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DACA II Review Task Force Conference Call Minutes
Wednesday July 28, 2021
9:00-10:30 AM Central

Minutes recorded by Patrick Lang
Direct any comments or corrections to: patrick.lang@swri.org

Membership:

The attendance list can be found as attachment # 1.

Agenda:

The proposed agenda can be found as attachment # 2.

Approval of Minutes:

Pat Lang advised that there were no requested changes or comments on the June16, 2021 minutes. A motion was made by Pat Lang and seconded by Bill Buscher to approve the minutes. The motion passed unanimously.

Endorsing the name “DACA III”:

Although it had been discussed in earlier meetings, Chairman Lang asked the group to consider the official name of the revised DACA II document to be “DACA III”. Since the DACA terminology is so well known and referred to in many other documents, it makes sense for the revised version of the document to have a similar name. The group agreed unanimously.

Scope and Objectives:

The group reviewed the scope and objectives section of the DACA II document. See attachment # 3 (first page) for the wording that was reviewed during the call. It was agreed that the history portion of the introduction and scope needed to be updated. David Doerr commented that the document really has two purposes which are to define accuracy and quality index (QI). Randy mentioned that another goal is to define a minimum performance.

Action Item #1:

Pat will revise the wording of the scope and objectives based on the input from the group and will distribute for review on the next call.

Review SwRI's first draft of the System Time Response Section of the DACA II Document:

At this point the group reviewed the first draft of the revised DACA II document that SwRI had prepared and distributed before the meeting. See attachment # 3 for the document with the change tracker notes displayed.

Regarding page 2 of 13 in the DACA II document, there was a lot of discussion on the resolution of the time constant measurement. SwRI was recommending that the resolution of the time constant value should be not greater than the data sampling rate. This would prevent the any interpolation between actual measured points. There was some opposition to this in the context that we are splitting hairs worrying about that potential little difference. In the end the group agreed to define the rate at 0.1 seconds.

On page 8 of 13, there we some discussion on a frequency generator in the TMC Verification section. A frequency generator is needed to check the RPM channel. George also mentioned that a Micromotion has a frequency output and the generator can be used to replace it when checking the system. David Doerr and Randy Harmon agreed that the intent of mentioning the frequency generator in that section was to be able to do a frequency sweep in order to measure response time. After a further discussion the group agrees to remove the reference to the frequency generator to measure response time and state that the TMC will use the step change method to audit system response time.

The recommended changes to Appendix A were reviewed by the group next. This one was straight forward in that most of the wording could be removed because it was mentioning specific types of filters. Refer to attachment # 4 to see the wording that is recommended to be removed.

Summary of Specific Time Constants:

David Doerr of Lubrizol put together a spreadsheet (see attachment # 4) that summarized the different time constants that are specified in many of the current test procedures. David pointed out that for a specific parameter like RPM, there are different time constants for different test procedures. It seems that there should be some level of consistency to these values. It was suggested that we need to consider including the recommended time constants in the DACA III document.

Next meeting Topic:

Pat Lang recommended that for the next meeting we review the document with the changes incorporated (accept changes in the change tracker in Word document) and the panel review again. We will also continue our discussion on the step change methodology as outlined in the TMC document “TMC System Time Response Measurement Guidelines” that was attached to the 6-16-21 minutes.

Adjournment:

The meeting was adjourned at 10:30 AM CDT.

Next meeting at the call of the chairman with a tentative date of September 1, 2021 at 10:30 EDT.

Attachment #1

Attendance List

Attendance List for DACA II Document Review Task Force

Name	Company	Present 7-28-21 X= present
Amol Savant	Valvoline	x
Al Lopez	Intertek	x
Bill Buscher		
Andrew Stevens	Lubrizol	x
George Szappanos		
David Doerr		x
Jim Matasic		
Randy Harmon	Southwest Research	x
John White		
Ron Barthold		x
Khaled Rais		x
Bob Warden		x
Mike Lochte		
Ankit Chaudhry		
Tom Wirries		x
Chris DesRuieeeau		
Bob Campbell	Afton	x
Tim Cushing	General Motors	x
Jim Gutzwiller	Infineum	x
Andy Ritchie		
Michael Tucker	Exxon Mobil	x
Rohit Rao		
Jason Griffin		x
Mike Deegan	Ford	x
Robert Stockwell	Oronite	x
Jeff Clark	Test Monitoring Center	
Rich Grundza		
Sean Moyer		x

Attachment #2

Agenda

AGENDA

Data Acquisition and Control Automation II (DACA II) Review Task Force
Virtual Meeting (WebEx)

Patrick Lang – Acting Chairman

Wednesday July 28, 2021– 9:00 AM to 10:30 AM (CDT)

1. Attendance

2. Review of the minutes from the 6-16-21 conference call, distributed on 7-9-21 by email from chairman.

3. Review Topic: System Time Response

    3.1. Approval from group to officially call the revised document "DACA III"
    3.2. Review and updated scope
    3.3. Review SwRI's first draft of changes to original DACA II document
    3.4. Continue discussion on system time response
        -Review LZ time constant summary

4. Determine topic for next meeting

5. New Business

6. Next Meeting: Tentatively Wednesday September 1st, 2021 at 10:00 to 11:30 EDT; chairman to send out calendar invite.

7. Adjournment

Attachment # 3

DACA II Word Document with Change Tracker Displayed

Data Acquisition and Control Automation II
Task Force Report

June 17th, 1997 Final Report

Introduction
The evolution of the dynamometer crankcase lubricant testing industry is entering a new era. New test types being developed are, for the first time, making exclusive use of computer equipment for data acquisition and process control. Recent advances in the performance, flexibility, and cost effectiveness of electronic equipment make this development possible; likewise, it brings forth a need to standardize on various aspects of the way data is acquired, logged, and used to interpret test operation. The Data Acquisition and Control Automation II (DACA II) Task Force was formed in August, 1996, to address these issues. The recommendations in this report are meant to be guidelines for use by test developers/surveillance panels in developing test specifications.

Scope
The DACA III Task Force was charged with ~~developing~~ specifying minimum performance specifications for ~~generic~~ Data Acquisition and/or Control systems suitable for use~~, with test specific minor modification,~~ with all targeted ~~GF-3~~ ASTM engine oil tests. Performance requirements will be differentiated for controlled and non-controlled operational parameters, and for steady state and transitory conditions. In addition, a means by which TMC engineers can verify compliance of a specific test apparatus will be specified. The Task Force will make use of existing ASTM reports (RR:D.02 -1210 "Data Acquisition Task Force Report", 12/9/85, and RR:D.02-¬1218 "Instrumentation Task Force Report to the ASTM Technical Guidance Committee", 12/31/87) on which this new work will be based. The Technical Guidance Committee was tasked in 2020 to review the DACA II document and make any appropriate changes.

Performance Specifications – Controlled Parameters, Steady State Conditions
Logging Rate:
The maximum period between successive logs of recorded data should be 2 minutes.

System Time Response:
In this report, discussions of the response time will refer to the overall response of the complete measurement and data acquisition system of a parameter, from the measurement probe to the final displayed or logged value.

A system's time response can be determined by measuring the amount of time to reach a certain percentage of an imposed step change. A widely used value is 63.2%, which is the definition of a time constant for a first order system. For example, for a thermocouple at 25°C ambient temperature being immersed into an ice/water mixture at O°C, the step change is 25°C. The response time of this measurement system is the time required for the temperature reading to reach 9.2°C:

```
t = time to (start value - (start value - end value) × 0.632)
```

or

```
t = time to (25 - (25 - 0) × 0.632) = time to 9.2°C
```

For each new test type being developed, a particular stand should be designated as the "Golden" stand, i.e. the stand used for test development, from which minimum test requirements will be derived. The maximum allowed response time of each system is derived from a measurement of the system used by the "Golden" stand during the test development. Because the response of a system can vary with different excitation modes, a uniform method of measurement of a system response time is necessary. The techniques used to measure the response times are:

Parameter	**Step Change**
Temperature	Insert probe from ambient air into ice/distilled water mixture to cover the length of the probe.
Pressure	Pressurize system from the measurement point (to include the entire system), then instantly release pressure. Time constant is of the response to the release in pressure.
Load	Remove previously applied weights quickly from the load cell.
Speed	Impose step change at the pickup connection through a frequency generator.
Flow	Method used to measure the time constant on the Golden stand.

Response time is measured from the imposition of the stimulus. Step change deltas should be at least 100 times the resolution of the measurement system. Time response resolution should be no less than 0.1 seconds ~~not greater than the sampling time. For example, if the sample is 0.1 seconds, then the time response should be to a tenth of a second (ie. no interpolation).~~ ~~If the measurement system is of a linear response type and not a first order system, the response of the system will be converted to a first order equivalent for the purpose of determining the response time.~~

~~Appendix A includes a section on the equivalency of linear averaging of discrete readings and systems which can be represented by a first order response.~~

Systems are to be designed with components that, when working together, will not exceed the maximum specified system response time.

Statistical Calculations:
The quality of the control of the parameter being measured shall be calculated through the use of the Quality Index (QI):

Commented [RH1]: Per 06/16/21 meeting – remove any specific mention of the type of filter required

Commented [RH2]: Per 06/16/21 meeting – remove any specific mention of the type of filter required

Commented [RH3]: Consider adding description of how filtering can affect QI calculations

$$QI_i = 1 - \frac{1}{n}\sum_{1}^{n}\left(\frac{U + L - 2X_i}{U - L}\right)^2$$

where:

U = Upper QI limit
L = Lower QI limit
X_i = Data reading at instance i
n = Number of readings thus far in the test

Perfect control of a parameter results in a QI of 1.00. Any deviation from the target lowers the QI. The amount and duration of the deviation affects the final QI for the parameter. How often the QI is updated, and, conversely, how many readings are taken also affect the effectiveness of the QI to capture the quality of the control of the parameter.

For multi-stage tests, the test developer/surveillance panel should determine whether or not a separate QI will be calculated for each stage. If separate Qls are calculated, and a single final QI is desired, the final QI should be an appropriately weighted average of the individual Qls.

The test developer/surveillance panel should determine, for each parameter, whether variations in the signal are random or cyclical. If random, a minimum of 10^3 samples must be used for the QI calculation. If cyclical, the period at which the data for the QI calculation is sampled for a parameter can be dependent upon the "period of the phenomenon of interest" (t_i). Phenomenon of Interest is defined as that quality of the measured parameter that is primary interest to the surveillance. For example, oil pressure may fluctuate with each oil pump gear mesh, but that is limited interest compared to larger fluctuations in pressure due to more macro processes. The QI sampling period can be derived from the **t** period by the following equation:

$$\text{QI Sampling}_{Max}(\text{sec}) = t/2$$

where:

t = period of phenomenon of interest in sec

note: the Nyquist theorem is 2 readings/period to reproduce the waveform

Any new test development shall include a determination of the cyclic period for each of the parameters of interest to be measured, if applicable. For parameters such as speed, intake vacuum, etc, that have an extremely fast response rate, with a corresponding cyclic period shorter than 2 sec, the minimum required QI sampling period should be determined from data from the Golden stand.

The laboratory systems employed must be able to calculate QI from in-progress test data, either in real time or on command. That is, the QI could be calculated and updated each time a reading is sampled, or the samples logged and the QI calculated from logged data.

For purposes of TMC verification, the laboratory data acquisition system should be capable of “dumping" sufficient data onto permanent media in electronic format. The data should include a time stamp for each reading, the data reading, and a final QI for that set of data. The data should be from an actual test stand and acquired, at a minimum, at the required QI calculation rate.

The upper and lower limits for the QI calculations are derived statistically from the operating conditions of the test development "Golden" stand. The limits should be adjusted and set during test development to result in a final QI of approximately .80 to .90 for each parameter on the Golden stand. These limits can be calculated from the operational data. This will result in a uniform criteria for assessing the quality of a test.

For test validity, the QI threshold should be below the QI of the test development Golden stand. This threshold should be determined after sufficient operational data from multiple labs have been generated.

Accuracy

The System Accuracy Table listed on the following page is the generic capability of an entire measurement system based on current conventional cost effective technology, taking into account reasonable environmental effects.

The inclusion of this table is intended to serve as a guide to the test developers and surveillance panels as to what is commonly possible using current technology. It is not intended to be an all inclusive summary of available technology. The DACA II task force has deliberately not listed the capabilities of equipment that, in its judgement, is not appropriate for use in an engine testing environment due to reliability, cost, or performance concerns.

Accuracies are stated for systems that have been calibrated using due diligence with NIST traceable equipment, and have been applied using good engineering practices. The recommended method to calculate the system accuracy is the Square Root of the Sum of the Squares of the component accuracy.

Current Measurement System Capabilities

Measurement Type	System Type	System Accuracy
Temperature	Thermocouple	0-200° ± 0.50 °C 200-1000° ± 2.00 °C
	RTD	± 0.12 °C
Pressure High (> 6.9 kPa)	Capacitive	± 0.2 % of Full Scale
	Strain	± 0.25 % of Full Scale
Pressure Low (0 - 6.9 kPa)	Capacitive	± 15 Pa
	Strain	± 14 Pa
Flow	Orifice Venturi	0.75% of reading
	Vortex (Liquid) Vortex (Gas)	± 0.75 % of reading ± 3.0 % of Full Scale
	Magnetic	± 1 % of reading
	Coriolis	± 0.25 % of reading
Speed	Frequency	± 1 rpm
Load	Strain Gage	± 0.25% of Full Scale

Non Controlled Parameters:
For non controlled (read-only) parameters, the following apply:
- The specification of response time of the measurement system is optional.
- Non controlled parameters do not lend themselves to QI calculations.

Transitory Conditions:
During a change in conditions, from one stage to another, or during scheduled startups or shutdowns, it may be desirable to keep tighter control of test conditions. During transitions, the minimum required data logging rate is 10% of the allowable transition time, or it is the steady state logging rate. whichever is fastest.

If a QI is to be calculated during transitory conditions, then it should be calculated independently from the steady state QI.

Resolution:
Minimum resolution of the acquired data should be at least 4 times the required system accuracy. Example: Test procedure requires an accuracy of 1.0 N. The minimum resolution is .25 N.

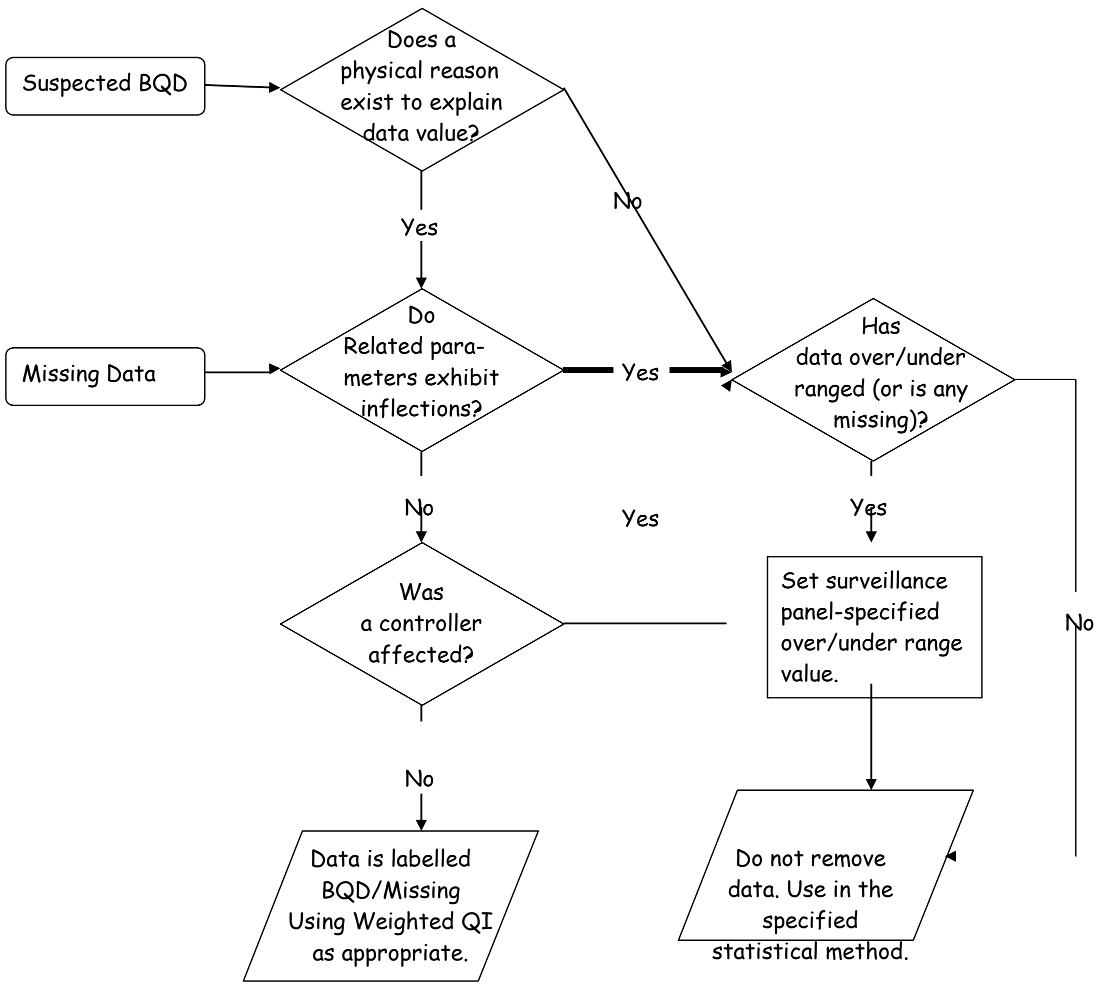
Calibration & Stability Requirements:
The calibration of laboratory equipment can affect its accuracy. The instruments used to calibrate the data acquisition system must have an accuracy four times that of the system it is calibrating.

1. The laboratory calibration standards will be traceable to a defined national standard, e.g., National Institute of Standards and Technology, and be verified at least annually.
2. Test measurement systems shall be calibrated using the laboratory standards mentioned in item 1 above at a frequency as prescribed by the individual test procedures. It is the Task Force's recommendation that all systems be calibrated a minimum of once every six months, or at any time the readout data indicates the need.
3. Whenever measurement equipment is changed, the system it is a part of should be calibrated.

Backup Data:
It is recommended each lab employ sufficient safeguards and redundancy to assure adequate test data logging in the event of electronic systems failure. Examples are redundant data storage, manual logging, screen dump, etc.

Bad Quality Data:
Some automated test cells may employ separate systems for the control of operating parameters, and for the acquisition and logging of data. In these systems, it is possible for the data acquisition system to suffer a temporary malfunction while the control system continues to maintain the proper conditions, or one control system "channel" may malfunction while the rest are unaffected. These malfunctions may result in missing or erroneous (such as 9999 deg C on a temperature) data points. These data points are referred to as Bad Quality Data (BQD). In cases of malfunctions in the test control system, in which the actual test conditions are affected, the deviations must be recorded, estimated, or otherwise incorporated into the final test QI for the parameter.

For each occurrence of suspected BQD or missing data, the following flowchart should be used:



This procedure includes a requirement for each test Surveillance Panel to set over/under-range limits. These limits will be used as substitutions for data that is acquired, but is physically impossible, such as a negative fuel flows, or temperatures of 9999°C.

In cases where the flowchart does not adequately fit the situation, the final determination of test validity and the disposition of the BQD will depend more upon engineering judgment.

In cases where data is labeled as BQD/missing, per the flowchart, the Adjusted QI is calculated as follows:

1) Remove BQD/missing data from data set per the flowchart
2) Calculate QI with remaining data points
3) Adjust QI by multiplying number of data points and dividing by the number of data points per the procedure, to obtain the QIBQD:

$$QIBQD = QI\left(\frac{n}{n_{total}}\right)$$

where: QI = QI calculated without missing/BQD points
n = number of data points used to calculate QI
n_{total} = total number of data points for a complete data set

4) Obtain the EOT QI as follows:

$$EOTQI = QI\left(\frac{n}{n_{total}}\right) + QIBQD\left(\frac{n_{BQD}}{n_{total}}\right)$$

where: QI = QI calculated without missing/BQD points
n = number of data points used to calculate QI
n_{total} = total number of data points for a complete data set
nBQD = number of missing/BQD data points ($n_{BQD} = n_{total} - n$)

Suitable backups should be employed by the labs to use as supporting evidence. The maximum logging interval for these backups should be 1 hour.

Missing data should not be more than 1% of the test length

Suitable backups should be employed by the labs to use as supporting evidence. The maximum logging interval for these backups should be 1 hour.
Missing data should not be more than 1 % of the test length.

TMC Verification:
For the purpose of aiding in TMC verification of a laboratory's filtering of input signals to their acquisition system, the step change method will be used. ~~it is recommended that each laboratory supply a function generator, capable of doing a frequency sweep, to input signals into each acquisition "channel". This will be used to determine the electrical cutoff frequency of each measurement system. Also, documentation on all known electrical and mechanical storage devices in each measurement system should be provided.~~ The TMC will use this information to verify that the ~~cutoff meets or is~~ system response meets ~~equivalent to~~ the specifications in the test procedure. ~~Appendix A outlines methods of determining equivalency among differing systems.~~

Commented [RH4]: Per 06/16/21 meeting – remove any specific mention of the type of filter required

Definitions:
PRECISION: The degree of mutual agreement between individual measurements from the process.

ORDER: The number of energy storage devices in the system. (Most process systems can be reduced to first order, i.e. one dominant energy storage device.)

FILTER: A means of attenuating signals in a given frequency range. They can be mechanical (volume tank, spring, mass) and/or electrical, which can be analog (capacitance, inductance) and/or digital (mathematical formulas). Typically, a low-pass filter attenuates the unwanted high frequency noise. Some signal filtration is necessary in order to assure sampled readings are not compromised due to noise. However, excessive filtration will mask irregularities in the process being measured and can result in an artificially high QI.

TIME CONSTANT (τ): A value which represents a measure of the time response of a system. For a first order system responding to a step change in input, it is the time required for the output to reach 63.2% of its final value.

CUTOFF FREQUENCY (f_c): The frequency point that divides the frequencies that pass through the system almost unattenuated and the frequencies that pass through the system but are greatly attenuated. For a first Order system, this value is calculated as follows:

$$f_c = \frac{1}{2\pi\tau}$$

where τ is the time constant

QI SAMPLING RATE: The rate at which data is acquired for use in the calculation of the QI.

SAMPLE FREQUENCY (f_s): The frequency at which a value is obtained for processing. This is normally considered for computer data acquisition, but is also true of a manual reading, i.e. once per hour.

DECIBEL (dB): A unit for measuring the ratio of the magnitude of two quantities (normally output voltage to input voltage). Calculated as follows:

$$dB = 20 * \log\left(\frac{Output}{Input}\right)$$

INPUT FREQUENCY (f_{in}): The frequency of the input signal. This is most certainly changing and includes real but unwanted noise. (Normally the noise is a higher frequency than the frequency of the expected signal.)

~~FIRST ORDER DIGITAL FILTER: The digital equivalent to a first order analog filter (electrical or mechanical).~~

Commented [RH5]: Per 06/16/21 meeting – remove any specific mention of the type of filter required

ACCURACY: The degree of agreement of an individual measurement with an accepted reference level.

DATA POINT: The value of a parameter after appropriate digital/analog filtering with due consideration for the time response of the system.

APPENDIX A
TMC Verification of System Filter Characteristics

Introduction

Engine Sequence testing laboratories may utilize statistical measures to indicate how tightly critical parameters are controlled. These measures can be affected by the amount of filtering associated with the acquisition of the data. In order to be able to make meaningful comparisons of data between different laboratories, testing procedures should be developed that require use of equivalent electrical and mechanical filtering. Data can be accurately compared and used in statistical calculations only when processed using equivalent filtering strategies that do not overly filter the data signals. The implementation of the testing procedure requires a method by which each lab can be tested to ensure minimum specifications are met. This document suggests verification procedures that could be used.

Filters

There are two types of filters to consider when measuring the performance of data acquisition and control systems; mechanical and electrical. Since both mechanical and electrical storage (or filtering) systems can exist in a control loop, the entire end-to-end signal path should be tested to determine a "system" time response. ~~Instances may exist where mechanical storage is non-existent and digital and/or non-computer-based electrical filtering is used to "enhance" the data signal. Some systems use non-exponential filtering techniques to smooth data, therefore rendering the "time constant" analyses of these systems inappropriate. Because of these differences, each laboratory should supply documentation on the nature of known electrical and mechanical filtering for each measurement system. To ease configuration, verification, and understanding, only first order low pass or moving average filters shall be used in computer software filtering.~~

Commented [RH6]: Per 05/11/21 meeting – treat data acquisition at system level, not component level

Verification Process

Each lab is responsible for meeting or exceeding (ie faster response) the procedural system response times for feedback control loops and any other selected parameters. The test developer will utilize a filtering strategy based on the minimum smoothing needed to provide a useable signal. Each lab will submit the known type of electrical and mechanical storage devices along with their loop response times. System response times longer than the maximum allowable response time will not be permitted.

APPENDIX A
TMC Verification of System Filter Characteristics

The TMC may visit test sites to verify stated filtering techniques and response times. This verification process is as follows:

Verification Procedure

~~1) Characterize Computer-Based filtering (signal processing) Perform step-response and/or frequency response test of the analog inputs and calculate filter time constant and frequency cut-off. Calculations are easy for first order systems:~~

~~a. Step Response -Apply step input voltage. Determine filter type: Exponential or linear. Calculate "time-constant" and cutoff frequency for exponential systems.~~
~~b. Frequency Sweep - Use function generator; input frequencies at incremental steps. Note frequency at which the computer "output" amplitude is 0.707 times the input amplitude for both low pass and moving average systems. This is the filter "cutoff" frequency. Calculate the time constant. The rate of decay of the output amplitude can be used to determine the order of classic low pass filters.~~

~~2)~~1) Loop Response Time
Each system will be tested as outlined in the DACA III Report for various parameter types. The loop response time test will capture the system response from sensor to logged value~~computer display.~~ The response time measurement is based on a time response to ~~85% because it has been determined that this is the point at which moving averages and their equivalent first order low pass filters have equal response times.~~63.2% of final value.

~~a. Ensure that equivalent filtering is used for cases where response times are to be compared between systems having different filter implementations.~~
~~b. Inject stimulus and measure time to 85%.~~
~~c.~~a. Compare response time of test system to response time in procedure on a loop by loop basis.

~~**Equating Low-mass and Linear averaging filters**~~
~~Once a filter order is verified, and frequency cutoff and time constant have been determined for an exponential responding system, it is easy to determine the equivalent moving average specifications and vice-versa. Experimental data has shown that measuring the time response to 45.4% and using this as the time~~

Commented [RH7]: 06/16/21 meeting - SwRI recommendation

Commented [RH8]: Recommended name for new document

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Commented [RH11]: Per 06/16/21 meeting – remove any specific mention of the type of filter required

constant when developing specifications for an exponential Low Pass filter produces roughly equivalent smoothing of data. This can be restated by saying that measuring the time to 45.4% of a full moving average response is equivalent to measuring the time response to 63.2% of a first order low pass filter. Applying these concepts, the following relations have been determined:

For a 100Hz sample rate:

a) 100 sample moving average @ 3rd order, cutoff = 0.48Hz filter
b) 100 sample moving average @ 1st order, cutoff = 0.37Hz filter
c) 10 sample moving average @ 3rd order, cutoff = 4.8Hz filter
d) 10 sample moving average @ 1st order, cutoff = 3.7Hz filter

Conclusion

Verifying time responses of like (both having classic LPF responses) systems is an easy task. Both system time responses are measured and directly compared for equivalency.

Verifying time responses of LPF versus Moving Average systems is not so straightforward. To ease the comparison between systems, the following are required:

1) On classic LPF style filter systems, keep software filter order to 1.
2) Use an equivalent low pass filter to the moving average (or vice versa).
3) Utilize the time to 85% for measuring system time responses.

Once the computer filtering systems have been equalized, the loop response times can be measured and the time response to 85% can be determined and compared for both systems.

Commented [RH12]: Per 06/16/21 meeting – remove any specific mention of the type of filter required

Attachment # 4

LZ Summary of Time Constants Specified in Various Test Procedures

Compiled July 2021 by Lubrizol

System Time Responses (sec)	Seq IIIF	Seq IIIG	Seq IIIH	Seq IX	Seq X	Seq VIE	Seq VH
Speed	0.10	0.10	0.10	0.50	0.50		1.90
Torque	0.60	0.60	0.60	0.70	0.70		
Flow (General)							
Coolant Flow	8.00	8.00	8.00	8.00	8.00		17.00
Rocker Cover Flow							2.00
Air Flow							
Fuel Flow						see note 1	
Pressure (General)							
Intake Air Pressure	0.75	0.75	0.75	1.20	0.20		2.60
Exhaust Air Pressure	1.20	1.20	1.20	1.20	0.20		1.70
Engine Coolant Pressure				1.20	2.00		2.00
Manifold ABS Pressure							1.80
Temperature (General)	2.40	2.40	2.40	2.40	0.60		2.40
Engine Oil In Temperature							
Engine Coolant Out Temperature							
Inlet Air Temperature							
BlowBy In							
RAC Coolant In							

Note 1: Procedure's only comment regarding filtering is "no filtering on fuel flow"

Compiled July 2021 by Lubrizol

System Time Responses (sec)	GMOD	Seq IVB	1P	1K1N	T11	T12	ISM
Speed	0.10	1.80	3.00	3.00	2.00	2.00	2.00
Torque	0.60	2.00					2.00
Flow (General)	8.00				45.00	45.00	45.00
Coolant Flow		8.00					
Rocker Cover Flow							
Air Flow			3.00				
Fuel Flow				73.00			
Pressure (General)		1.70	3.00	3.00	3.00	3.00	3.00
Intake Air Pressure	0.75		3.00	3.00			
Exhaust Air Pressure	1.20		3.00	3.00			
Engine Coolant Pressure							
Manifold ABS Pressure							
Temperature (General)	2.40	2.80	3.00	3.00	3.00	3.00	3.00
Engine Oil In Temperature							
Engine Coolant Out Temperature							
Inlet Air Temperature							
BlowBy In							
RAC Coolant In							

Note 1: Procedure's only comment regarding filtering is "no filtering on fuel flow"

Compiled July 2021 by Lubrizol

System Time Responses (sec)	ISB	CAT C13	T13	DD13
Speed	2.00	2.00	2.00	2.00
Torque	2.00			2.00
Flow (General)	45.00		45.00	45.00
Coolant Flow				
Rocker Cover Flow				
Air Flow				
Fuel Flow		40.00		
Pressure (General)	3.00	3.00	3.00	3.00
Intake Air Pressure				
Exhaust Air Pressure				
Engine Coolant Pressure				
Manifold ABS Pressure				
Temperature (General)	3.00	3.00	3.00	3.00
Engine Oil In Temperature				
Engine Coolant Out Temperature				
Inlet Air Temperature				
BlowBy In				
RAC Coolant In				

Note 1: Procedure's only comment regarding filtering is "no filtering on fuel flow"