium speed) Nominal = ________mm/s	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				Net average
	Avg				
Speed Setting 'H' (High speed) Nominal = ________ mm/s	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				Net average
	Avg				

ERROR CHECKING TABLE

		Distance Setting						
		D1		D2		D3		
Speed setting	Serial number	Speed (v)	Error (Δv)	Speed (v)	Error (Δv)	Speed (v)	Error (Δv)	
Speed Setting 'L' (low speed) Nominal= ______mm/s	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							Net Maximum
		Max error	% age =					
Speed Setting 'M' (Medium speed) Nominal = ______mm/s	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							Net Maximum
		Max error	% age =					
Speed Setting 'H' (High speed) Nominal = ______ mm/s	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							Net Maximum
		Max error	% age =					