SpeedPod
Detailed Performance Data

1. GENERAL

SpeedPod is a measurement gauge with inertial sensor technology, designed to measure multiple characteristics of a door system including minimum closing speed, opening speed, window vibration, hinge angle, and hinge friction.

This collection of studies has been performed to provide an accurate picture of the performance of the gauge in a wide variety of circumstances which have been chosen to represent real-world applications.

The different scenarios cover the following cases with the associated conclusions:

- **Repeatability and Gap Mode Tolerance**
  Validate the influence of this system parameter and its influence on result accuracy.
  Repeatability (Range) = 0.69 x Gap Tolerance

- **Gauge Repeatability and Reproducibility**
  Validate the expected repeatability and reproducibility for standard operations of SpeedPod.
  Repeatability of 30mm/sec for Gap Mode of 50mm/sec and Reproducibility of 0.4%

- **Gauge Orientation Sensitivity**
  Validate the influence of random orientations during installation and the impact on measurement results. Average Sensitivity of 0.5% with Maximum Sensitivity of 0.8%

- **Gauge Placement Sensitivity**
  Validate the influence of random positioning of the gauge during installation and the impact on measurement results. Average Sensitivity of 0.20% with Maximum Sensitivity of 0.46%

- **Gauge Temperature Sensitivity**
  Validate the influence of gauge temperature on measurement results.
  Temperature Sensitivity of 0.07% per 10°F or 0.12% per 10°C.

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2. GAP MODE TOLERANCE

2.1 Definition

SpeedPod has a function called “gap mode” for which the operator can set a “gap tolerance.” This gap tolerance represents the largest acceptable difference between the highest speed at which the door did not close and the lowest speed at which the door closed. The measurement is considered completed only when the gap tolerance has been satisfied. This measurement guarantees that attempts were made to close a door with the lowest possible energy.

2.2 Procedure

SpeedPod is installed on a door in line with standard operating procedures.

The population consists of the following variables:

- 1 Operator
- 1 Front Door
- 30 Measurements per Configuration
- 5 Different Gap Settings: 25, 50, 75, 100, and 125 mm/sec

The goal is to establish a relation between the user-defined tolerance and the uncertainty for the final results.

2.3 Data Collection

The SpeedPod used in this study is a standard unit that has gone through calibration and quality control per EZMetrology standard operating procedures.

- Type SpeedPod
- Serial Number 10033
- Calibration Date 15 August 2022

The operator will establish the minimum closing speed respecting the tolerance setting for each configuration. As soon as the gauge indicates successful completion using the finish flag on the screen, the value is recorded. (see Data Table 7.1)

For each setting, the range is evaluated for the population of 30 readings.

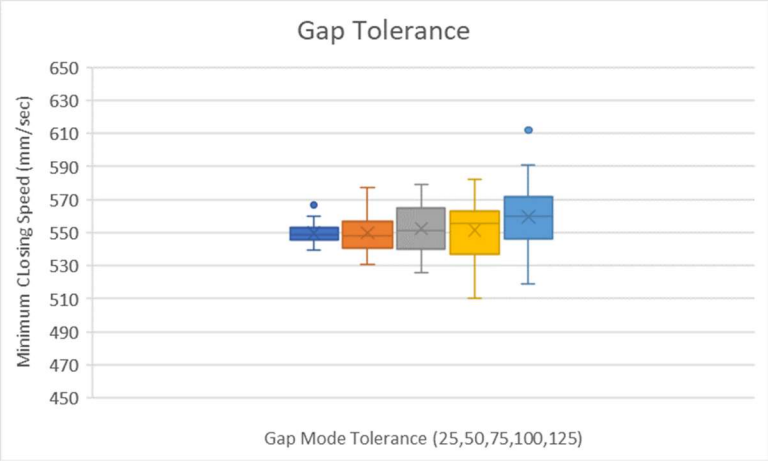

Figure 1: Correlation between Gap Tolerance and Measurement Range

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The box-and-whisker chart demonstrates that the expected range is closely related to the allowable gap tolerance.

Gap Tolerance (mm/sec)	25	50	75	100	125
Measured Range (mm/sec)	27	46	53	66	93

Table 1: Correlation between Gap Tolerance and Measurement Range

The numerical table of the established range for the population and the matching gap tolerance confirms this relation.

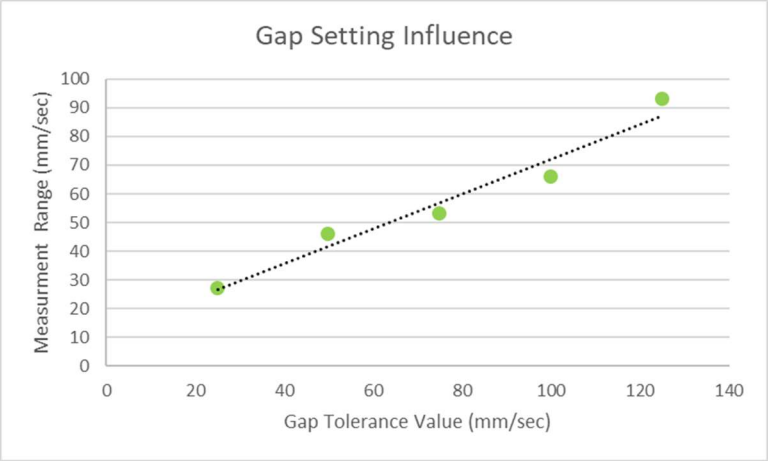

Figure 2: Correlation between Gap Tolerance and Measurement Range

A graphical representation of that same data set illustrates a linear relationship between the gap tolerance and the expected range. During the execution of the test, the operators observe an increase in cycle time when the gap tolerance is reduced. In the framework of providing an accurate representation, the relationship between recording time and the setting has been noted.

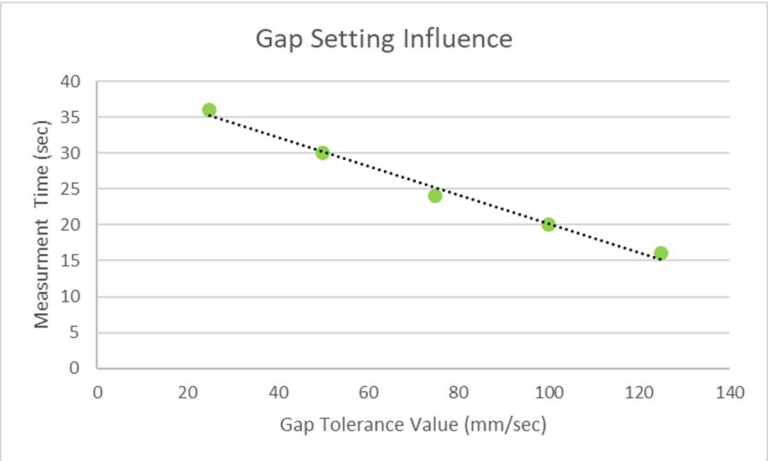

Figure 3: Correlation between Gap Tolerance and Measurement Time

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2.4 Conclusion

There is a clear linear correlation between the expected measurement range and the selected value for the gap tolerance. The study illustrates the following conclusion:

Repeatability (Range) = 0.69 x Gap Tolerance

For practical application, EZMetrology would recommend adopting a simple 1:1 relationship when choosing the settings.

EZMetrology estimates the influence of gap value for average cycle time as follows:

Gap Value (mm/sec)	Average Cycle Time (sec)
25	35
50	30
75	25
100	20
125	15

EZMetrology recommends taking all aspects of an inspection plan into consideration since measurement time increases with reduced gap tolerance.

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3. GAUGE R & R

3.1 Definition

As a measurement gauge, SpeedPod is subject to repeatability and reproducibility where repeatability refers to the ability to obtain identical values for a single operator and reproducibility refers to the ability to obtain identical values for multiple operators.

3.2 Procedure

SpeedPod is installed on a door in line with standard operating procedures. Gap mode tolerance is set at 50mm/sec. This value represents a setting which allows the inspection process to be completed within a reasonable time frame. As demonstrated in the first test, average cycle time will be a function of gap value.

The population consists of the following variables:

- 3 Operators
- 4 Doors: Two Front Doors, Two Rear Doors
- 30 Measurements per Configuration

3.3 Data Collection

The SpeedPod used in this study is a standard unit that has gone through calibration and quality control per EZMetrology standard operating procedures.

- Type SpeedPod
- Serial Number 10033
- Calibration Date 15 August 2022

The operator will establish the minimum closing speed respecting the tolerance setting for each configuration. As soon as the gauge indicates successful completion using the finish flag on the screen, the value is recorded. (see Data Table 7.2)

The data was graphed in the following box-and-whisker plots:

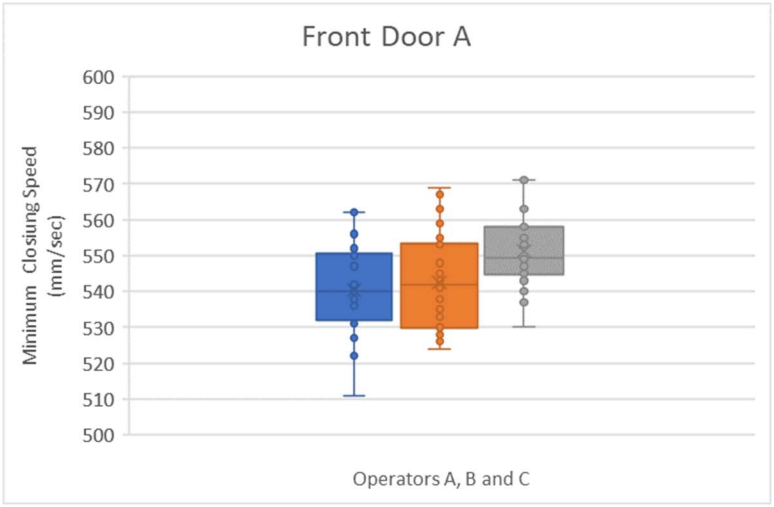

Figure 4: Front Door A, 3 Operators, 30 Measurements

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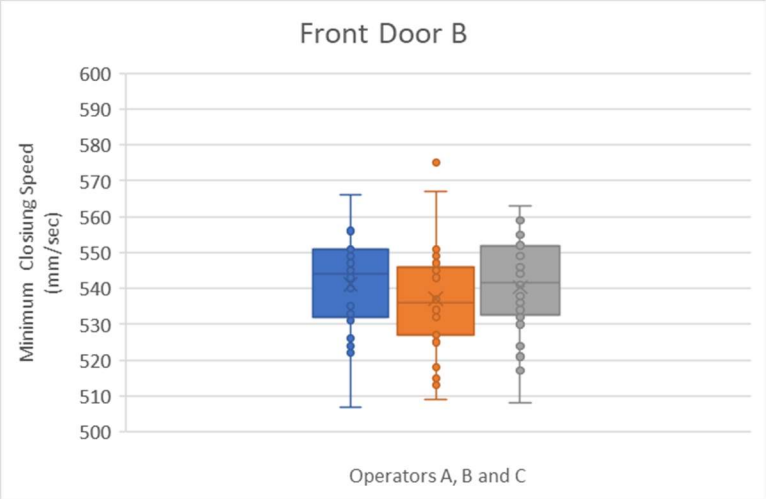

Figure 5: Front Door B, 3 Operators, 30 Measurements

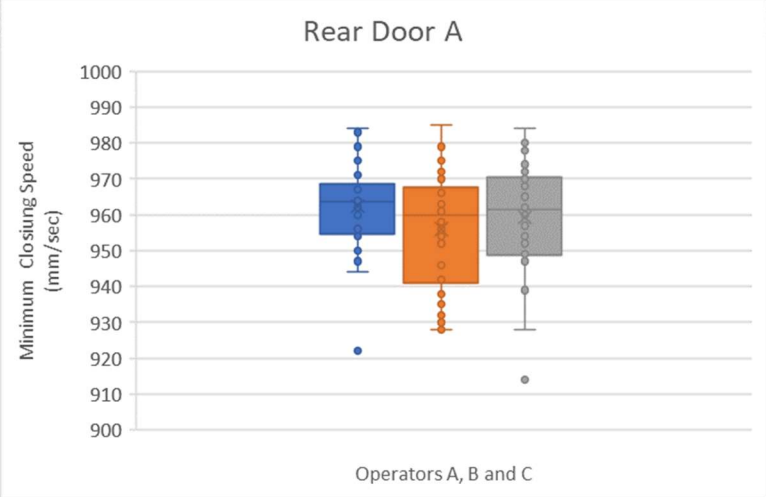

Figure 6: Rear Door A, 3 Operators, 30 Measurements

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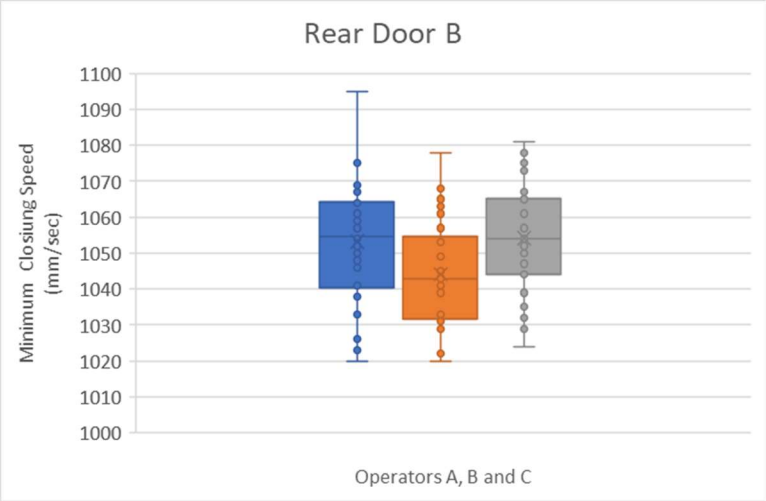

Figure 7: Rear Door B, 3 Operators, 30 Measurements

Each test setup shows similar variation for the repeatability from a given operator.

When taking the repeatability out of the equation, all operators measure within a limited difference from the average.

	Operator A	Operator B	Operator C
Front Door A	24	26	20
Front Door B	26	29	26
Rear Door A	25	33	32
Rear Door B	33	28	29
Average	27	29	27

Table 2: Minimum Closing Speed (mm/sec) and Repeatability per Operator per Door based on 30 Repetitions

Observing the different results between the different operators yields the following results:

	Front Door A	Front Door B	Rear Door A	Rear Door B
Operator A	540	541	962	1053
Operator B	543	537	956	1044
Operator C	551	540	959	1054
Average	545	540	959	1050

Table 3: Minimum Closing Speed (mm/sec) and Reproducibility between Operators per Door

	Front Door A	Front Door B	Rear Door A	Rear Door B
Operator A	0.8%	0.3%	0.3%	0.3%
Operator B	0.4%	0.4%	0.3%	0.6%
Operator C	1.2%	0.1%	0.0%	0.3%
Maximum	1.2%	0.4%	0.3%	0.6%
Average	0.4%			

Table 4: Minimum Closing Speed (mm/sec) and Reproducibility between Operators per Door

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3.4 Conclusion

As previously established, the variation in operator repeatability is around 30mm/sec within a 95% confidence interval. Note that this value is related to the configuration of the test where the gap mode is set to 50mm/sec.

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Repeatability of 30mm/sec for Gap Mode of 50mm/sec

The reproducibility is significantly better with a value less than 10mm/sec.

Reproducibility of 0.4%

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4. GAUGE ORIENTATION

4.1 Definition

SpeedPod's 3-axis sensors, smart algorithms, and physical design allow the gauge to be mounted in any orientation on a door, providing tremendous convenience for the user by removing any mounting constraints. This test is designed to quantify the influence of device orientation on final measurement results.

4.2 Procedure

SpeedPod is installed on a door in line with standard operating procedures. Gap mode tolerance is set at 50mm/sec.

The population consists of the following variables:

- 1 Operator
- 1 Door
- 6 Different Orientations
- 30 Measurements per Orientation

Since the system remains on the same door, the results will be evaluated based on repeatability for all configurations.

4.3 Data Collection

The SpeedPod used in this study is a standard unit that has gone through calibration and quality control per EZMetrology standard operating procedures.

- Type SpeedPod
- Serial Number 10033
- Calibration Date 15 August 2022

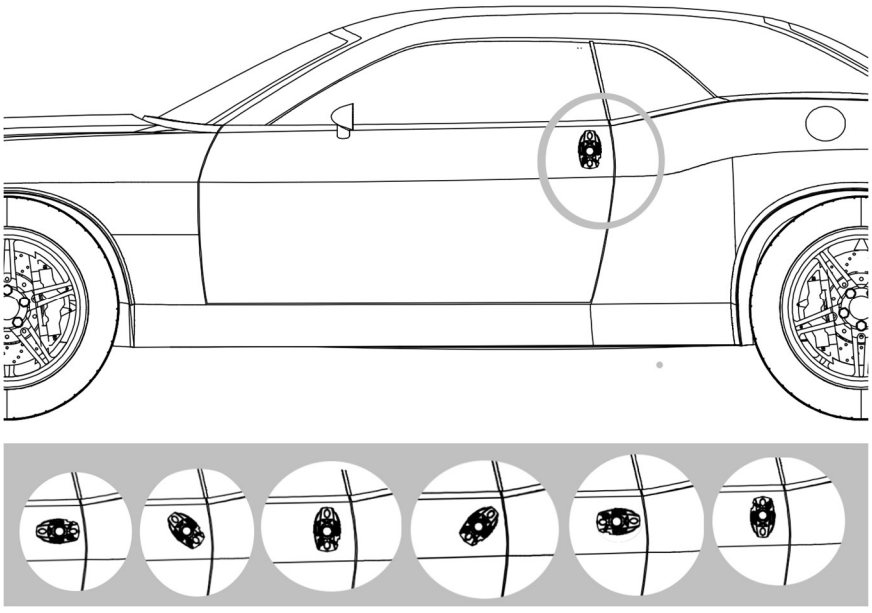

Figure 8: SpeedPod Gauge Orientations

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The operator will establish the minimum closing speed, respecting the tolerance setting for each configuration. As soon as the gauge indicates successful completion using the finish flag on the screen, the value is recorded. (see Data Table 7.3)

The box-and-whisker chart below shows the measurements grouped by orientation:

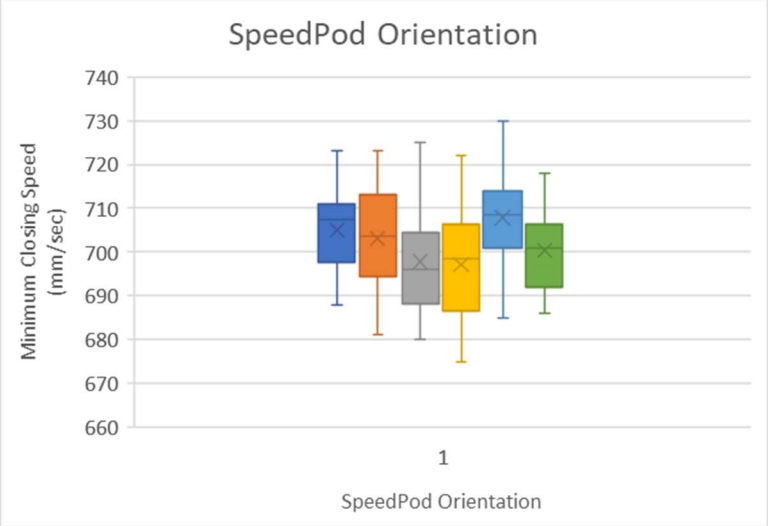

Figure 9: Multiple Orientations on the Same Door (0,45,90,135,180,270°)

The results are consistent with expectations for the acquisition settings.

Mounting Angle	0°	45°	90°	135°	180°	270°
2 Sigma (95%) (mm/sec)	17	23	23	27	21	18
Average (mm/sec)	705	703	698	697	708	700

Table 5: Repeatability and Minimum Closing Speed (mm/sec); Repeatability per Orientation based on 30 Repetitions

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When evaluating the results of the different orientations, there is an average variation of 0.5% with a maximum of 0.8%.

Mounting Angle	0°	45°	90°	135°	180°	270°
Variation (%)	0.4%	0.2%	0.6%	0.7%	0.8%	0.2%
Average	0.5%					

Table 6: Variation between Minimum Closing Speed per Orientation

4.4 Conclusion

The influence of the gauge orientation can have a minor influence on the final results:

Orientation Sensitivity 0.5% with Maximum of 0.8%

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5. GAUGE LOCATION

5.1 Definition

To simplify operation, the SpeedPod gauge does not need to be mounted only in one specific location, but rather, can be placed within a certain zone on a given door. This test evaluates sensitivity of measurement results for different gauge locations.

5.2 Procedure

SpeedPod is installed on a door in line with standard operating procedures. Gap mode tolerance is set to 50mm/sec.

The population consists of the following variables:

- 1 Operator
- 1 Doors
- 6 Locations
- 30 Measurements per Configuration

The repeatability for each location as well as the variation between the locations is evaluated.

5.3 Data Collection

The SpeedPod used in this study is a standard unit that has gone through calibration and quality control per EZMetrology standard operating procedures.

- Type SpeedPod
- Serial Number 10033
- Calibration Date 15 August 2022

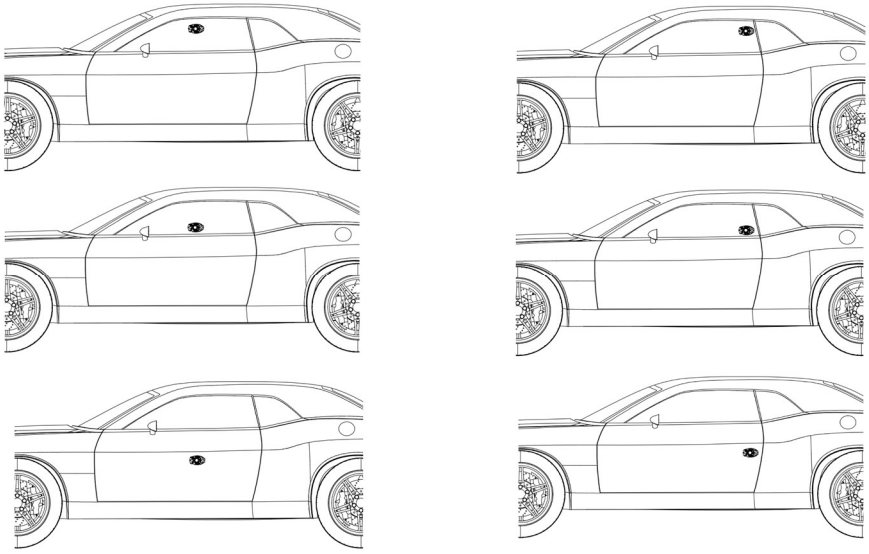

Figure 10: SpeedPod Gauge Positions

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The operator will establish the minimum closing speed respecting the tolerance setting for each configuration. As soon as the gauge indicates successful completion using the finish flag on the screen, the value is recorded. (see Data Table 7.4)

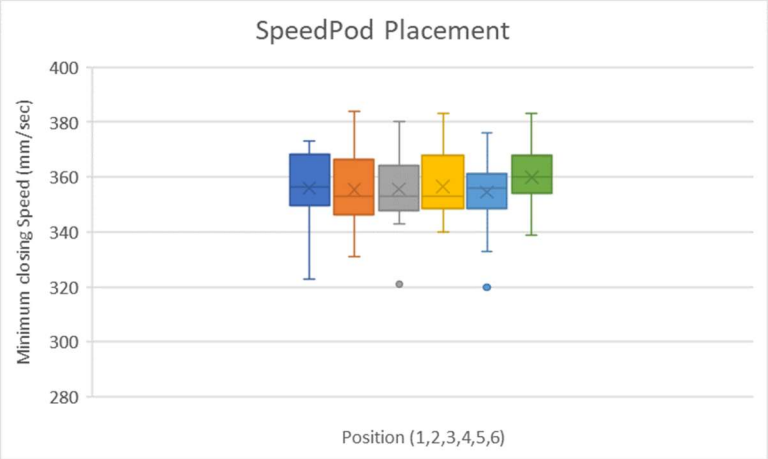

Figure 11: Six Distinct Positions on the Same Door

The box-and-whisker graph illustrates the variation per location and the respective variation between the different positions. In the table, the numerical values are compared.

SpeedPod Location	Top Left	Top Right	Center Left	Center Right	Bottom Left	Bottom Right
2 Sigma (95%) (mm/sec)	28	28	24	23	25	22
Average (mm/sec)	356	356	356	356	355	360

Table 7: Minimum Closing Speed (mm/sec) from Different Positions

The percentage variation of the minimum closing speed yields the following results:

SpeedPod Location	Top Left	Top Right	Center Left	Center Right	Bottom Left	Bottom Right
Variation (%)	0.12%	0.24%	0.19%	0.04%	0.50%	1.01%
Average	0.35%					

Table 8: Variation on Minimum Closing Speed (%) from Different Positions

5.4 Conclusion

Gauge position on a door can have a minor influence on the final measurement results:

Positioning Sensitivity 0.35% with Maximum of 1.01%

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6. GAUGE TEMPERATURE

6.1 Definition

SpeedPod's flexibility will expose the gauge to different temperatures. This test evaluates the impact of temperature on the gauge's performance.

6.2 Procedure

SpeedPod is subjected to different temperatures for greater than three hours; the gauge is then assumed to be at the exposure temperature.

The population consists of the following variables:

- 1 Operator
- 1 Rotation Reference Fixture
- 6 Measurements per Temperature

Each test is performed within a few minutes after the gauge has been removed from a climate chamber which allows the reference rotation fixture to remain at a constant temperature. The test is performed immediately to minimize adaption to the new environment. The number of runs is limited to 6 to further minimize temperature variation.

The reference rotation fixture moves at constant speed and is measured with the gauge. The results are then compared to the original rotational data.

6.3 Data Collection

The SpeedPod used in this study is a standard unit that has gone through calibration and quality control per EZMetrology standard operating procedures.

- Type SpeedPod
- Serial Number 10033
- Calibration Date 15 August 2022

The operator places the gauge on the reference fixture. The motorized reference fixture will generate rotation at a constant speed. The gauge's measurement readings can be compared for different temperatures.

For the gauge at different temperatures, the system captures slightly offset speed measurements as represented in the box-and-whisker chart.

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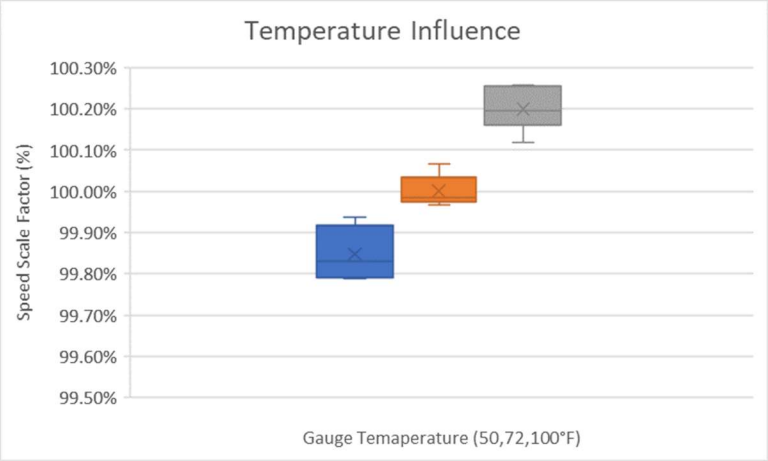

Figure 12: Speed Scaling at 3 Different Temperatures and 6 Repetitions

The numerical values provide a more accurate picture of the variation or drift:

Speed Scale Facor (%)			
	Temperature		
Trial	**50°F**	**72°F**	**100°F**
1	99.79%	99.97%	100.25%
2	99.79%	100.07%	100.18%
3	99.83%	100.02%	100.12%
4	99.91%	99.98%	100.21%
5	99.83%	99.99%	100.17%
6	99.94%	99.98%	100.26%
Average	99.85%	100.00%	100.20%
2 sigma (95%)	0.12%	0.08%	0.11%

Table 9: Variation due to Temperature (%) at 3 Different Temperatures

When expressed as a function of temperature, a linear relation can be established to determine the temperature sensitivity of the gauge measurements.

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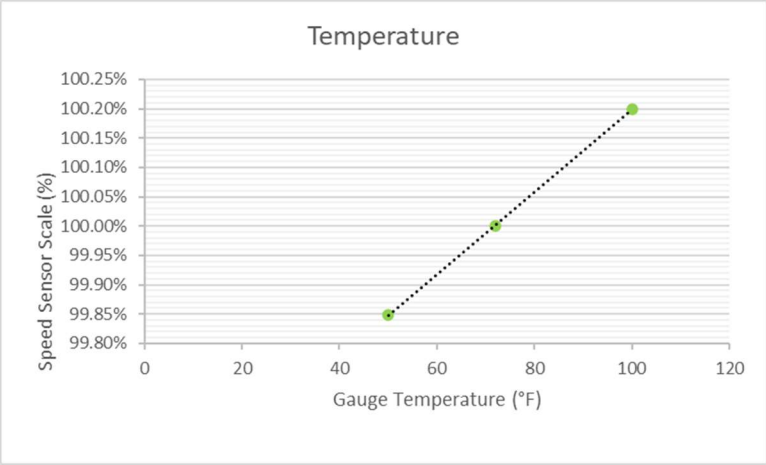

Figure 13: Average Scaling per Temperature and Linear Regression

Temperature	-10°F	0°F	10°F
Deviation (%)	-0.07%	0	0.07%

Table 10: Variation due to Temperature (%) following Linear Regression

6.4 Conclusion

Gauge temperature has a minor influence on final measurement results.

Temperature dependance is 0.07% per 10°F or 0.12% per 10°C

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7. DATA TABLES

7.1 Gap Tolerance Study

	Minimum Closing Speed (mm/sec)				
Trial	Gap Tolerance (mm/sec)				
	25	50	75	100	125
1	548	557	577	510	554
2	547	534	542	565	557
3	548	560	526	578	536
4	544	531	528	581	559
5	546	542	545	516	565
6	547	547	538	536	570
7	556	540	558	529	548
8	544	561	568	548	567
9	546	557	540	560	547
10	543	557	571	564	577
11	549	547	536	582	571
12	559	554	579	561	527
13	549	562	563	535	574
14	548	539	564	532	545
15	549	544	555	538	561
16	544	548	548	555	612
17	557	541	547	537	591
18	540	545	543	545	549
19	560	577	551	549	575
20	555	557	568	551	542
21	567	539	552	563	541
22	548	549	559	555	584
23	542	568	553	558	580
24	543	550	537	560	553
25	552	538	543	529	567
26	551	546	540	556	562
27	556	573	555	567	525
28	549	537	535	558	571
29	552	553	577	574	519
30	552	548	576	557	558
Average	550	550	552	553	560
2 Sigma (95%)	6	11	15	17	21
Range	27	46	53	66	93

Table 11: Data Samples Gap Mode : (1 Operator, 1 Door, 30 Repetitions, 5 Gap Settings)

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7.2 Gauge R&R Study

Front Door A			
Minimum Closing Speed (mm/sec)			
Trial	Operator A	Operator B	Operator C
1	541	528	543
2	511	524	537
3	531	530	545
4	523	533	546
5	536	529	530
6	552	528	564
7	532	526	550
8	522	554	553
9	538	545	545
10	542	526	558
11	527	553	554
12	540	543	546
13	532	539	547
14	552	541	550
15	562	535	571
16	532	563	571
17	537	559	571
18	536	536	559
19	536	543	538
20	550	569	544
21	540	549	555
22	552	543	549
23	543	548	543
24	539	538	558
25	556	555	563
26	540	563	555
27	547	567	555
28	556	546	547
29	543	536	548
30	562	528	540
Average	540	543	551
2 Sigma (95%)	24	26	20
Range	51	45	41
Average		545	
2 Sigma (95%)		25	
Range		60	
Reproducability	4	2	6

Table 12: Data Samples Gauge R&R: (3 Operators, Front Door A, 30 Repetitions)

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Front Door B			
Minimum Closing Speed (mm/sec)			
Trial	Operator A	Operator B	Operator C
1	534	518	530
2	532	513	532
3	533	525	517
4	536	527	508
5	507	534	536
6	532	515	521
7	531	526	535
8	526	528	534
9	549	527	535
10	522	509	524
11	524	532	538
12	548	543	549
13	552	528	559
14	531	533	541
15	540	543	542
16	557	546	533
17	547	547	535
18	549	535	552
19	548	545	544
20	535	549	546
21	546	549	531
22	543	551	550
23	556	545	542
24	552	543	563
25	551	543	552
26	545	535	555
27	534	546	552
28	566	537	555
29	557	567	546
30	551	575	553
Average	541	537	540
2 Sigma (95%)	26	29	26
Range	59	66	55
Average		540	
2 Sigma (95%)		27	
Range		68	
Reproducability	2	2	1

Table 13: Data Samples Gauge R&R: (3 Operators, Front Door B, 30 Repetitions)

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Rear Door A			
Minimum Closing Speed (mm/sec)			
Trial	Operator A	Operator B	Operator C
1	922	963	958
2	944	935	914
3	963	971	954
4	950	928	984
5	967	928	928
6	947	946	950
7	951	956	966
8	976	930	957
9	979	963	948
10	965	942	952
11	962	938	975
12	968	954	949
13	960	961	947
14	954	975	965
15	971	931	980
16	955	959	969
17	984	970	948
18	964	973	939
19	968	952	978
20	956	964	972
21	967	979	963
22	960	932	940
23	965	967	974
24	962	958	970
25	983	963	962
26	972	985	969
27	967	956	968
28	962	972	960
29	951	962	961
30	975	966	981
Average	962	956	959
2 Sigma (95%)	25	33	32
Range	62	57	70
Average		959	
2 Sigma (95%)		30	
Range		71	
Reproducability	3	3	0

Table 14: Data Samples Gauge R&R: (3 Operators, Rear Door A, 30 Repetitions)

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Rear Door B			
Minimum Closing Speed (mm/sec)			
Trial	Operator A	Operator B	Operator C
1	1023	1022	1032
2	1046	1029	1024
3	1038	1020	1057
4	1033	1042	1044
5	1020	1043	1035
6	1055	1034	1053
7	1059	1043	1047
8	1054	1030	1075
9	1057	1054	1061
10	1064	1053	1058
11	1041	1041	1054
12	1026	1044	1073
13	1069	1063	1054
14	1052	1057	1054
15	1048	1039	1067
16	1068	1041	1078
17	1075	1033	1050
18	1067	1057	1029
19	1053	1045	1068
20	1062	1068	1052
21	1038	1031	1051
22	1065	1078	1036
23	1061	1031	1044
24	1034	1029	1065
25	1060	1032	1039
26	1095	1043	1081
27	1053	1061	1062
28	1050	1046	1066
29	1068	1065	1053
30	1062	1049	1062
Average	1053	1044	1054
2 Sigma (95%)	33	28	29
Range	75	58	57
Average		1050	
2 Sigma (95%)		31	
Range		75	
Reproducability	3	6	4

Table 15: Data Samples Gauge R&R: (3 Operators, Rear Door B, 30 Repetitions)

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7.3 Gauge Orientation Study

	Mounting Angle (degrees)					
Trial	**0°**	**45°**	**90°**	**135°**	**180°**	**270°**
1	702	693	695	692	713	687
2	710	700	697	678	711	701
3	711	699	725	676	723	691
4	698	681	689	679	730	714
5	699	706	693	705	706	699
6	708	716	713	691	710	693
7	708	707	700	675	719	696
8	733	696	701	700	712	687
9	715	698	692	682	700	718
10	709	705	719	706	698	688
11	710	691	700	702	724	704
12	708	707	694	688	714	696
13	712	689	684	699	707	702
14	688	719	686	722	718	714
15	692	702	704	707	717	686
16	709	695	716	689	708	702
17	689	712	703	701	712	711
18	706	707	686	698	701	692
19	711	695	685	680	691	704
20	695	688	706	693	713	700
21	701	705	698	719	705	712
22	714	693	708	679	709	706
23	718	685	689	713	685	701
24	702	716	703	712	714	697
25	697	718	715	696	695	706
26	697	700	680	704	707	708
27	713	710	689	706	686	705
28	693	721	686	707	702	690
29	707	723	686	694	702	692
30	705	717	693	721	701	707
Average	705	703	698	697	708	700
2 Sigma (95%)	19	23	23	27	21	18
Range	45	42	45	47	45	32
Average			702			
2 Sigma (95%)			23			
Range			58			

Table 16: Data Samples Gauge Orientation (1 Operator, 1 Door, 6 Orientations, 30 Repetitions)

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7.4 Gauge Position Study

Trial	Top Left	Top Right	Center Left	Center Right	Bottom Left	Bottom Right
1	323	331	354	370	320	343
2	323	338	353	343	359	371
3	366	348	363	347	367	346
4	339	352	343	349	341	340
5	371	375	372	347	339	359
6	349	371	352	340	343	350
7	361	347	348	349	376	361
8	350	368	374	350	362	355
9	369	370	351	344	356	378
10	367	350	353	362	365	368
11	360	379	370	353	359	357
12	354	364	355	370	361	359
13	333	357	353	383	356	339
14	342	384	349	343	333	383
15	357	352	343	352	347	365
16	353	335	364	361	349	354
17	368	355	360	368	367	373
18	373	363	372	375	372	354
19	373	366	358	355	358	372
20	352	347	360	368	357	348
21	356	350	350	376	356	355
22	361	349	347	361	338	366
23	351	363	347	352	350	365
24	372	339	321	354	356	354
25	341	372	352	368	360	364
26	370	354	380	350	353	363
27	373	344	370	358	374	355
28	355	335	345	349	355	368
29	360	364	346	344	352	365
30	355	343	365	353	356	368
Average	356	356	356	356	355	360
2 Sigma (95%)	28	28	24	23	25	22
Range	50	53	59	43	56	44
Average			356			
2 Sigma (95%)			25			
Range			64			

Table 17: Data Samples Gauge Positions: (1 Operator, 1 Door, 6 Positions, 30 Repetitions)

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