Test Method Compliance
Generic discussion document

CEC Management Board

November 2009

Aims

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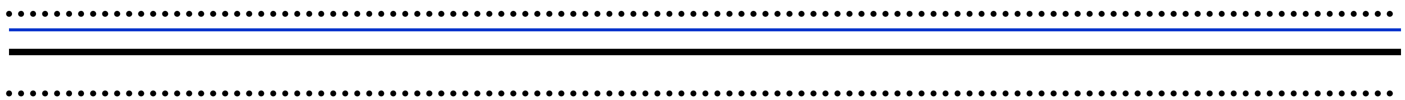
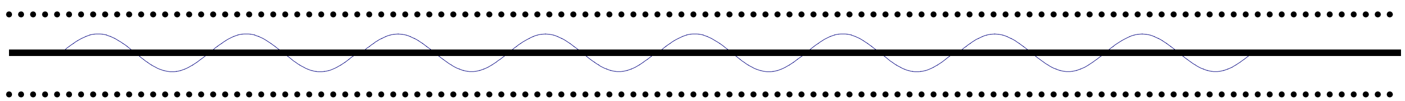
- Alignment with set point values
- Demonstrating conformance with the procedure
- Data-led discussions between group members
- Stimulus for continued improvement

Running Close to a Set Point

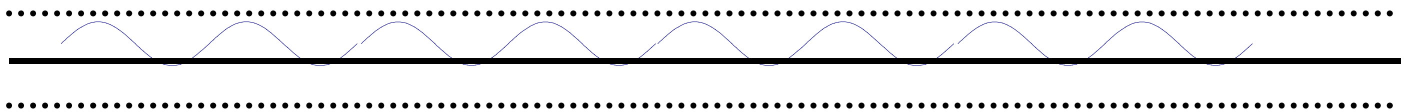
Offset



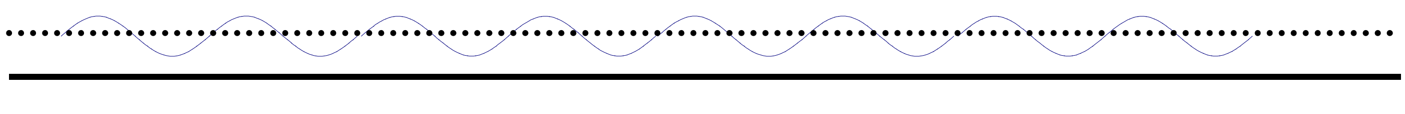
Hunting about a set point, staying within control limits



Hunting about a set point with bias



Hunting, bias and occasional operation outside control limits



Others....eg drift etc

Options

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- **Number of out of limits occurrences**
  - Easy to implement
  - A large number of out of limit occurrences is emotive and therefore a good driver of improved performance
  - Does not distinguish small from large events
  - Requires parameter to be operating outside a control limit
  - Does not drive alignment with the setpoint
- **Integral of [X-Limit]*time for each control parameter**
  - Harder to implement
  - Distinguishes small from large events
  - Requires parameter to be operating outside a control limit
  - Does not drive alignment with setpoint

…Continued

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- **Quality Index**
  - Harder to implement
  - Accommodates all events with a weighting dependent on scale
  - Drives set point alignment
  - All parameters are normalised so that QI=1.0 implies perfection
  - Can be made to rank 'perfect' [QI]=1 to 'Just acceptable [QI=0] to 'Invalid' [QI<0] by adjusting U and L
  - Abstract concept and the square term is very harsh on one-off major deviations

$$QI = 1 - \frac{1}{n}\sum_{i=1}^{n}\left\{\frac{U + L - 2X_i}{U - L}\right\}^2$$

$$X_i = Current\_Value$$

$$U = Upper\_control\_value$$

$$L = Lower\_control\_value$$

$$n = number\_of\_measurements$$

Scope

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- **All controlled variables with set point values**
  - Speed, Torque, Fuel Flow, Coolant Temperature etc
- **Some consequential variables which are considered important**
  - Exhaust Temperature, Boost Pressure, Compressor Outlet Temperature etc

Which Technique To Choose

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- Out of limit occurrences is emotive [which in this context is good], but is insensitive to the scale of the event and does not drive alignment with the set point
- Integrated alarms are harder to implement, are sensitive to scale, but do not drive alignment with the set point
- QI is harder to implement, is sensitive to the scale of an event and does drive alignment with the set point, can be set up to distinguish between perfect, valid, marginal and invalid tests - but is rather abstract
- All three help a data-led discussion between members and hence stimulate dialogue and continuous improvement

- On balance…

Favour Quality Index

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$$QI = 1 - \frac{1}{n}\sum_{i=1}^{n}\left\{\frac{U + L - 2X_i}{U - L}\right\}^2$$

$$X_i = Current\_Value$$

$$U = Upper\_control\_value$$

$$L = Lower\_control\_value$$

$$n = number\_of\_measurements$$

QI=1 implies perfect alignment with the set point
QI=0 implies general alignment with the upper and lower control values
QI<0 implies operation outside of the control values for too large a portion of the test

U and L are chosen to place QI=0 at a marginally acceptable level of deviation

Sample Engine Test Variables

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- Speed
- Torque
- Fuel flow
- Coolant temp
- Exhaust gas temp
- Coolant temperature increase across the engine
- Intercooler outlet temperature
- Others?

- NB smoke and sump temperature not included because smoke measurement is awkward and sump temperature will depend on oil composition

Logging Frequency

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- Define unambiguously so all labs do the same

Setting U and L

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- The EOT QI value depends on the tolerance values set for U and L
- Typical QI values should be in a sensitive range, sufficiently far away from 1 that there is scope for improvement and not too low that the precision of the measuring equipment becomes important
- Review early data and set U and L to give QI values of zero for a test which is considered marginal, but OK

What to calculate

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$$QI = 1 - \frac{1}{n}\sum_{i=1}^{n}\left\{\frac{U + L - 2X_i}{U - L}\right\}^2$$

$$X_i = Current\_Value$$

$$U = Upper\_control\_value$$

$$L = Lower\_control\_value$$

$$n = number\_of\_measurements$$

- Point values of the ‘bracket’
- -1*sign(bracket)*bracket*bracket
- Cumulative QI values over the whole test
- End of cycle QI values for each of the critical parameters

QI Report

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- **Three graphs per parameter:**
  - Each X value throughout the test
  - -1*sign(bracket)*bracket*bracket
  - Cumulative QI value
- **Aiming for ~300 values per graph**

Sample Output For X

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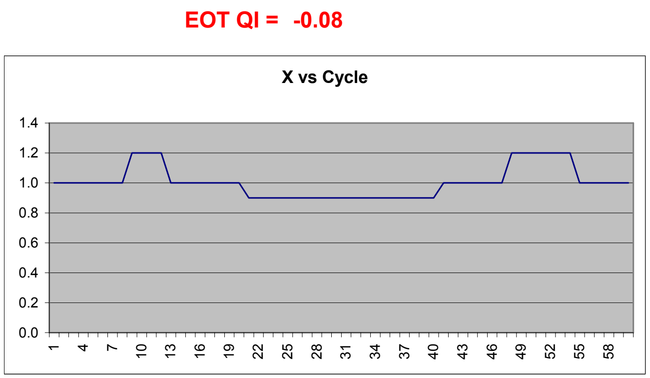
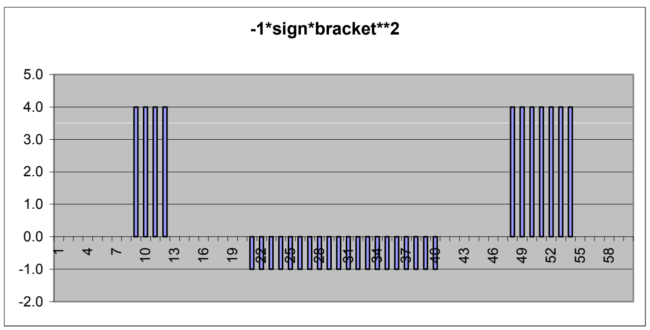
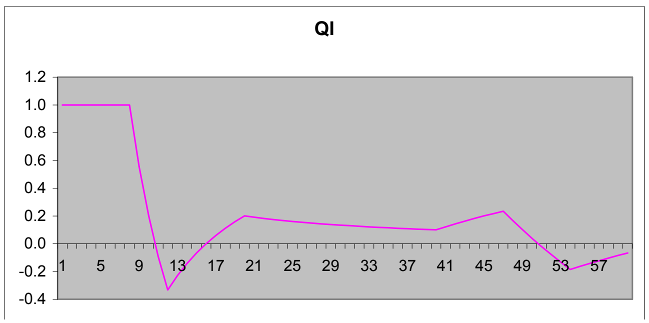


End of test QI value for X

Actual values of X for each cycle – target =1.0
Indicates where the deviations occur



Squared deviation from set point
Highlights where the major contributions to QI occur



QI = cumulative normalised mean square deviation from the set point
Depicts how QI evolves over the whole test