AUTOMOTIVE GASOLINE ENGINE OIL STANDARD

(JASO M 364:2019)

ANNEX TO APPLICATION MANUAL

SYSTEM TO MANAGE TEST SEVERITY AND PRECISION OF FIRING FUEL ECONOMY TEST BASED ON REFERENCE OILS

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JASO Engine Oil Standards Implementation Panel

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1. Introduction

This document has been prepared as a part of the activities of the JASO Engine Oil Standards Implementation Panel, which was established voluntarily by various industrial organizations and academic associations related to engine oils in Japan, to ensure proper implementation of JASO Engine Oil Standards in Japan and overseas. This document describes the process to control test severity and precision of the Gasoline Engine Oil Firing Fuel Economy Test Procedure (JASO M 366:2019) and its application in the Automotive Gasoline Engine Oil Standard (JASO M 364: 2019) established by the Society of Automotive Engineers of Japan, Inc.

The operational rules defined in this document shall be maintained and revised by the Gasoline Fuel Economy Test Surveillance Panel which will be formed under the JASO Engine Oil Standards Implementation Panel, or the JASO Next Generation Gasoline Engine Oil Taskforce, or the Firing Fuel Economy Test Procedure Working Group formed under the Taskforce, in order to solve any severity, precision, operational issues, and any technical issues..

2. Reference Engine Oils to Manage Test Precision of Firing Fuel Economy Test

Reference oils for the test precision control is shown in table 1. The fuel economy improvement (FEI) and the standard deviation are the result of the JASO Round Robin test during the test procedure development of the JASO M 366:2019. The test monitoring system described in this Annex document is based on these reference oil values.

Table 1. Fuel Economy Improvements and Standard Deviations for JASO Reference Oils

Reference Oil	SAE Grade	Fuel Economy Improvement (FEI)	
		Mean, %	Standard Deviation, %
GE108A	0W-8	1.10	0.236
GE208	0W-8	0.97	0.231
GE216	0W-16	0.64	0.251

Table 2. Repeatability and Reproducibility of JASO Round Robin Test Results

Item		Value, %
Pooled Standard Deviation		0.21
Repeatability	Standard Deviation (Sr)	0.21
	r	0.58
Reproducibility	Standard Deviation(SR)	0.25
	R	0.69

3. Calibration Requirements by Reference Oils

Test engines need to be calibrated by the procedure defined below to confirm test precision with engines. The calibration period is valid up to three months or 25 fuel economy tests (whichever comes first) for the specific test engine and test stand combination. The number of engine tests includes JASO BC tests and Reference Oil tests.

In this test procedure, the fuel economy improvement (FEI) for reference oil or candidate oil is calculated as the improvement of total fuel consumption of the reference oil or the candidate oil relative to the average of the JASO BC test result before them (BC Before, BCB) and the JASO BC test result after them (BC After, BCA). In this case, the BCA of previous set of tests can be utilized as the BCB of next set of tests, provided that no modification is made on the test engine/stand which might affect their conditions and the period of downtime between the BCA and BCB is within seven days.

In this document, "candidate oil" means test oils evaluated in this test procedure other than JASO reference oils shown in Table 1 in Section 2 and JASO BC.

3.1. New Test Stand

Operationally valid calibration tests with all three JASO reference oils shown in Table 1 are required to calibrate each engine/stand. No other oils other than these JASO reference oils can be run between calibration tests. The order of tests with three JASO reference oils and their test numbers are

assigned by Japan Lubricating Oil Society (JALOS). The test order is assigned in a random manner. The calibration is completed with no parameters calculated from three calibrations tests exceeding limits shown in Table 3 (Level 2 limit for Zi, Level 3 limit for ei). When any of these parameters exceed the limit, additional reference test must be conducted until last three reference tests meet the limits.

3.2. New Test Engine with Existing Test Stand

As the same as above, calibration tests with three JASO reference oils are required. The order of tests and test numbers are assigned by JALOS.

3.3. Extension of Calibration Period of Existing Test Engine/Stand

One additional test with one of three JASO reference oils is required. Once the result meets the limits, the calibration period is extended for 3months or 25 tests (including the BCB test, the reference test, and the BCA test) (whichever comes first). The reference oil is assigned by JALOS. The reference oil shall be chosen from two reference oils which were not used at the last calibration test in a random manner.

If the test result does not meet the limits, additional calibration test can be run.

3.4. Re-Install Existing Engine with Existing Test Stand

As the same as above, one calibration test with one of three JASO reference oils is required. One successful calibration test provides the calibration period for three months or up to 25 tests (whichever comes first). The LTMS charts must include reference test data on the same engine before the downtime out of the test stand.

In case that the test stand is modified or the test engine is installed into the different test stand, the engine/stand must be considered as a new engine/stand and three calibration tests are required. In the JASO Round Robin, each test laboratory had one test stand. The laboratory factor is not separated from the test stand factor.

3.5. Additional Reference Test during Calibration Period

Test laboratory can run additional reference test at any time when the test severity is suspected even before the end of the Period.

The reference oil shall be chosen from two reference oils which were not used at the last calibration test in a random manner by JALOS.

4. Test Severity and Precision Management by Lubricant Test Monitoring System (LTMS)

This document is issued in reference to the Lubricant Test Monitoring System (LTMS) disclosed by the ASTM as the methodology for the severity and precision control of ASTM tests. Definition of terms are based on the ASTM LTMS.

Table 3 shows parameters defined for the LTMS for JASO Gasoline Engine Oils - Firing Fuel Economy Test Procedure (JASO M 366:2019).

EWMA Chart is the plot of parameter related to the severity adjustment (S.A.) by results of reference

tests for each test engine. The meaning that the K value for Level 1 Alarm is "0.000" is to apply the S.A. to all candidate test results based on the latest EMWA parameter.

Table 3. LTMS Constants

		EWMA Chart (Zi) Severity		Lab/Engine Prediction Error (ei) Severity	
Chart Level	Limit Type	Lambda	Alarm (K)	Limit Type	Limit (K)
Lab/Engine [A]	Level 1 Level 2	0.3	0.000 ± 1.800	Level 1 Level 2 Level 3	± 1.351 ± 1.734 ± 2.066
Industry [B]	Level 1 Level 2	0.2	± 0.775 ± 0.859		

[A] Constants for construction of control charts for each individual engine

[B] Constants for construction of control charts as Industry Trend for entire industry data

4.1. Control Chart Construction

Following 3 parameters shall be calculated for the construction of control charts for this test. The Shewhart chart and the EWMA chart based on the industry reference test data shall be disclosed on the home page of the JASO Engine Oil Standards Implementation Panel when new data is added into the industry database in order to understand the overall trend.

4.2. Shewhart Chart (Severity Monitoring) (Yi)

The vertical axis of this control chart represents the standardized calibration test results (Y),
These results are plotted against completion date order which is on the horizontal axis.
Y is calculated as follows:

$$Y_i = \frac{T_i - \mathrm{MEAN}}{\mathrm{STANDARD\ DEVIATION}}$$

Ti : Test result at test order i in appropriate units (% in this test procedure).

Yi : Standardized test result at the test order i.

Standardized test result with the mean and the standard deviation of reference oil used in the calibration test(showing the gap of the standard deviation from the mean (target) of reference oil.

The followings are the control chart limits for the Shewhart chart for monitoring severity.

$$0 \pm K$$

K is the constant that determines the chart's estimated false detection rate. The false detection rate is the percentage of time that a plotted result will fall outside the control limits when, in fact, no change in the process has occurred. As K increases, the false detection rate decreases. However, the false detection rate must be balanced with the chart's sensitivity to real changes in the process. This sensitivity is diminished as K increases. K is test type specific.

4.3. Exponentially Weighted Moving Average (EWMA) Chart (severity Monitoring) (Zi)

The vertical axis of this control chart represents the EWMA of standardized calibration test results . These results are plotted against completion date order which is on the horizontal axis.

Zi = EWMA of the standardized test result at test order i.

$$\mathrm{Z_i} = (\mathrm{LAMBDA})\mathrm{Y_i} + (1 - \mathrm{LAMBDA})\mathrm{Z_{i-1}}$$

where :

$$0 \leq \mathrm{LAMBDA} \leq 1$$

$$Z_0 = \frac{Y_1 + Y_2 + Y_3}{3}$$

In this test procedure, three reference tests are required for a new test engine/stand calibration. Zo is calculated as the mean of these three test results.

Lambda is the smoothing constant and must be between 0 and 1. As Lambda decreases, past data points are given more weight and the resulting plot gets smoother. When Lambda is set equal to 1, the EWMA chart is equivalent to the Shewhart chart. 0.2 ~ 0.4 is generally applied to ASTM tests. Sequence VID is the ASTM fuel economy test procedure that JASO M 366 referenced to and it applied Lambda = 0.3 for the individual engine chart and Lambda = 0.2 for the industry chart. The JASO Firing Fuel Economy Test Working Group decided to apply these Lambda values to the JASO M 366:2019, since the test methodology is similar to the Sequence VID.

4.4. Prediction Error from EWMA (ei)

The vertical axis of this control chart represents the Prediction Error from EWMA (Zi) of standardized calibration test results. These results are plotted against completion date order, which is on the horizontal axis.

ei is calculated as follows:

$$\mathrm{e_i} = \mathrm{Y_i} - \mathrm{Z_{i-1}}$$

where :

Yi = Standardized test result at test order i.

Z_{i-1} = EWMA of the standardized test result at test order i-1.

Three difference alarm levels are defined for the ei.

These are equivalent to the confidence intervals based on the sum of the variance of single test and the variance of EWMA. Level 1, Level 2, and Level 3 are equivalent to 80%, 90% and 95% respectively. These are calculated as follows.

The variance of EWMA is defined as follows.

$$s_{ewma}{}^2 = [lambda/(2 - lambda)] \times s^2$$

$$s^2 + s_{ewma}{}^2 = s^2 + [lambda/(2 - lambda)] \times s^2$$

$$\sqrt{s^2 + s_{ewma}{}^2} = s \times \sqrt{1 + [lambda/(2 - lambda)]}$$

95% confidence interval is defined as +/-1.96 times of standard deviation for a single test.

$$1.96 \times \sqrt{1 + [0.2/(2 - 0.2)]} = 2.066$$

In this test procedure, only when the Level 3 alarm is exceeded, an additional reference test must be conducted and the test laboratory must follow following processes. The Y value calculated by the additional reference test is defined as Yi+1.

Case 1) |Yi - Yi+1| ≤ [ei Level 3 Limit]
Keep the Yi value as is.

Case 2) Yi > Zi-1 and Yi - Yi+1 > [ei Level 3 Limit]
Revise the Yi to be [ei Level 3 Limit] + Zi-1

Case 3) Yi < Zi-1 and Yi - YI+1 < -[ei Level 3 Limit]
Revise the Yi to be [ei Level 3 Limit] + Zi-1

Case 4) If none of Case 1), 2), and 3) is true
Keep the Yi value as is.

Once the proper Yi value has been determined, update the charts. If these parameters are within limits, the engine/stand can be utilized for further candidate oil evaluations.

5. Reference Oil Assignment

When a test laboratory runs calibration tests, these tests must be recorded with test key numbers assigned by JALOS.

Three calibration tests are required with three JASO reference oils for a new test engine/test stand calibration. Based on the request from the test laboratory, JALOS assigns the order of three JASO

reference oil tests and their test key numbers in a random manner. The test laboratory must run the calibration tests in the order notified by JALOS.

When a test laboratory requests JALOS to assign one reference test for an extension of calibration period for an existing engine/stand, JALOS assigns one reference oil from two JASO reference oils other than the reference oil used in the last reference test in a random manner. JALOS notifies the reference oil and its test key number to the test laboratory.

6. Report of Calibration Test

A test laboratory shall report calibration test results to JALOS soon after completions of reference oil tests. Following items shall be reported.

Table 4. Report Items for Reference Oil Test

Item	Form	Remark
Test Key Number	Serial number starting from 10000	Assigned by JALOS prior to the reference test
Laboratory Code	One Alphabet character	JASO Round Robin participating laboratories continue to use existing codes. A new laboratory needs a code assigned by JALOS.
Completion Date	8 digits in YYYYMMDD	Date of the BC After test
Reference Oil Code	Chosen from GE108A, GE208, or GE216	
Test Stand Code	Identifier of a test stand within a test laboratory	simple number is enough
Test Engine Code	Identifier of a test engine within a test laboratory	simple number is enough
Number of Fuel Economy Measurement Tests	Total test run number on the engine, including JASO BC, reference oils, and candidate oils	When BCB, reference oil, and BCA are run, the count is 3.
Test Result	The value with 2 decimal places	
Validity of the Test (Inclusion in the LTMS)	Y for operationally valid test. N for operationally invalid test.	Invalid test must be excluded from the LTMS charts.

7. Construction of Reference Oil Test Database and Disclosure of Industry Control Charts

JALOS constructs an industry EWMA chart based on all valid data reported in accordance with section 6 from all laboratories against completion date order in the calculation process shown in the section 4 with using Lambda = 0.2 for the industry in Table 3.

If the plotted data exceeds the Level 1 Limit or the Level 2 Limit, JALOS notifies it to the JASO

Gasoline Engine Fuel Economy Test Surveillance Panel. When the result exceeds Level 1 Limit and does not exceed the Level 2 Limit, the Surveillance Panel notifies the caution to all test laboratories. When the result exceeds the Level 2 Limit, the Surveillance Panel takes actions to investigate causes and countermeasures.

8. Test Validity Check and Severity Adjustment

8.1. Definition of BC Shift, Calculation Method, and its Acceptance Criteria

BC Shift represents the variation of the total fuel consumption between the BCB test and the BCA test. Fuel economy improvement targets for each JASO reference oil is defined as relative reduction of fuel consumption to the average of the BCB test and the BCA test. As the indicator of test repeatability, the BC Shift defined as follows.

$$[\text{BC Shift}(\%)] = \frac{[\text{TFCBCB}(\text{kg/h})] - [\text{TFCBCA}(\text{kg/h})]}{[\text{TFCBCB}(\text{kg/h})]} \times 100$$

BC Shift (%) : Variation of total fuel consumption between the BC Before and the BC After

TFCBCB : Total Fuel Consumption of BC Before (kg/h)

TFCBCA : Total Fuel Consumption of BC After (kg/h)

Based on the JASO Round Robin result, a set of tests shows a BC Shift exceeding ±0.80% is defined invalid test.

8.2. Severity Adjustment for Candidate Test

For each individual test engine/test stand, a latest Zi value calculated by the EWMA chart is applied to calculate its severity adjustment.

$$\text{S.A.} = (-Z_i) \times (pooled\ Standard\ Deviation)$$

The "pooled standard deviation" is 0.21% as defined in Table 2.

The Zi represents the variation of the test engine/stand from the target values of reference oils defined by the JASO Round Robin based on the cumulative data. The S.A. has a minus sign in order to adjust the variation. The S.A. value shall be rounded to two decimal places and applied to candidate test results.

For example, when Zi =0.4, the S.A. is calculated as (-0.4) x 0.21% = -0.084%. Then the S.A. is rounded to -0.08% and applied to a candidate result. If a candidate test result is 1.10%, then 1.02% = 1.10% + (-0.08%) is the final test result with the severity adjustment.

9. Example of Control Chart Construction

There are two types of control charts, one is constructed by each test laboratory with each test engine/test stand for the severity adjustment, and another one is constructed by JALOS to monitor the industry trend based on all test laboratories who conduct this fuel economy test for the JASO M 364:2019 engine oil standard. The industry chart is disclosed on the home page of the JASO Engine Oil Standards Implementation Panel

Examples of control charts are shown below. The test data is from the JASO Round robin. The completion date is not actual date, but assigned for constructing examples. Test results with GE116 are also plotted in these charts.

9.1. Control Charts for Individual Test Laboratory

Figure 1 shows the example of the Shewhart Chart (Yi) of one of test laboratories.

The Yi is the standardized value by the target mean and the standard deviation defied for JASO reference oil. Plus value means mild trend, minus value means severe trend.

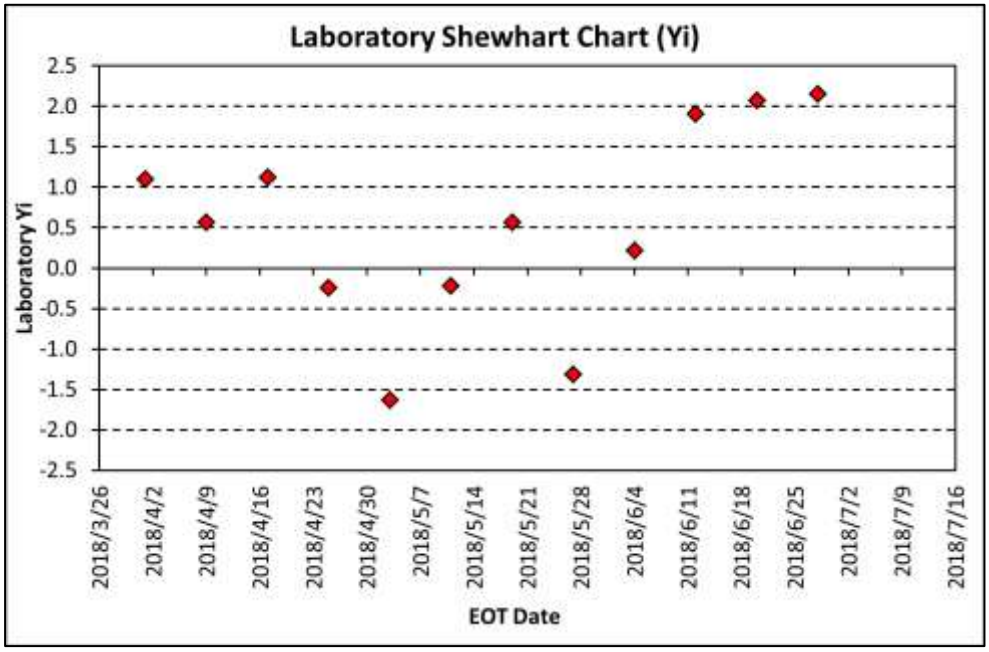

Figure 1. Example of Shewhart Chart (Yi) for a test laboratory

Figure 2 shows the example of EWMA Chart (Zi) calculated from Yi. Level1 Limit, ±0.000 is applied to the Zi for each test laboratory, that is, the S.A. is calculated for all candidate tests based on the latest Zi value. The Level 2 Limit is ±1.800. No exceeding data point is found in Figure 2. This confirms that the test laboratory has no problem on the severity trend.

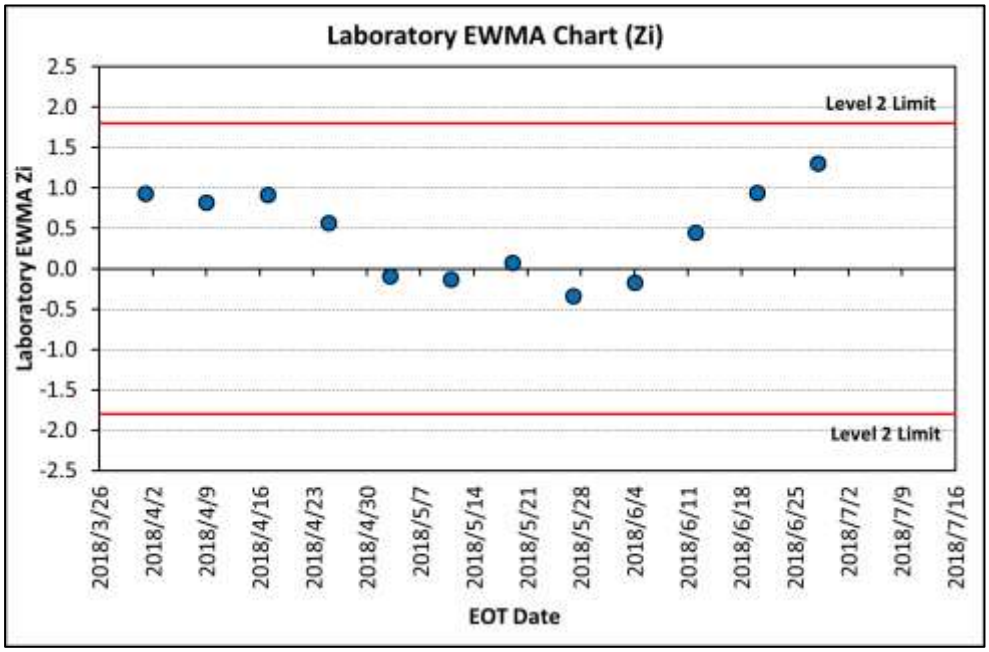

Figure 2. Example of EWMA Chart (Zi) for a test laboratory

Figure 3 shows an example of Prediction Error Chart (ei) calculated based on the Yi in Figure 1 and the Zi in Figure 2.

In this cart, 4th test and 9th test exceed the Level 3 Limit, ±2.066. If these are conducted for calibration purpose, then additional test is required as described in the section 4.4. In case of Figure 3, the value of |Yi - Yi+1| falls in the Case 1 defined in the section 4.4, then the calibration is completed with one additional test and the test engine/test stand can continue to be utilized for candidate tests.

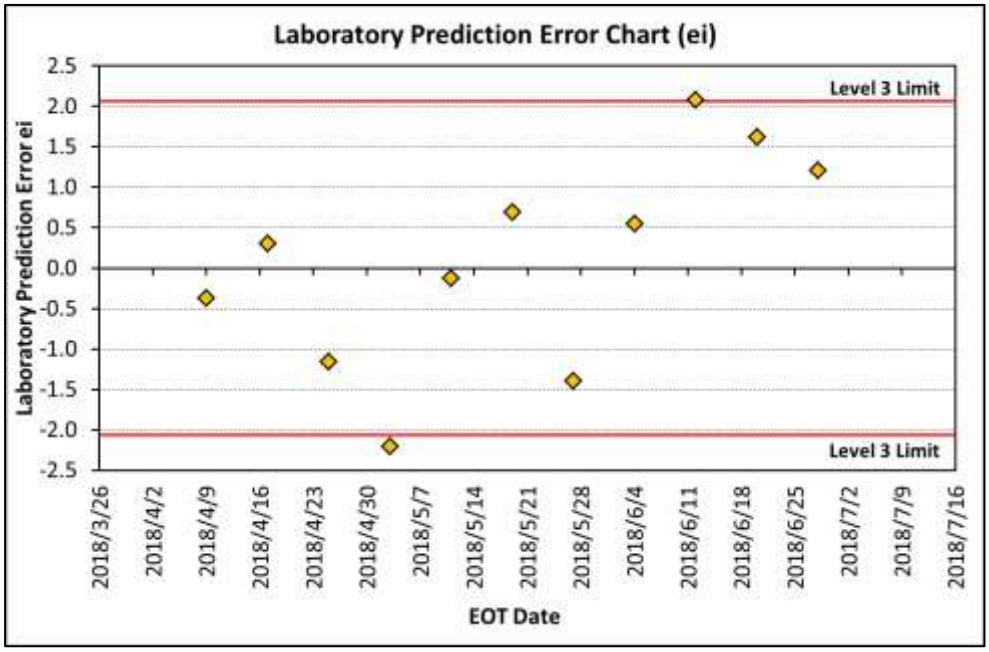

Figure 3. Example of Prediction Error Chart (ei) for a test laboratory

9.2. Example of Industry Control Chart Construction

Figure 4 shows an example of Shewhart Chart (Yi) with entire industry data.

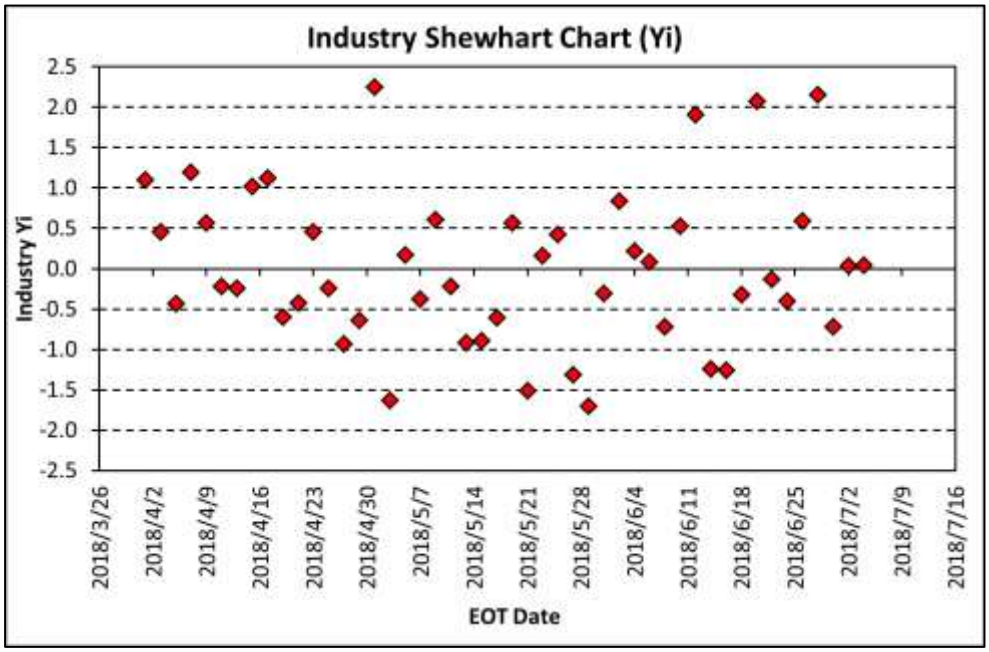

Figure 4. Example of Shewhart Chart (Yi) for the entire Industry

Figure 5 shows an example of EWMA Chart (Zi) calculated based on the Yi in Figure 4.

Slowly moving trend around zero can be found, but no test exceeds the limits. Thus, it is confirmed that the industry severity is well under control.

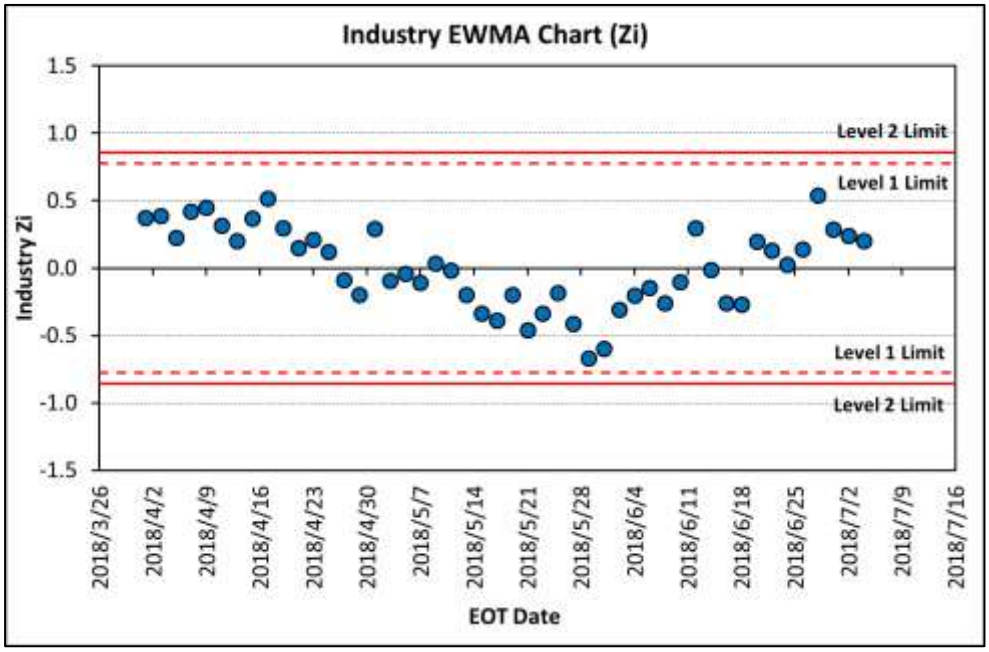

Figure 5. Example of EWMA Chart (Zi) for the entire Industry