Project Update

High Temperature Connector Committee Testing Support – Phase II

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Presentation Agenda

- Why are we doing this (Purpose)?
- What are we doing?
- What are some of the results?
- Another way to look at the results (Control Charts)?
- Final thoughts / What's left to do?

Presentation Agenda

Why?

Purpose

- Conduct testing on connectors used with HTLS conductors, which will help the industry better understand their performance under tension
- Help support the *ANSI C119.7 Committee on Connectors for Use with High Temperature Conductor* by providing information that will help them finalize the development a test standard for connectors used with high temperature conductor.

Purpose

- Questions our work helps the ANSI C119.7 Committee Answer
  - What effect do different tensioning schemes have connector temperature and resistance?
  - What should be the elevation temperature target?
  - What tensioning scheme should be used?
  - What issues will laboratories experience when testing at high temperatures?

Tasks

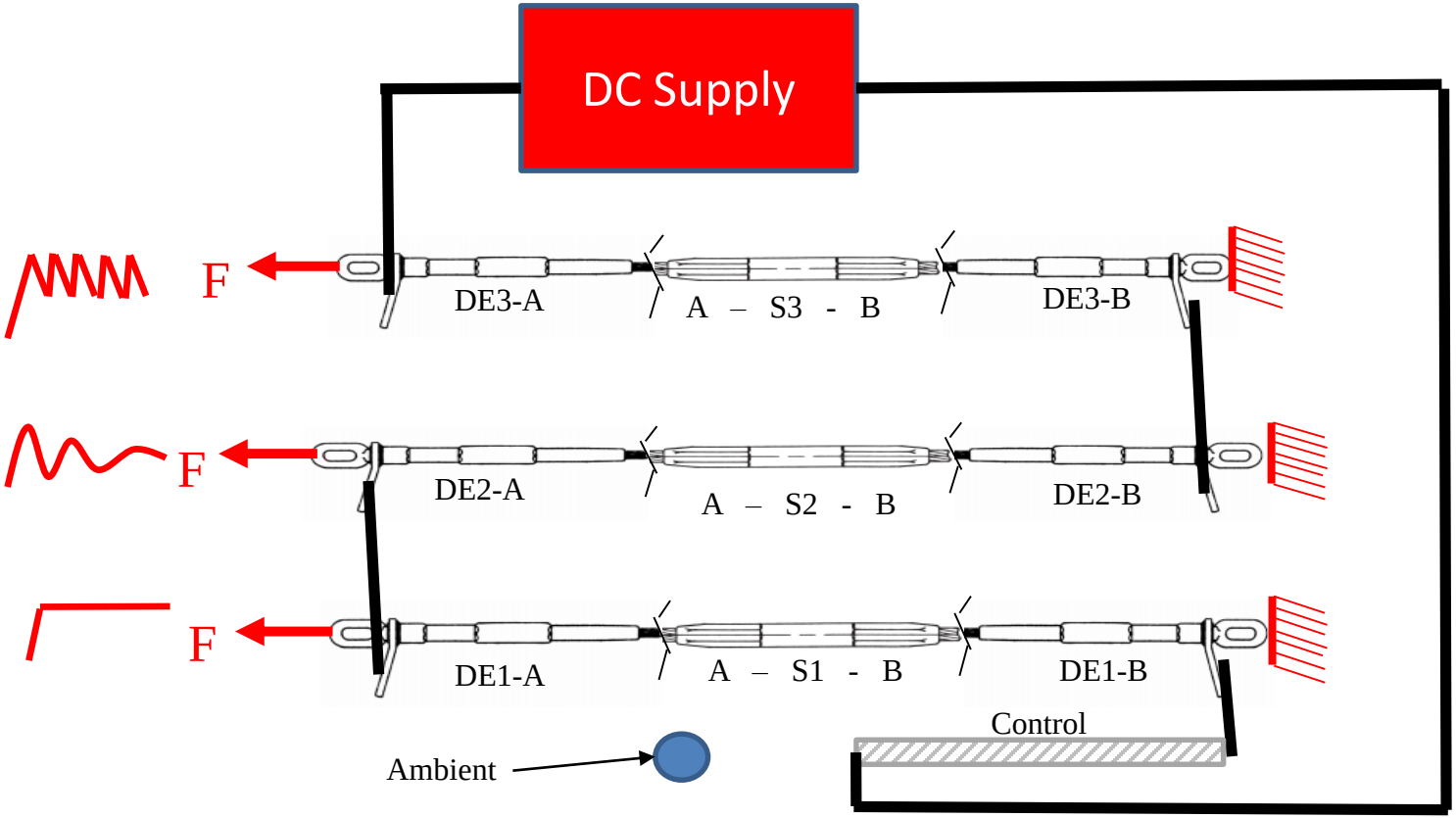
1) Order materials
2) ✓ Finalize testing parameters with TAs and ANSI C119.7
3) ✓ Design and build tension frames
4) ✓ Conduct current cycle test first loop
5) ✓ Tensile test first loop samples
6) Conduct current cycle test second loop
7) Tensile test second loop samples
8) Conduct current cycle test third loop
9) Tensile test third loop samples
10) Prepare closeout
11) Write report
12) Communicate with TAs
13) Communicate with ANSI C119.7

Presentation Agenda

What?

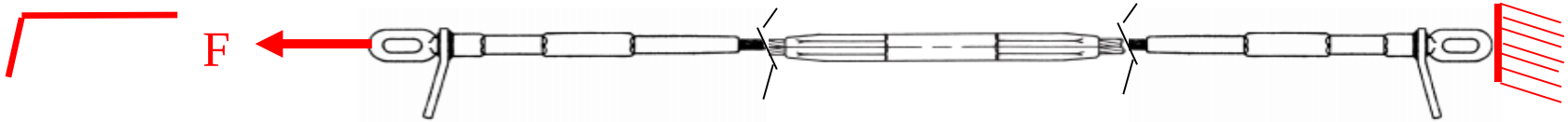
The Tension Frames

CCT Loop Diagram

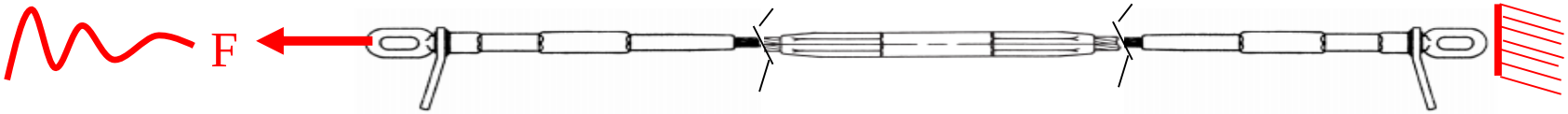


Test Plan (Tension Conditions)

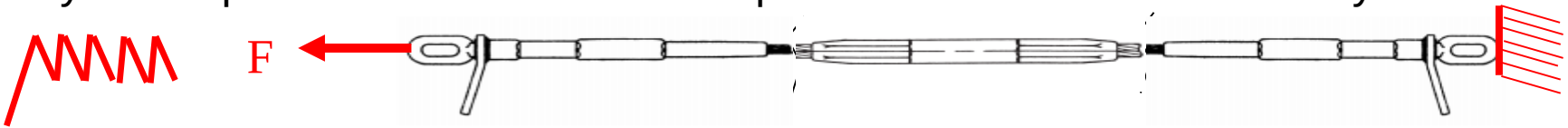
Condition 1: constant tension at 18% RBS; temperature cycle between room temperature and 250° C for 1500 cycles



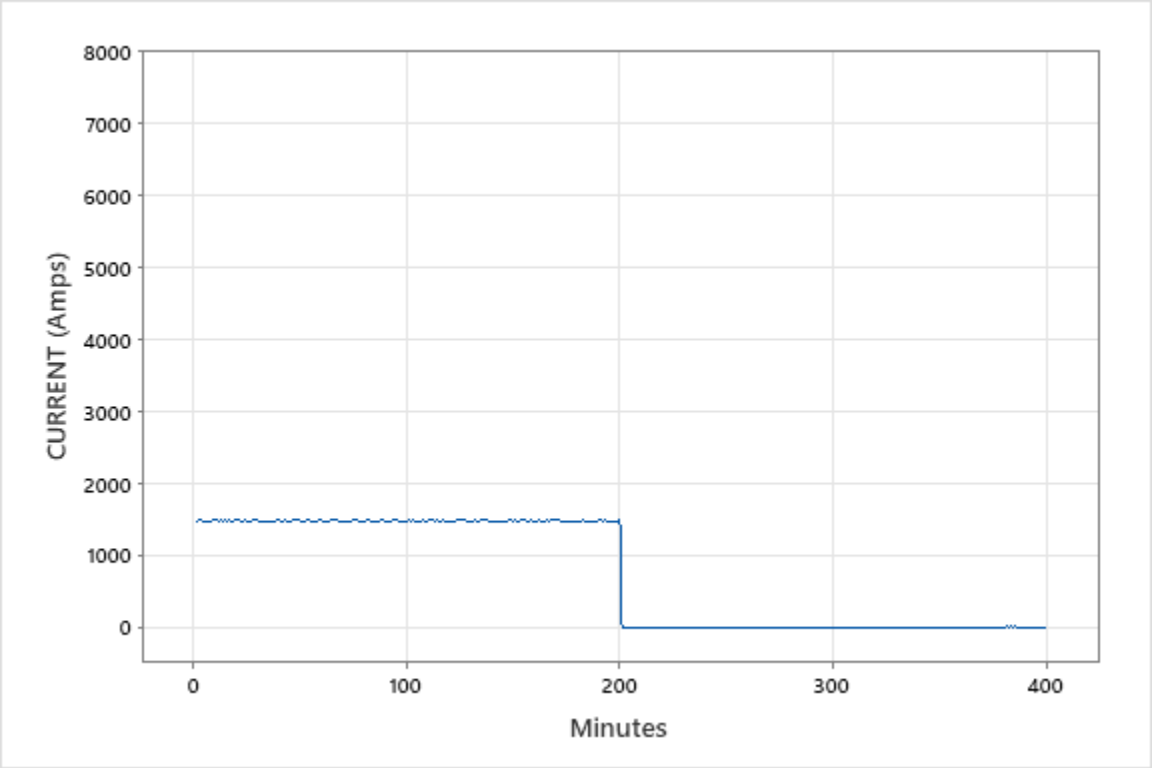
Condition 2: fixed displacement based on initial tension of 25% RBS (tension will vary as it heats and cools); temperature cycle between room temperature and 250° C for 1500 cycles; similar to EPRI 1500 cycle test



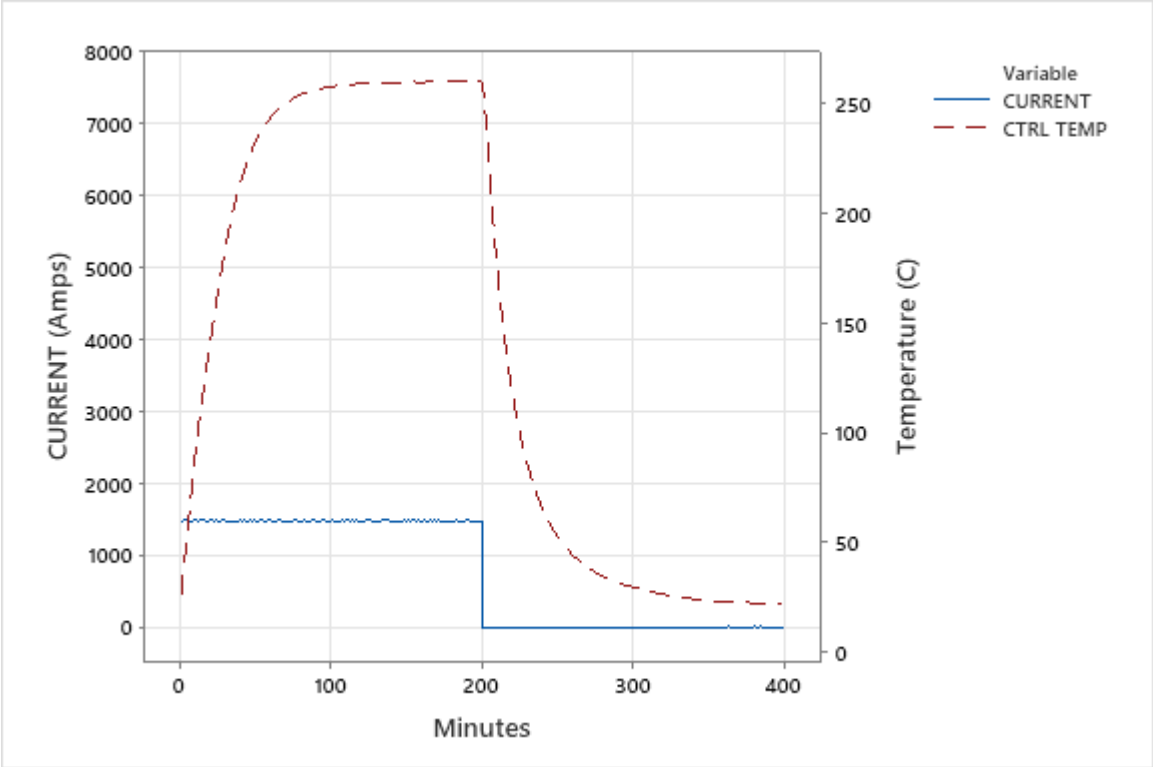
Condition 3: tension – set to 25% RBS and then reset cold every 10th cycle; cycle temperature between room temperature and 250° C for 1500 cycles



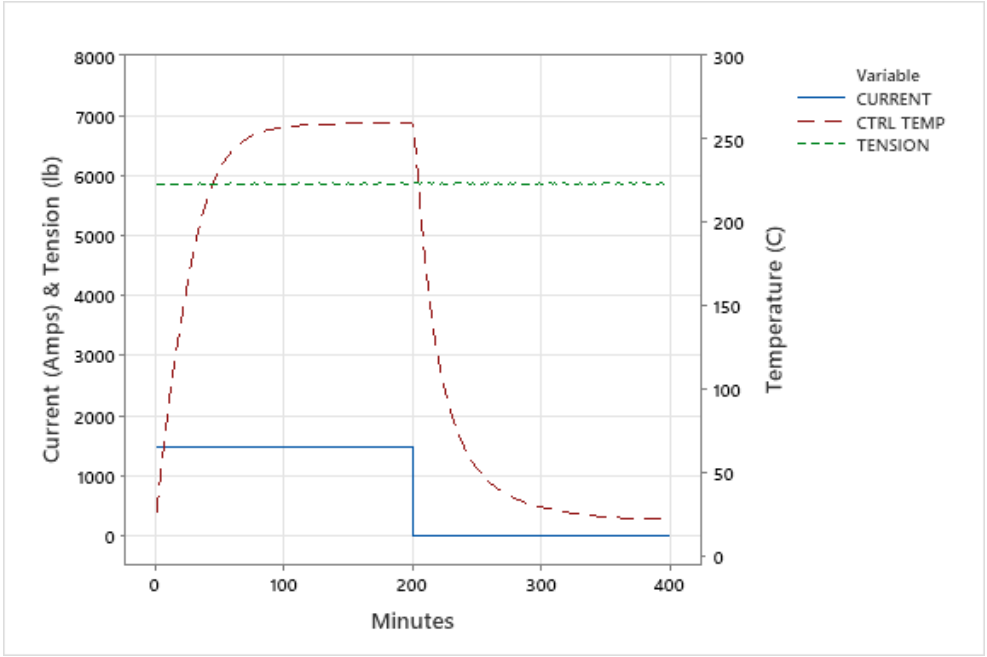
Test Plan (1 of 5)

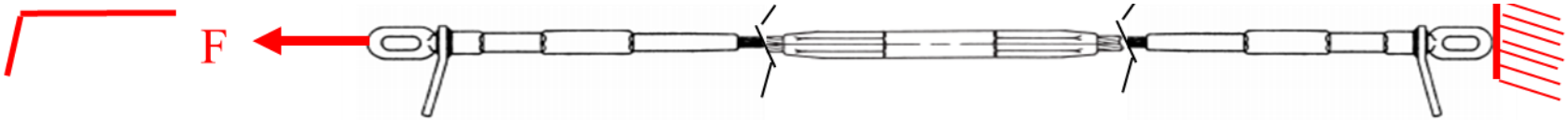


Test Plan (2 of 5)



Test Plan (3 of 5)





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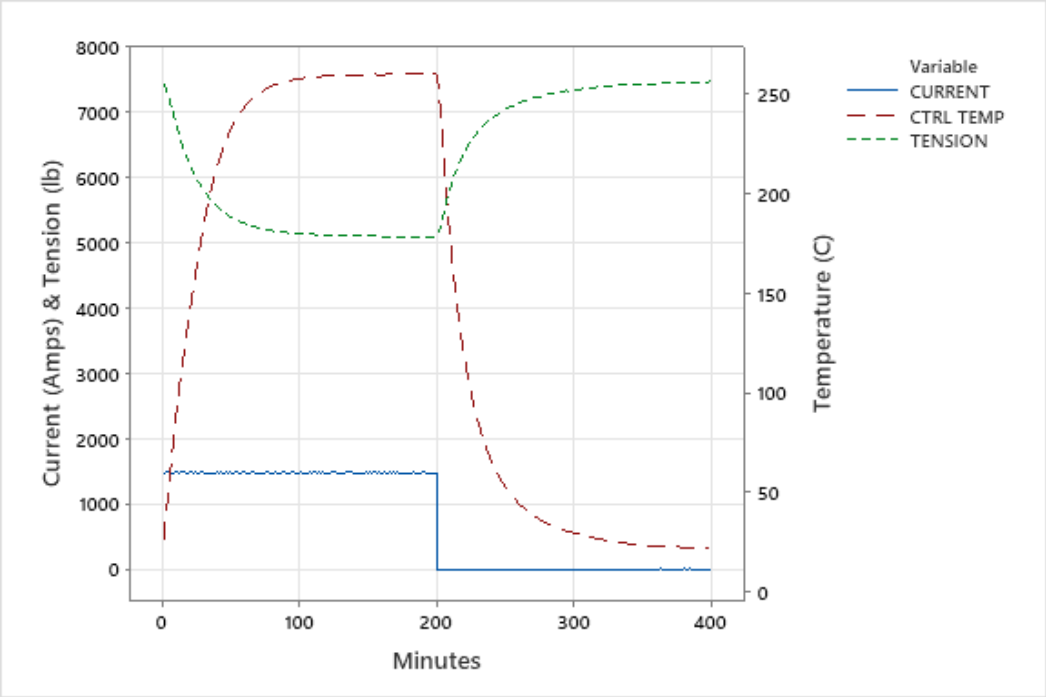
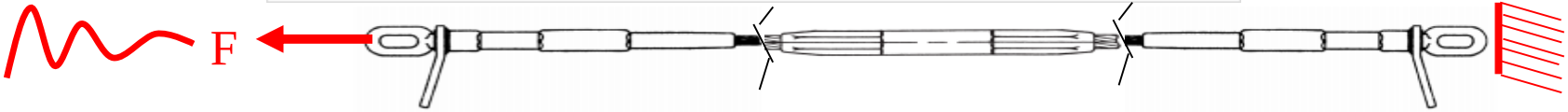
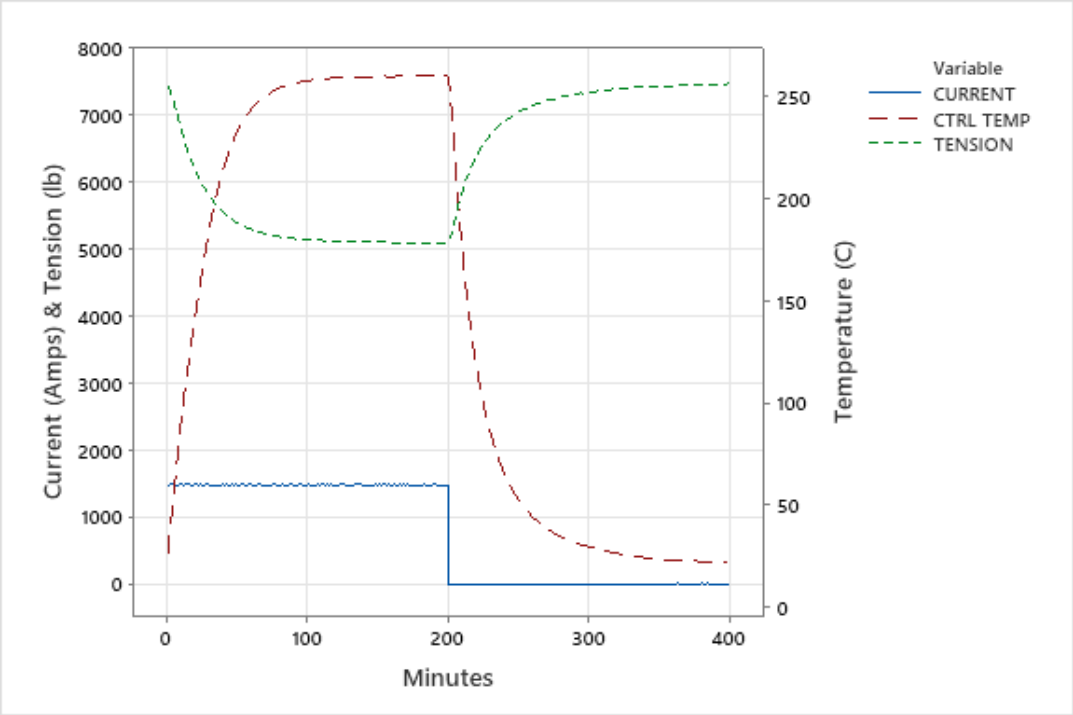


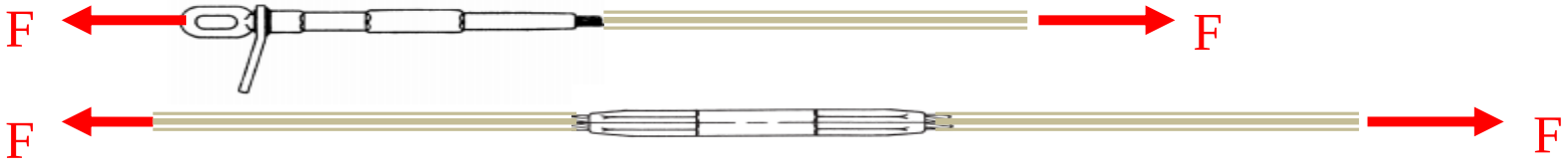


Test Plan (5 of 5)



Results

- There will be three tension conditions for each CCT loop.
- For all three sample sets:
  - Samples consist of 1 splice and 2 dead-ends with Drake ACSS HS285.
  - Samples are approximately 30 ft. long (eye to eye).
  - Tension is recorded every minute.
  - Temperature (connectors, control, ambient) every minute
  - Current is recorded every minute.
  - Control temperature is set to 250° C and is continuously monitored.
  - DC resistance of connectors is measured every 25th cycle using wire equalizers.
  - Cycle time is 200 minutes on, 200 minutes off.
- After 1500 cycle CCT, all samples will be separated for tensile testing.



Presentation Agenda

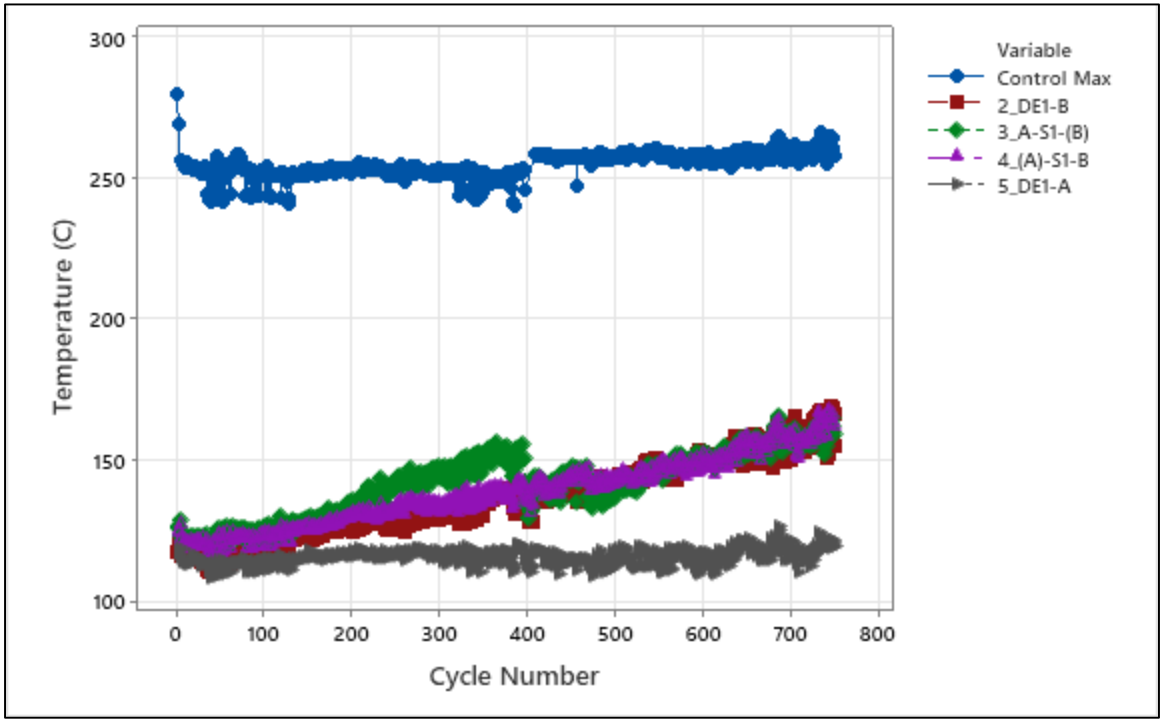
Results

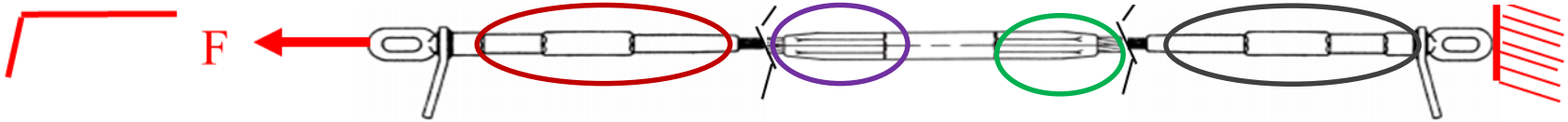
Through Cycle 750 (March 31)

Results: C119.4 Criteria

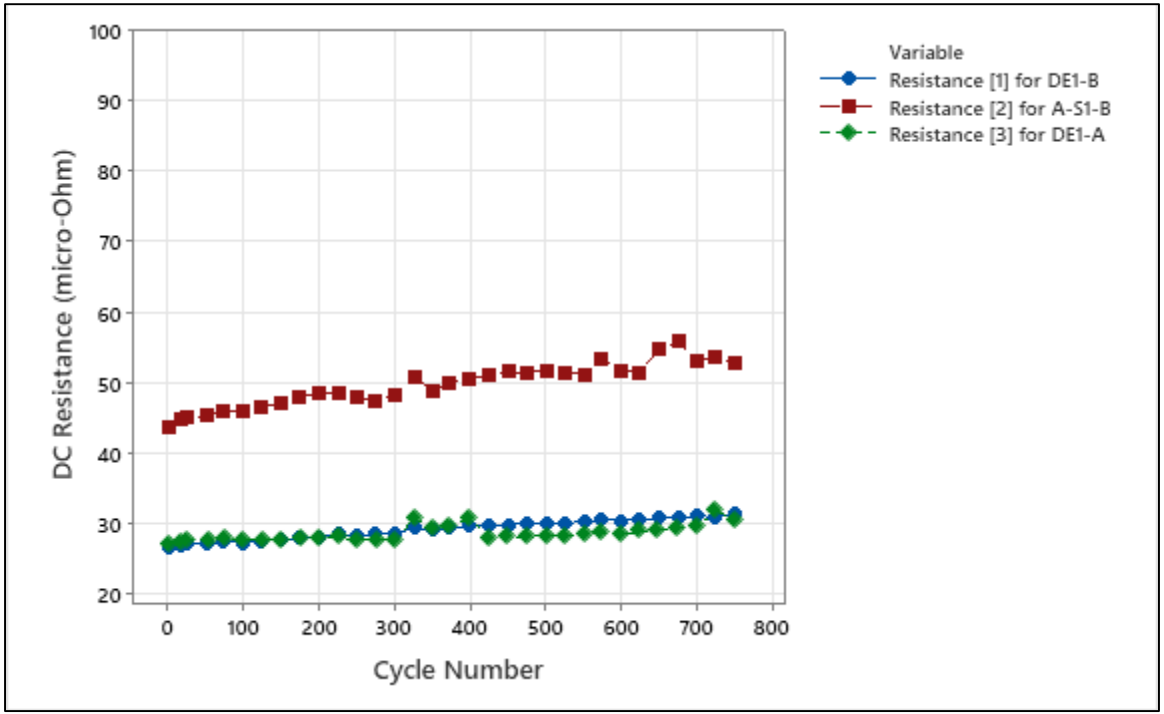
- Maximum temperature: the temperature of any single connector may not exceed that of the control
- Temperature stability: Connector temperatures must be within +/- 10°C of their average
- Resistance stability: Resistance of any connector must be within +/- 5% of their average
- These are interim results
- The ANSI C119.7 Committee may have different criteria!

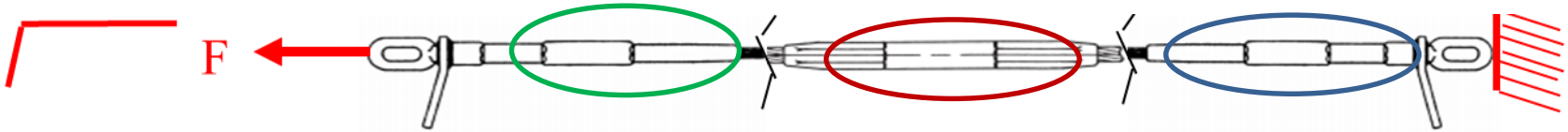
Results: Temps for Continuous Tension



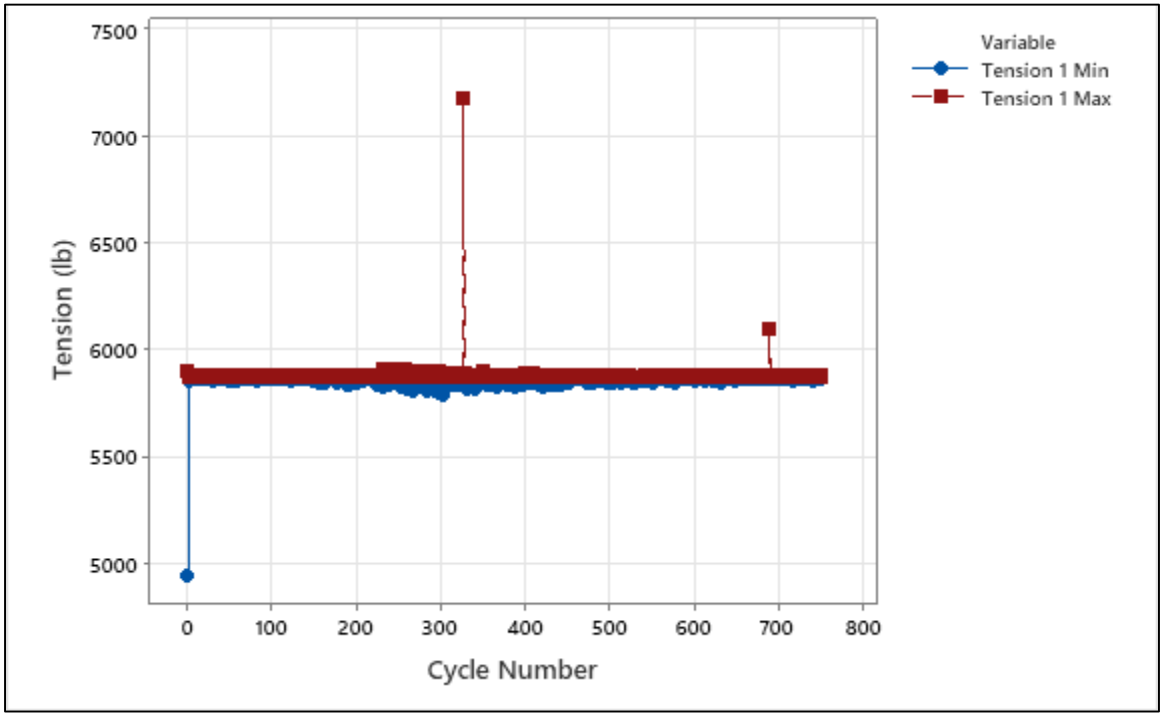


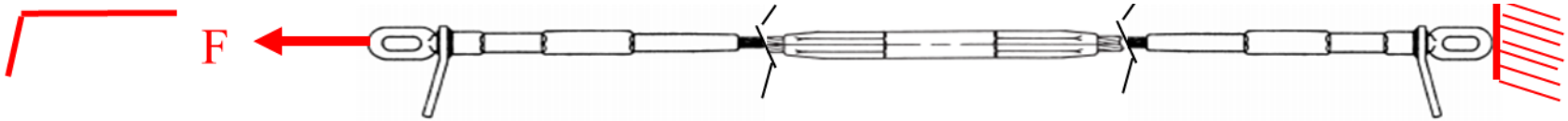
Results: Resistance for Continuous Tension



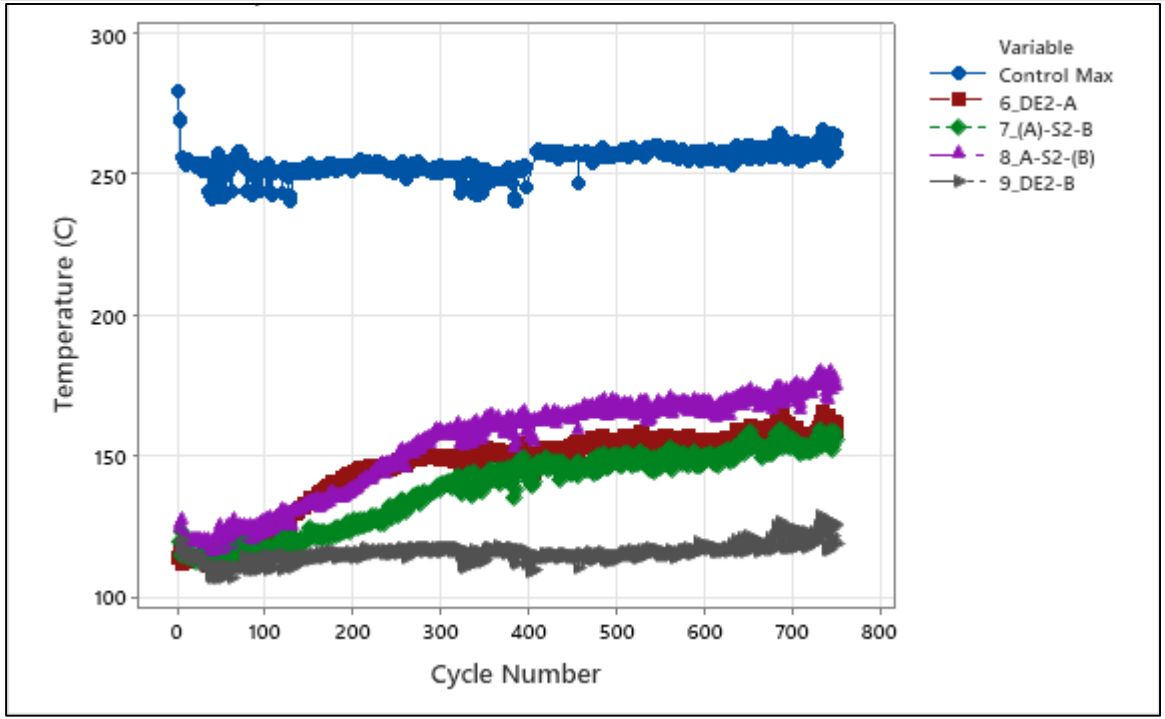


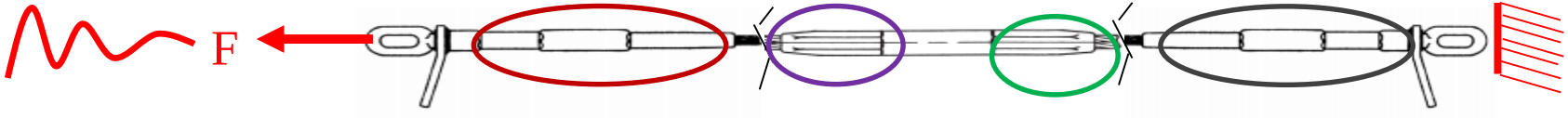
Results: Tension for Continuous Tension



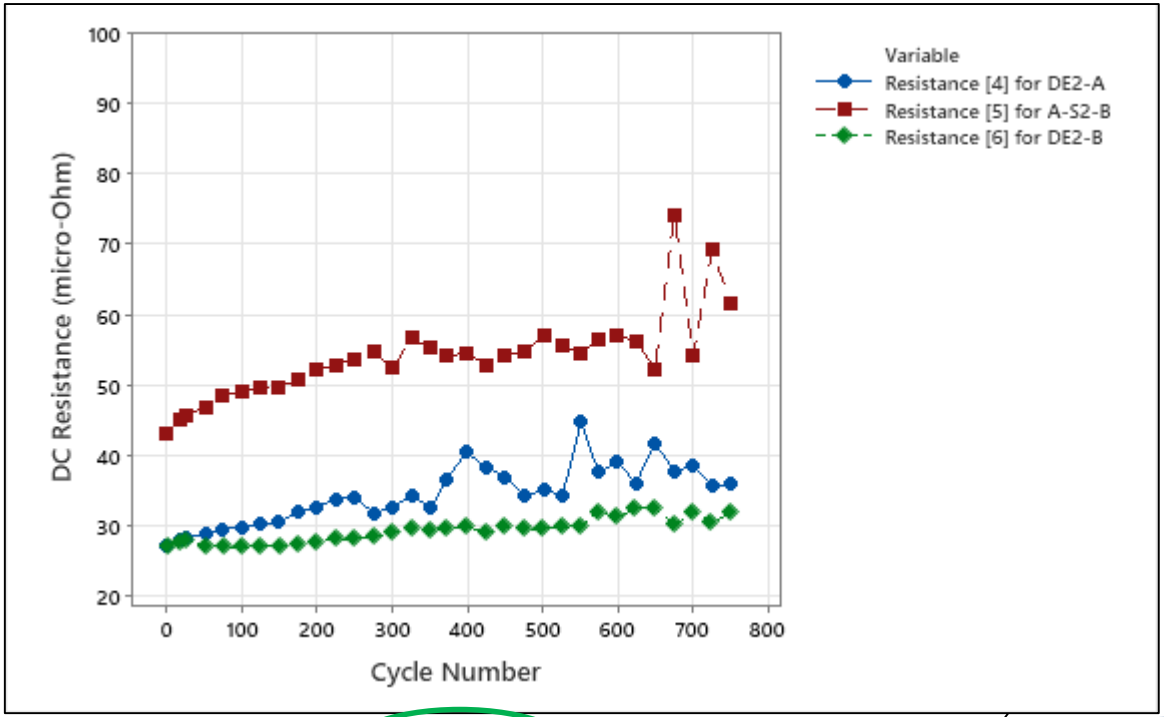


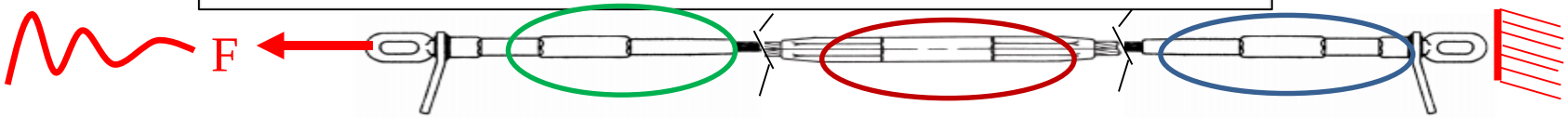
Results: Temps for Set It & Forget It



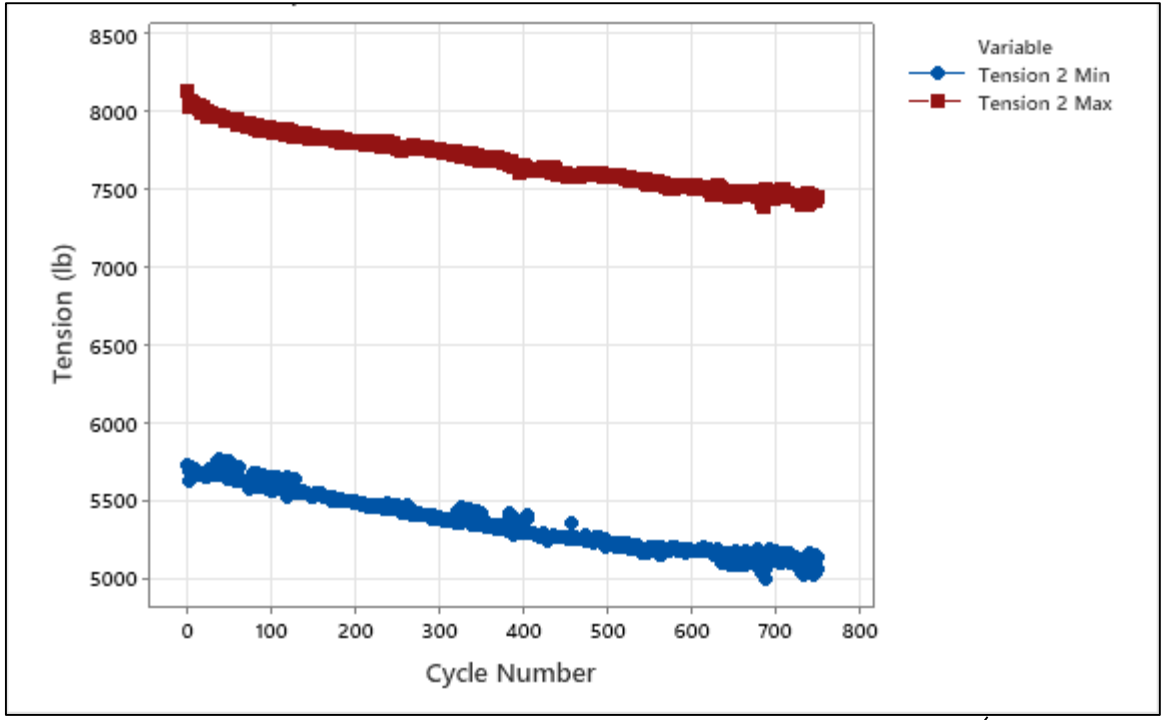


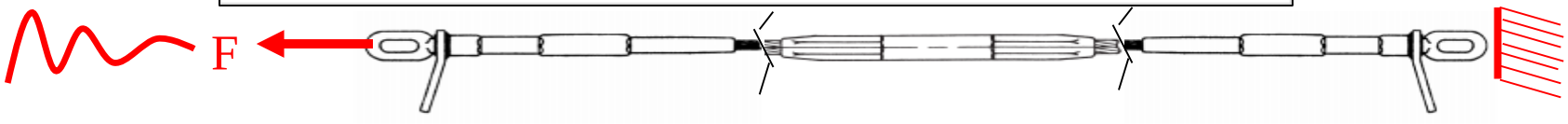
Results: Resistance for Set It & Forget It





Results: Tension for Set It & Forget It





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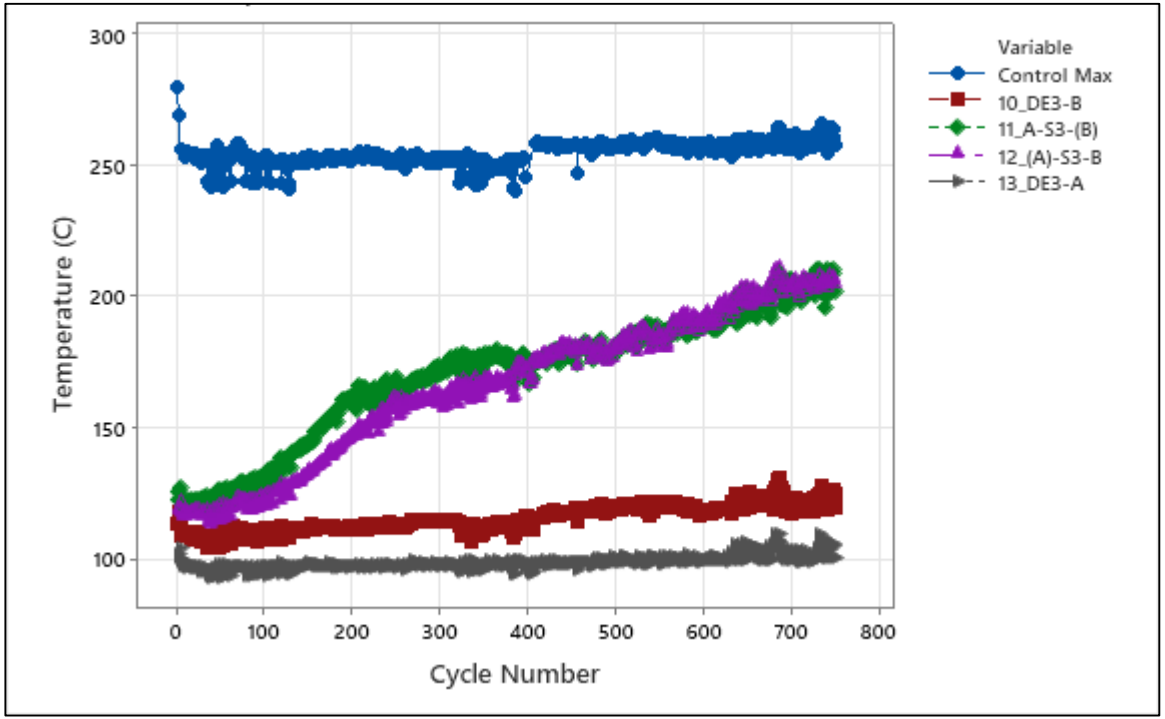
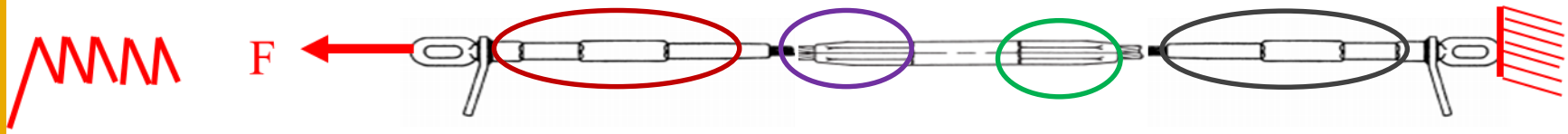
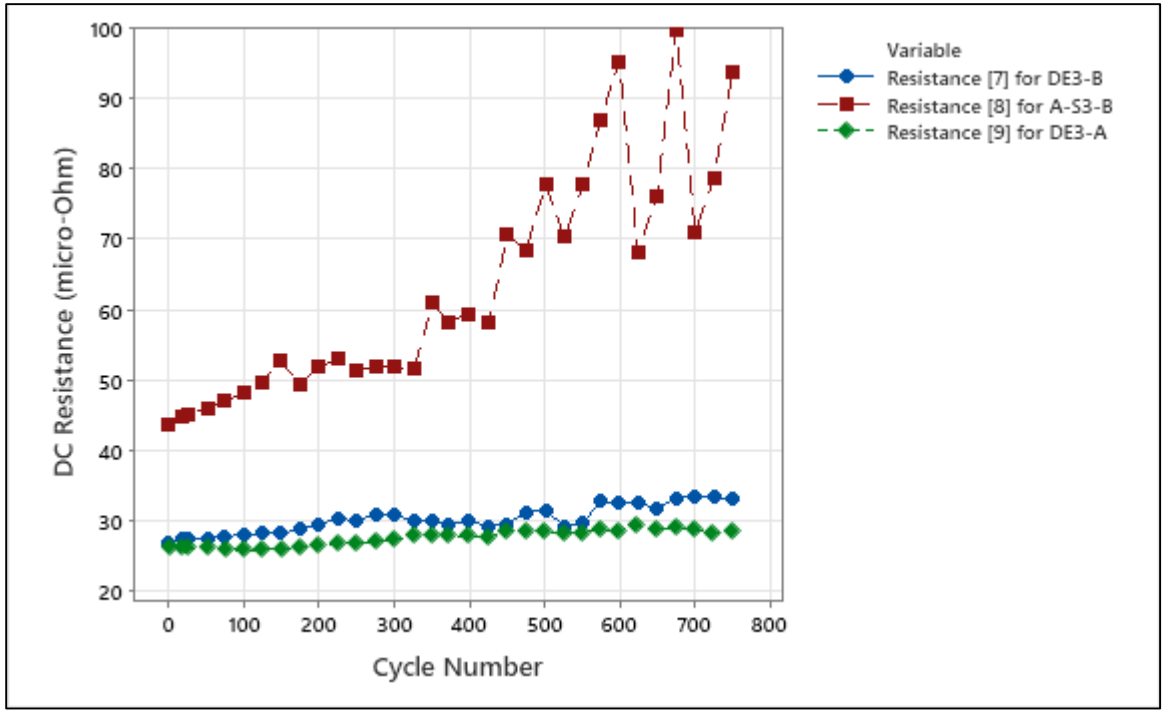
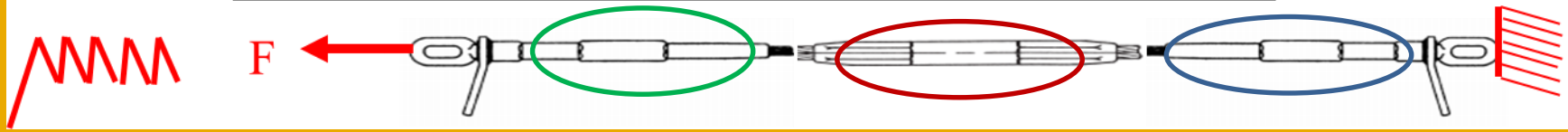


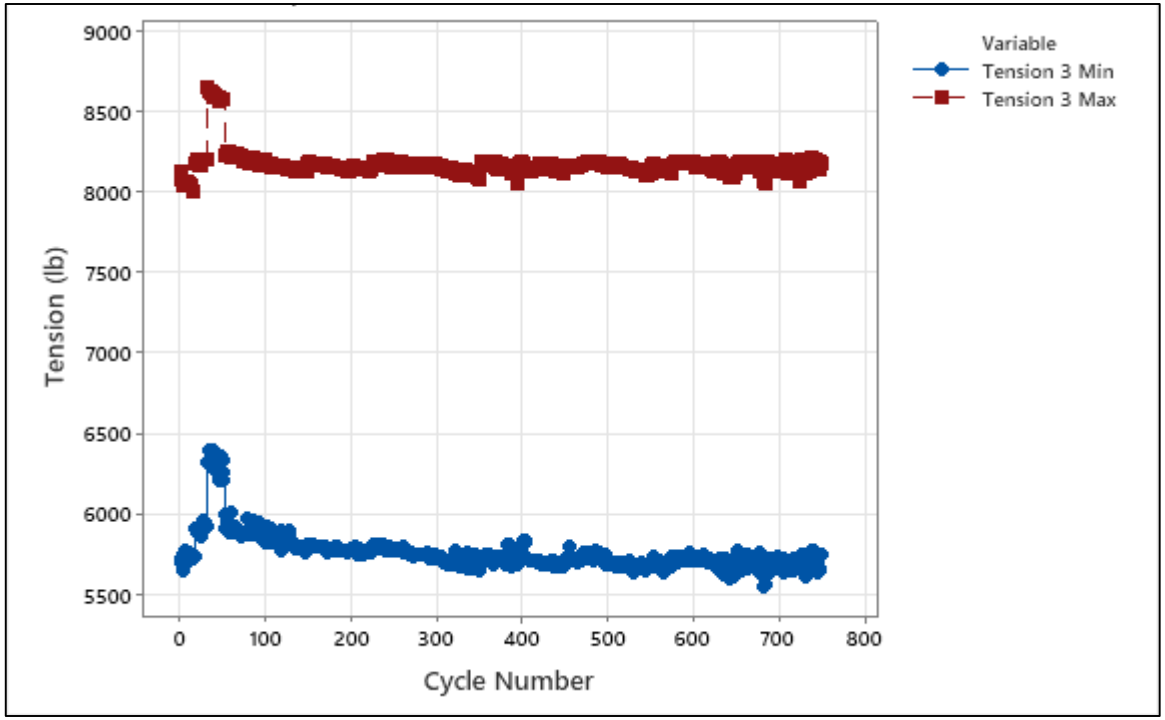


Results: Resistance for Set It & Reset It

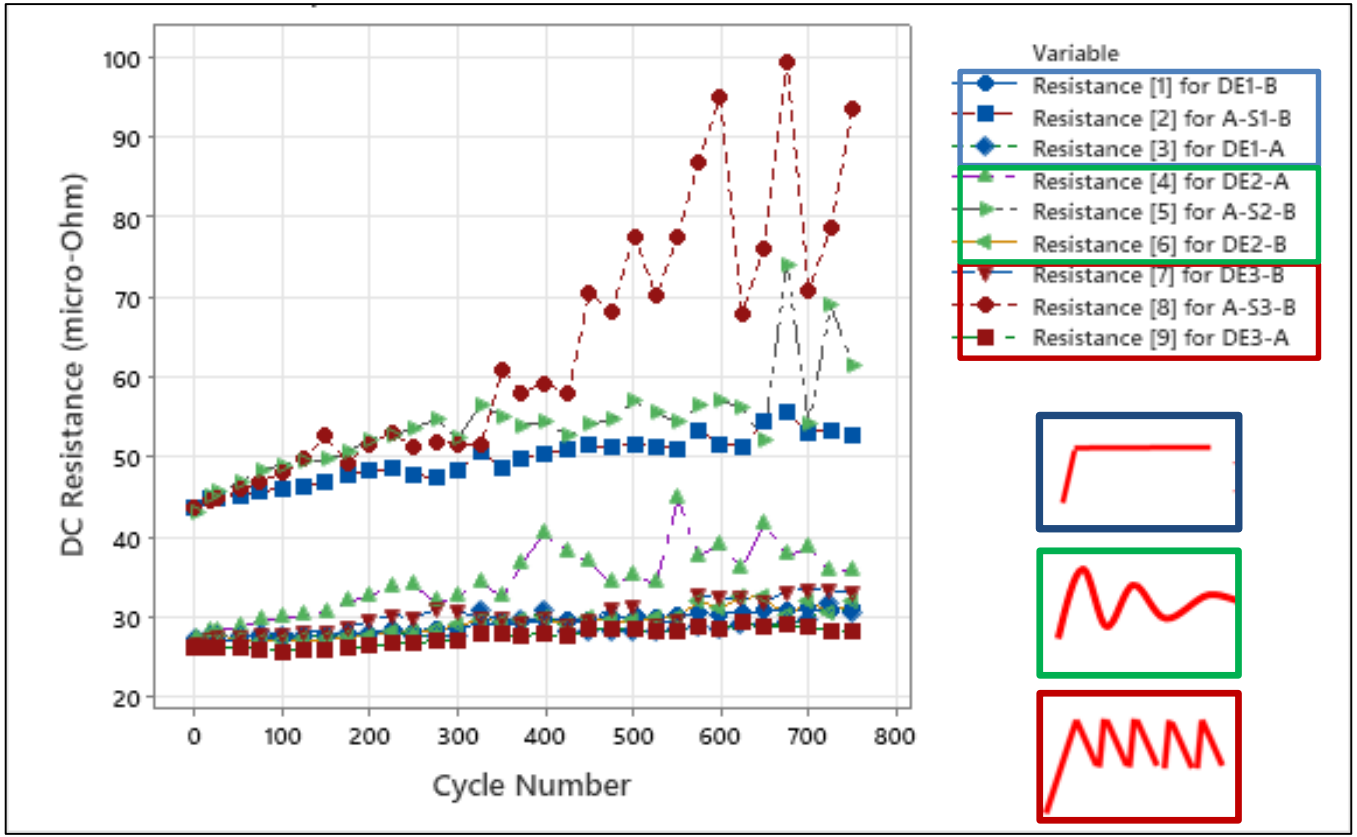




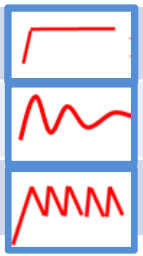
Results: Tension for Set It & Reset It



Results: Resistance – All Tension Conditions



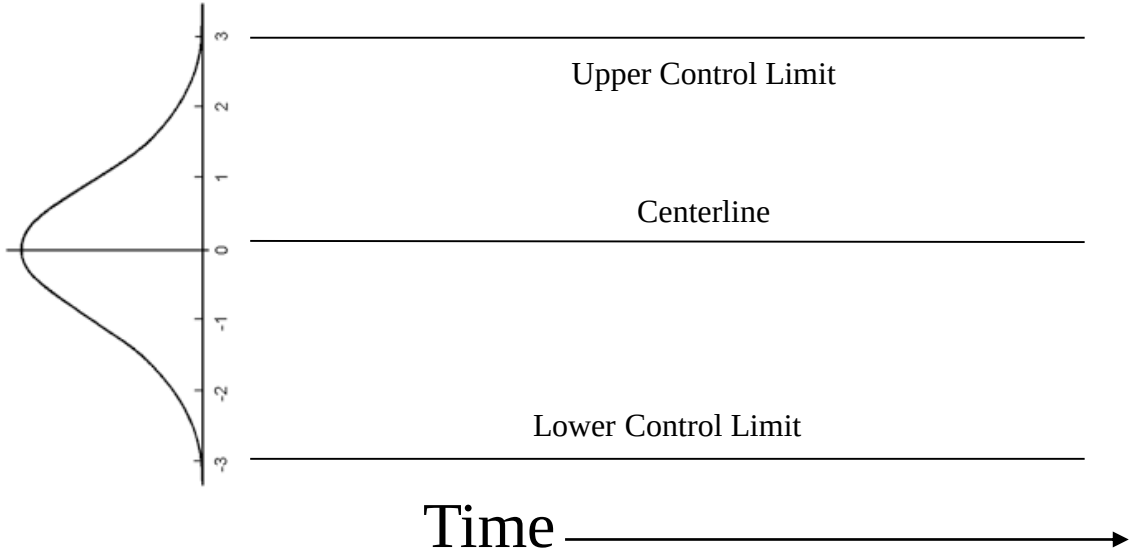
Ranking Tensioning Schemes

	# Conn Max Temp	# Conn Temp Stability	# Conn Res Stability	Final Rank
	3	1	2	1
	3	1	1	3
	3	2	1	1

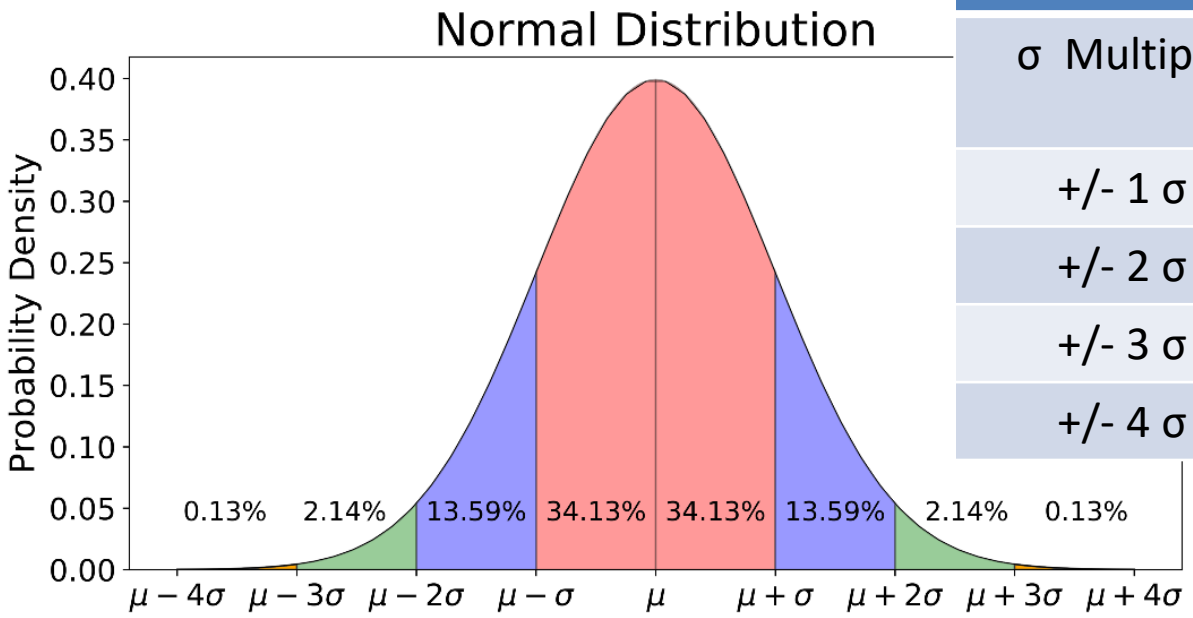
Alternate Methods

Alternate Methods: Control Charts (1 of 3)

- What if we use a control chart methodology to evaluate data?
- Control charts help us determine if our measurements are due to randomness or some cause, i.e. the connector is failing!



Alternate Methods: Control Charts (2 of 3)

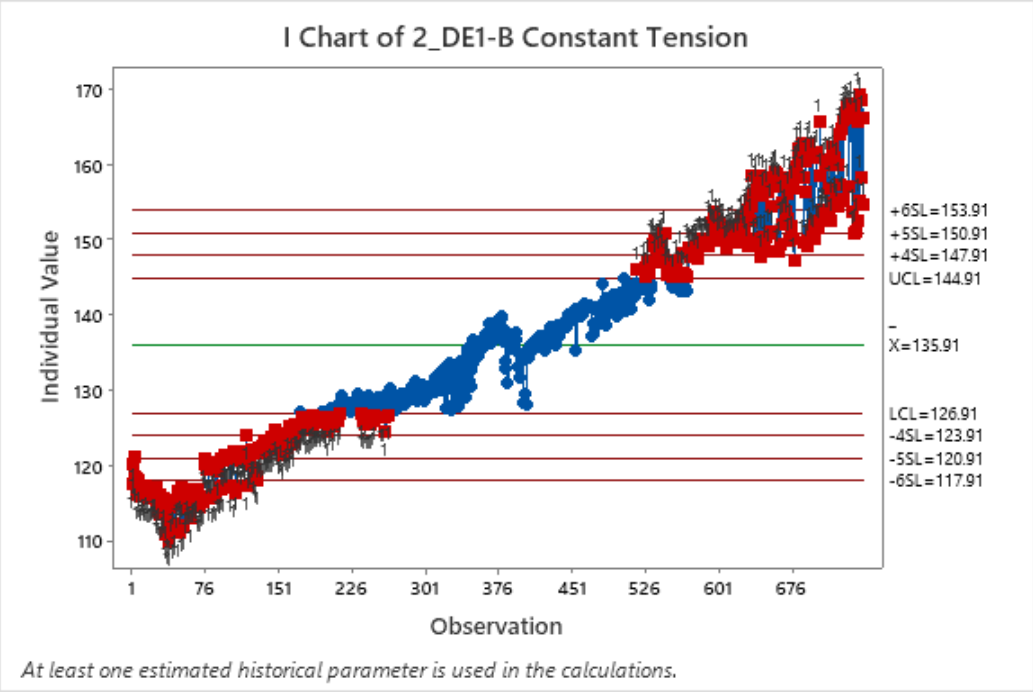


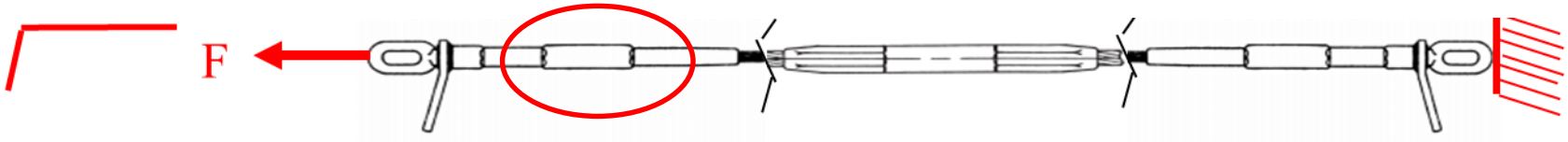
Out of 500 Measurements	
σ Multiple	Expected Observations
+/- 1 σ	341
+/- 2 σ	477
+/- 3 σ	499
+/- 4 σ	500

Alternate Methods: Control Charts (3 of 3)

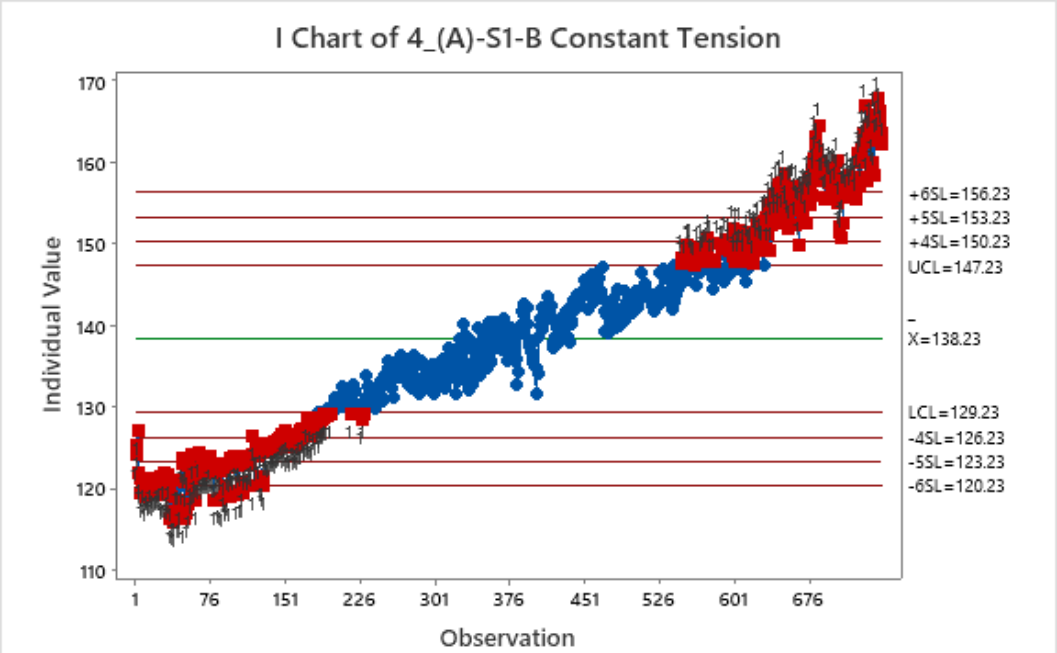
- The current method uses acceptance limits of $\overline{X}$ +/- %$\overline{X}$.
- The problem here is that the limits depend on the value of the mean:
  - Typical average resistance of a connector (IEC method) is ~ 80 micro-Ohm, so limits are 80 +/- 4 mico-Ohm.
  - Typical average resistance of 6’ of conductor + the connector (ANSI method) are typically ~200 micro-Ohms. So, limits are 200 +/- 10 micro-Ohm.
- +/- 3σ or +/- 4σ is independent of the mean value of the measurements.
- Since the limits are dependent on σ, natural variability from drafts are taken into account.

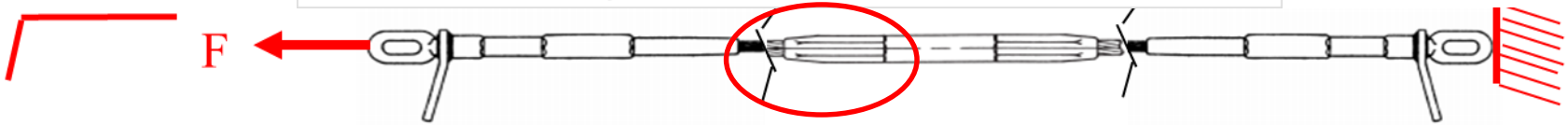
Temps: DE1-B / Constant Tension



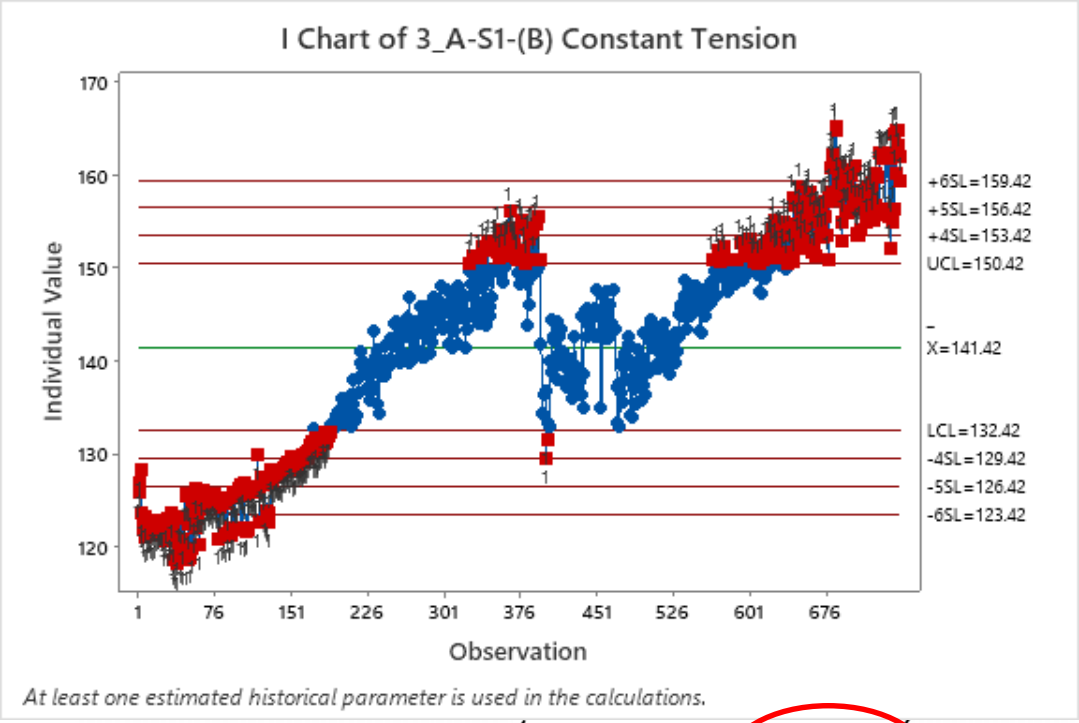


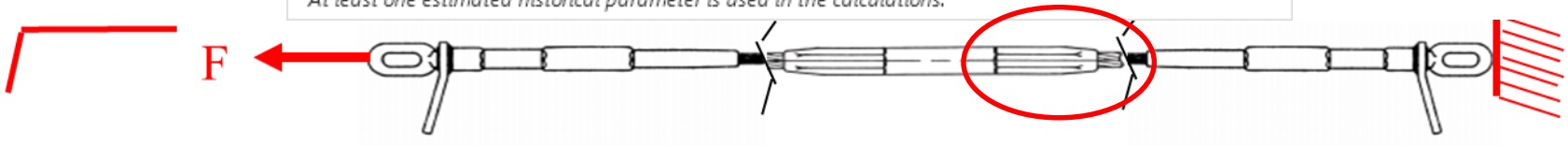
Temps S1-A / Constant Tension



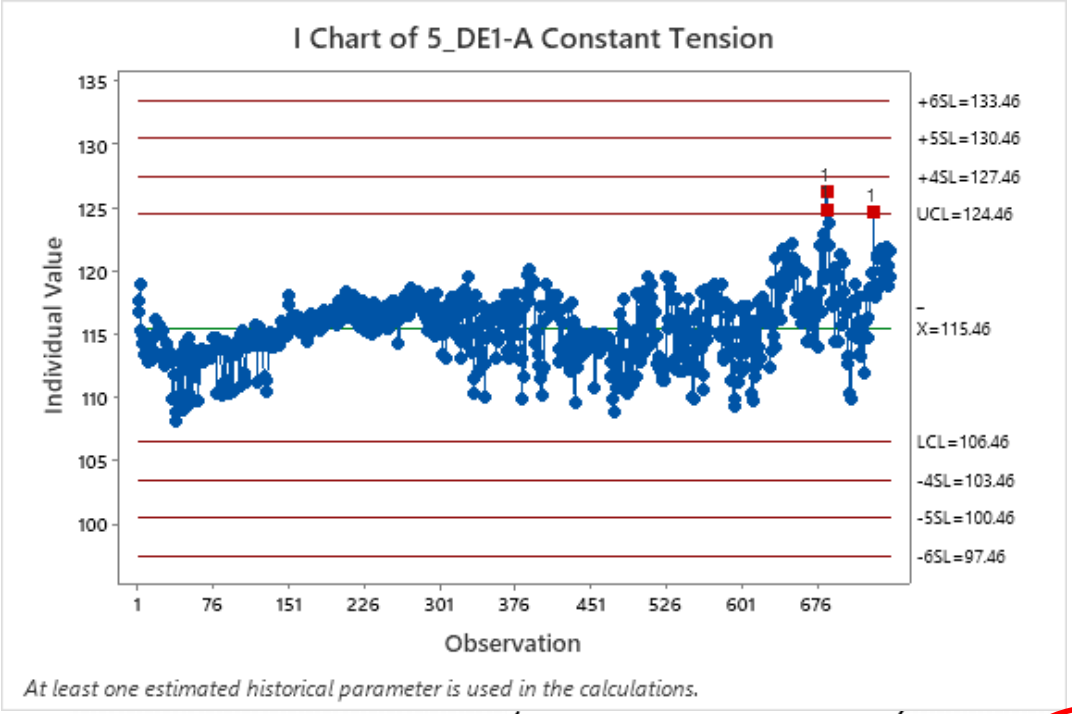


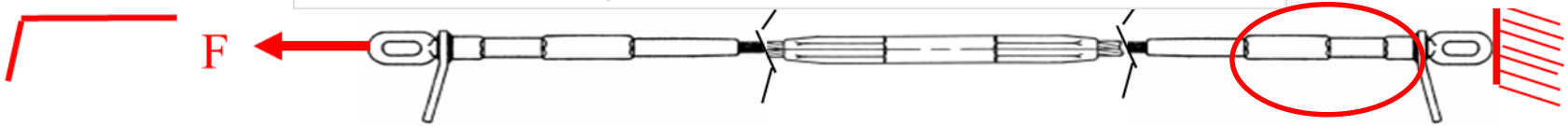
Temps S1-B / Constant Tension



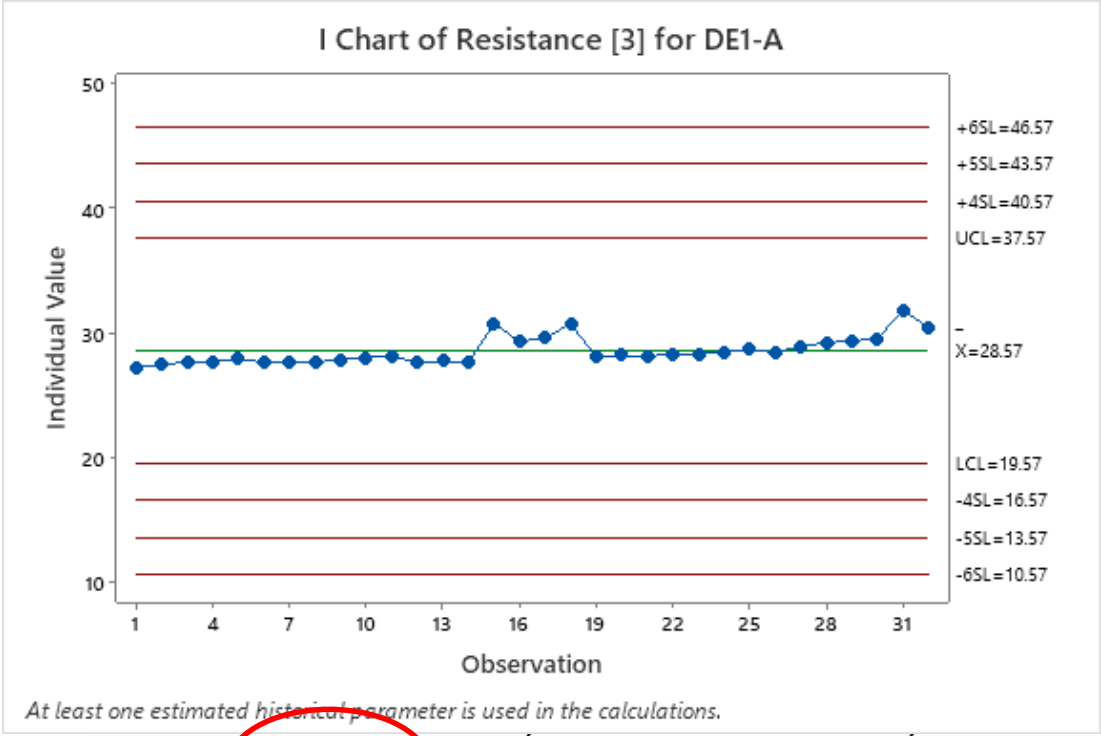


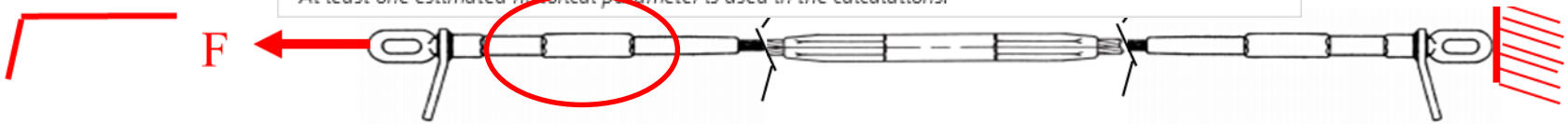
Resistance D1 / Constant Tension



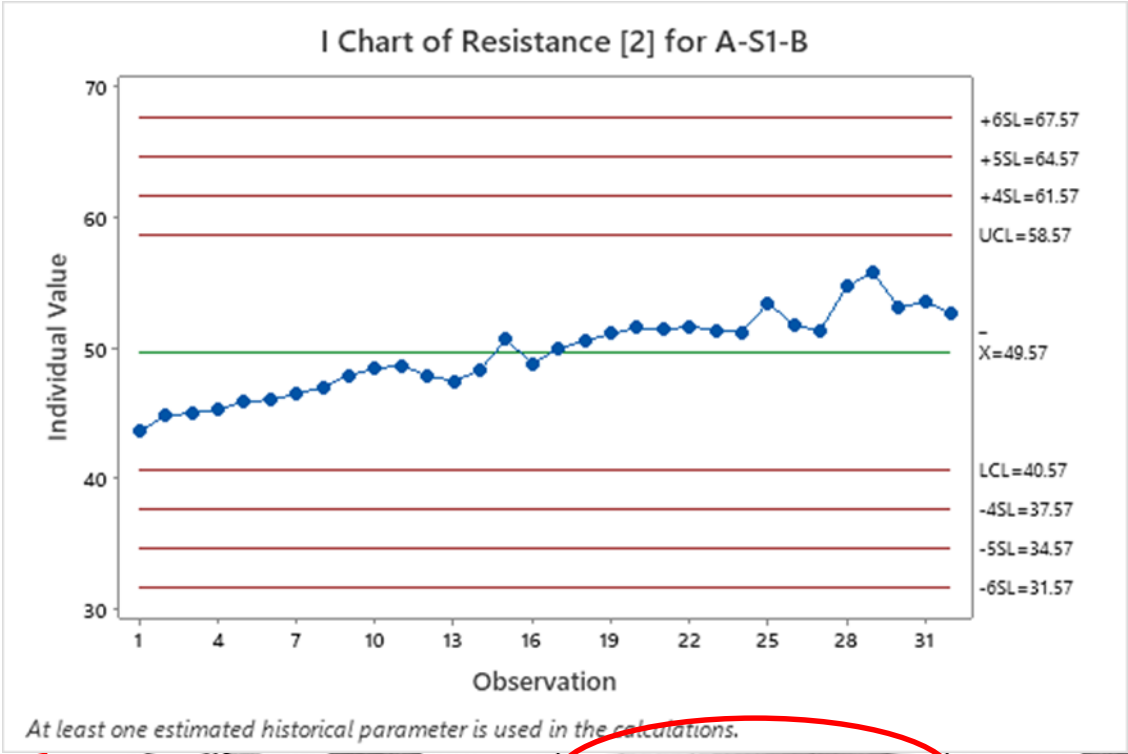


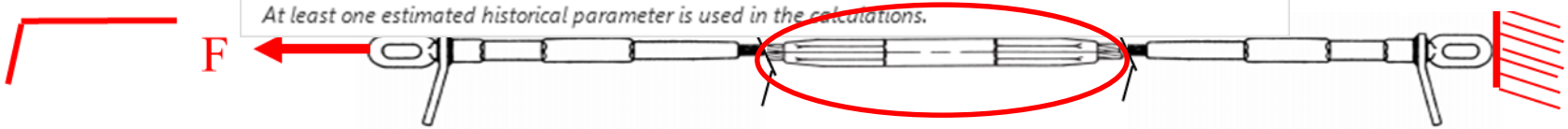
Resistance DE1-A



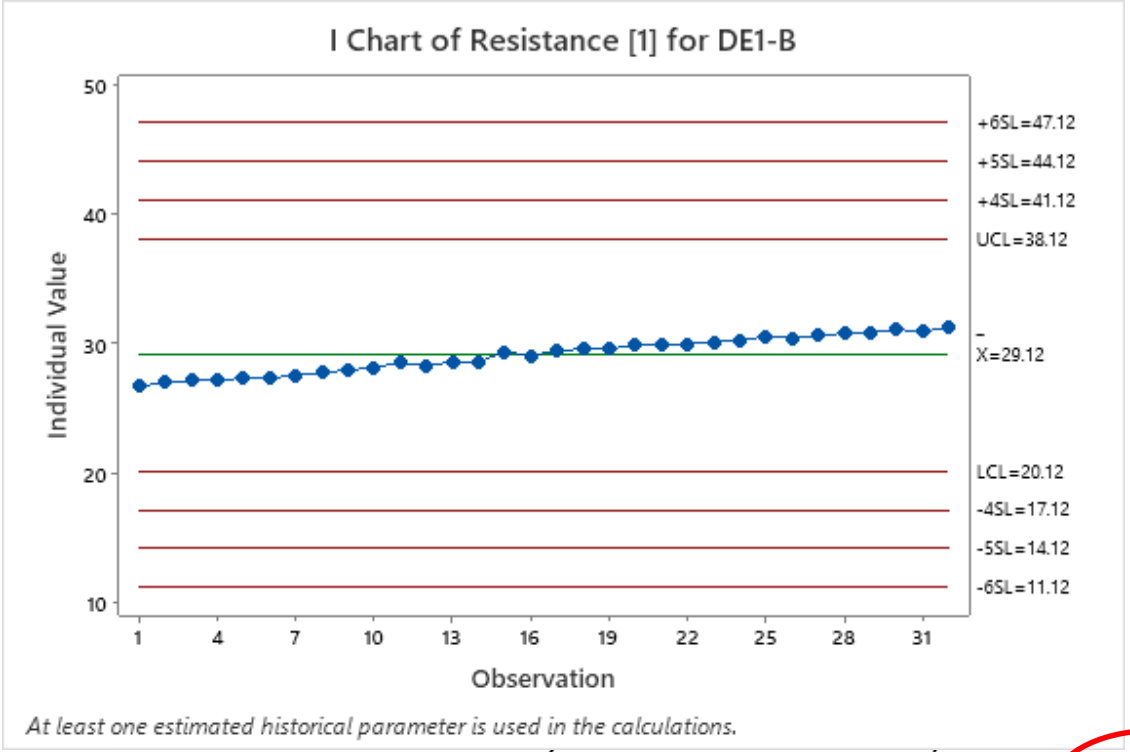


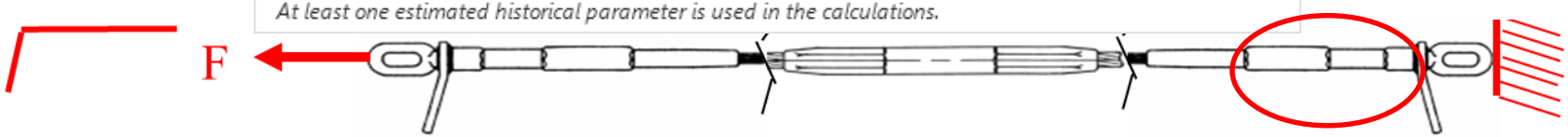
Resistance S1 / Constant Tension



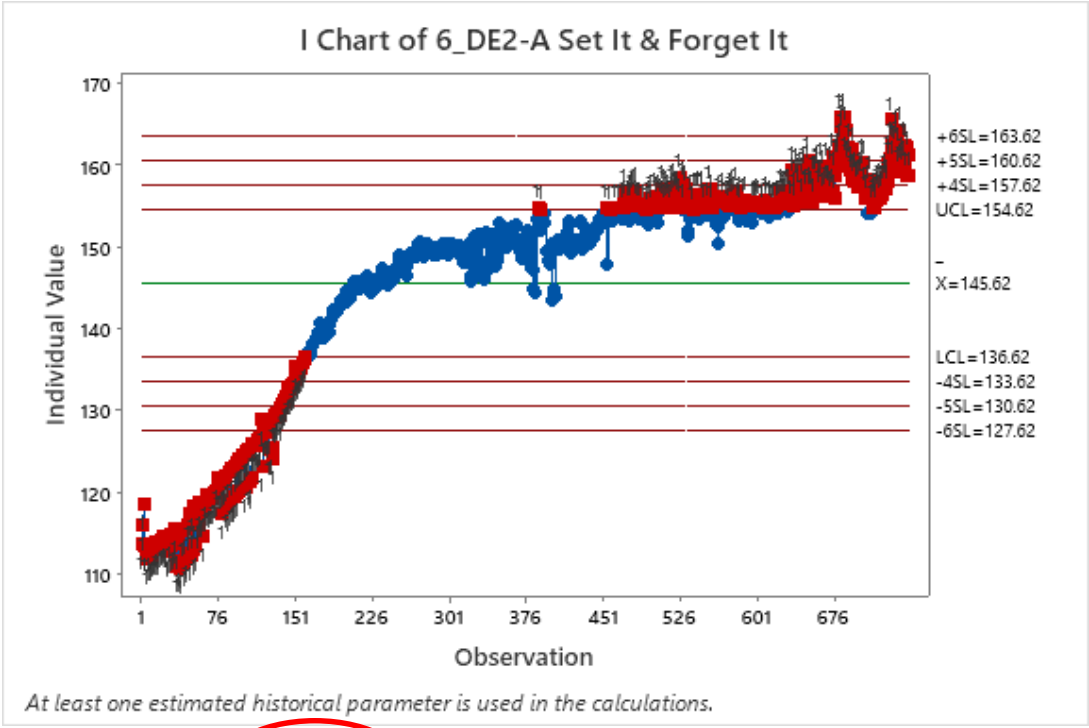


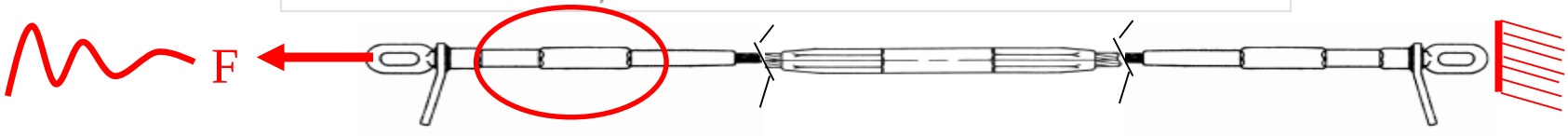
Resistance DE1-B / Constant Tension



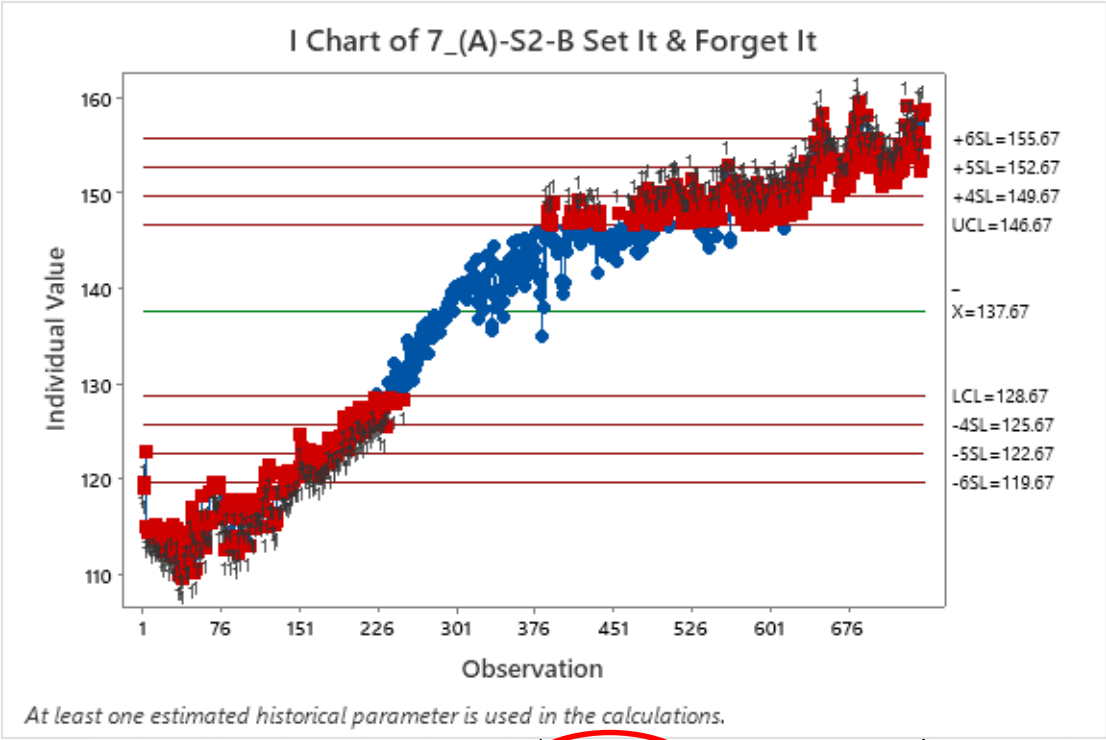


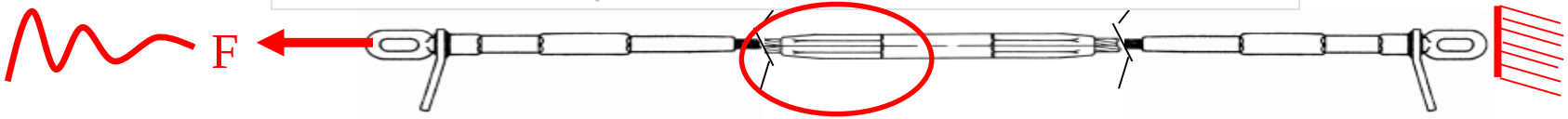
Temps DE2-A / Set It & Forget It



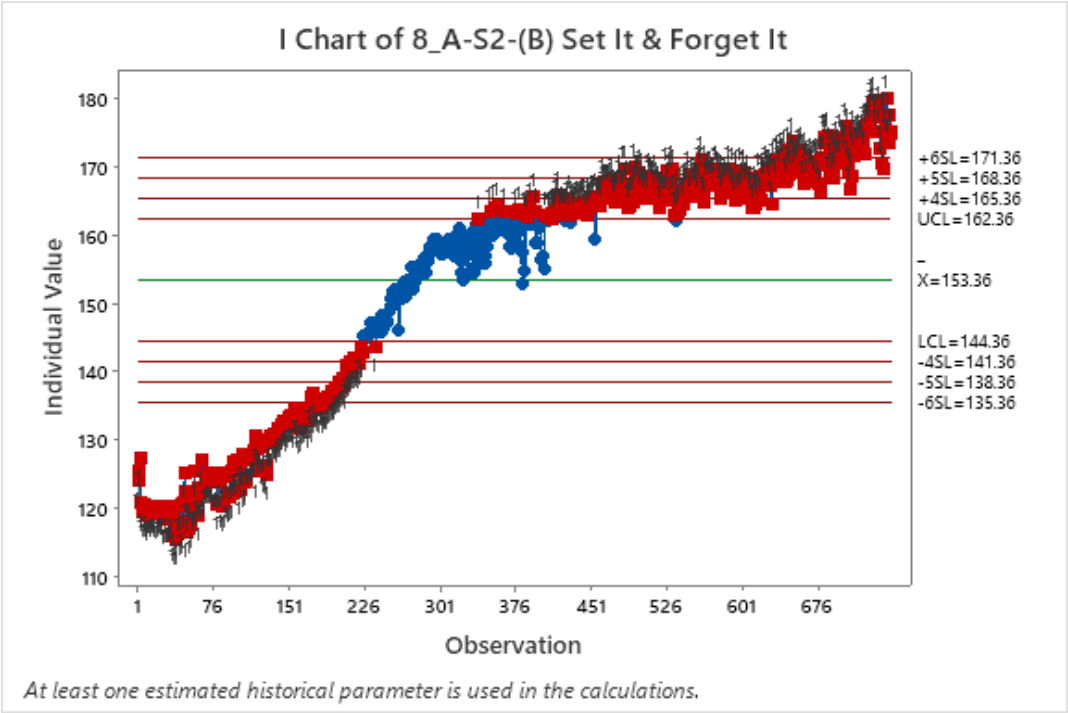


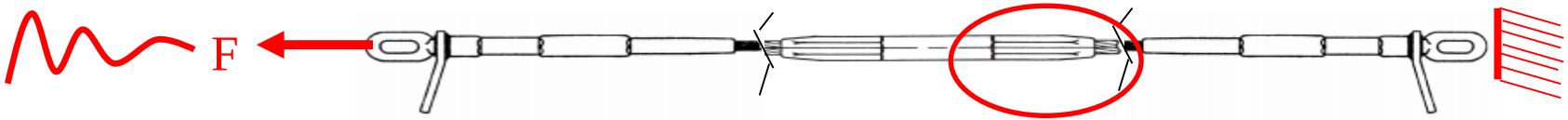
Temps S2-A / Set It & Forget It



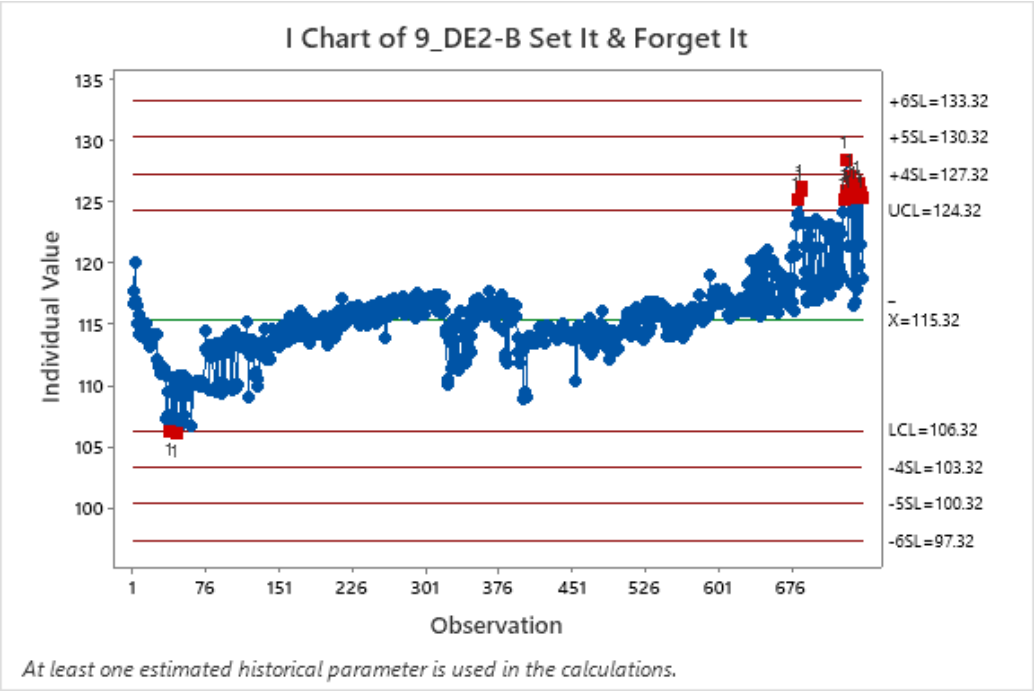


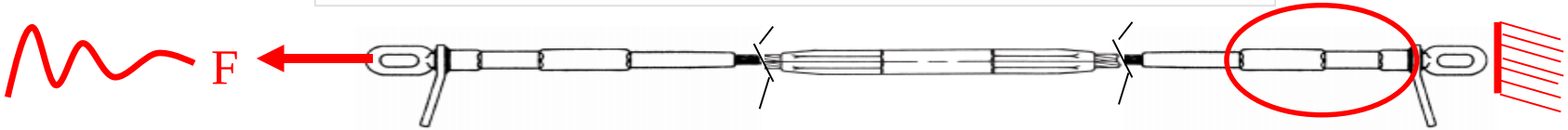
Temps S-B / Set It & Forget It



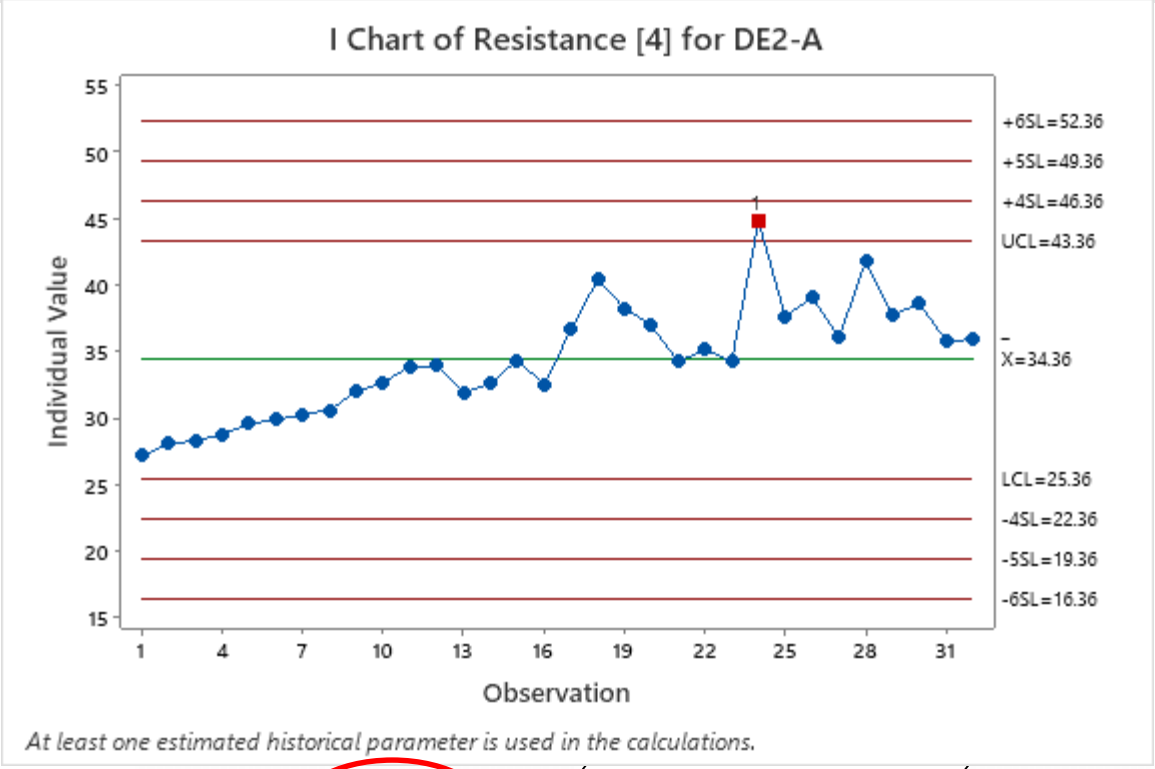


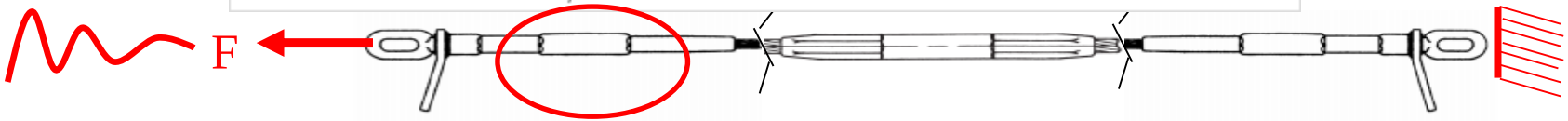
Temps DE2-B / Set It & Forget It



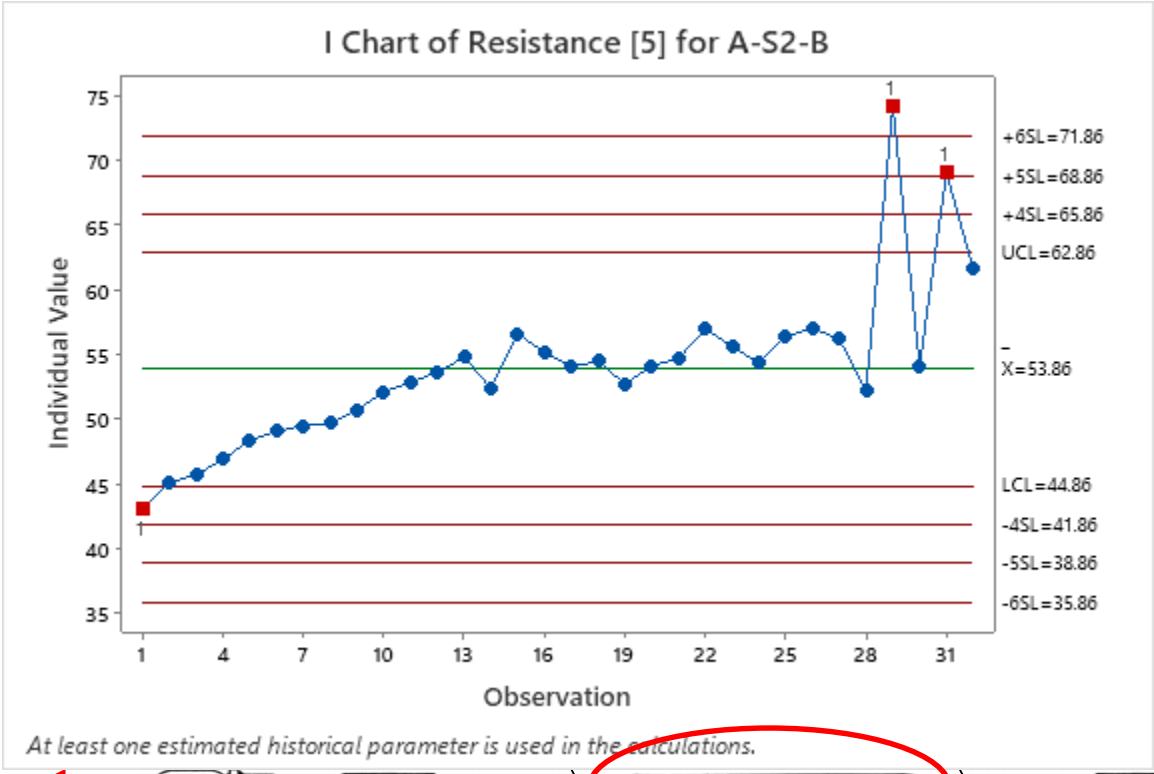


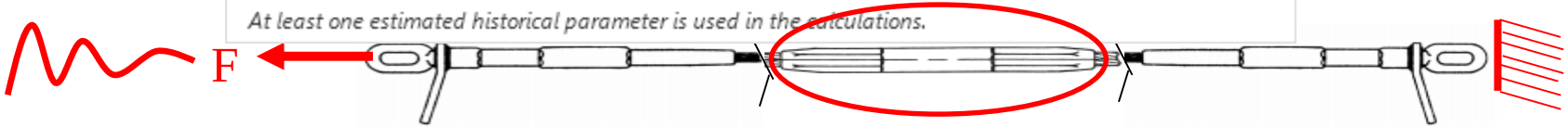
Resistance DE2-A / Set It & Forget It



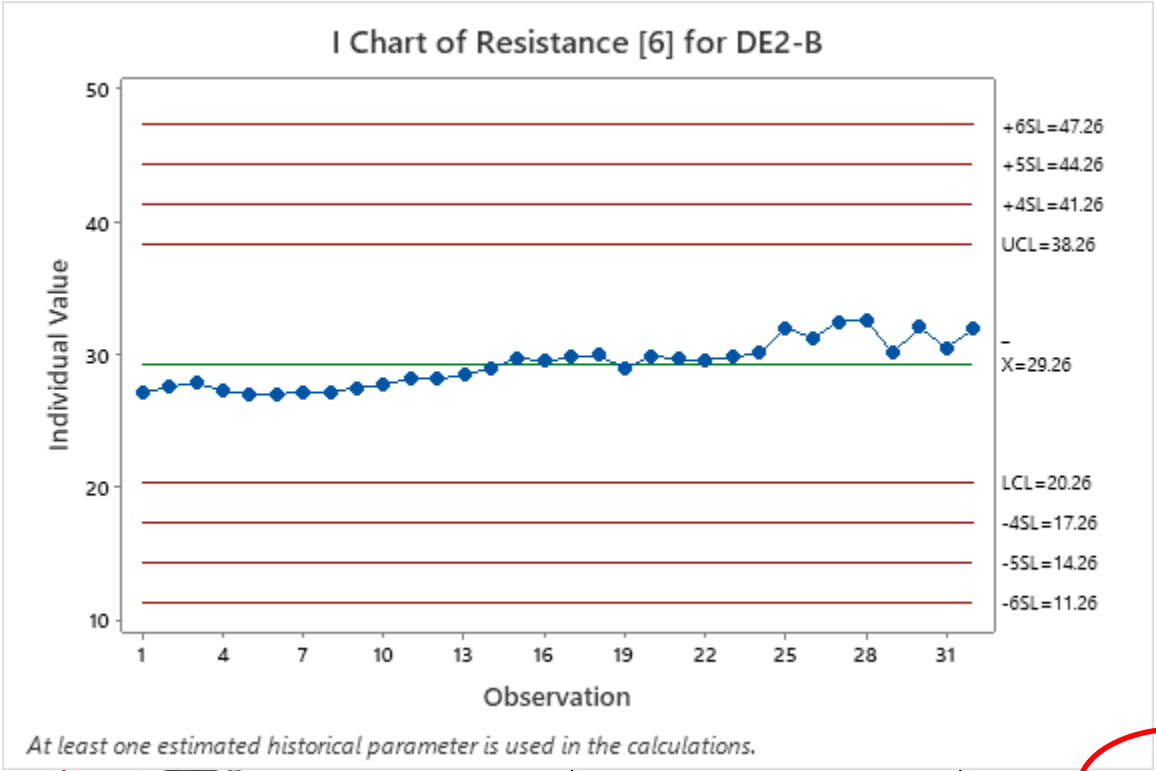


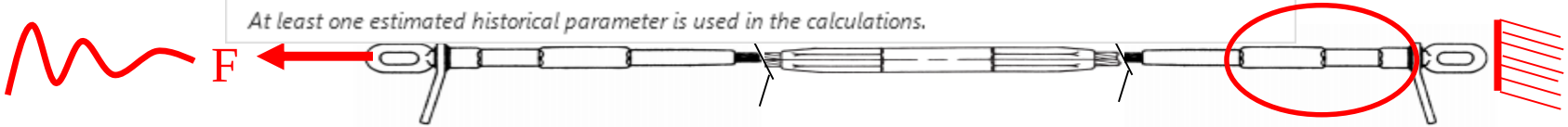
Resistance S2 / Set It & Forget It



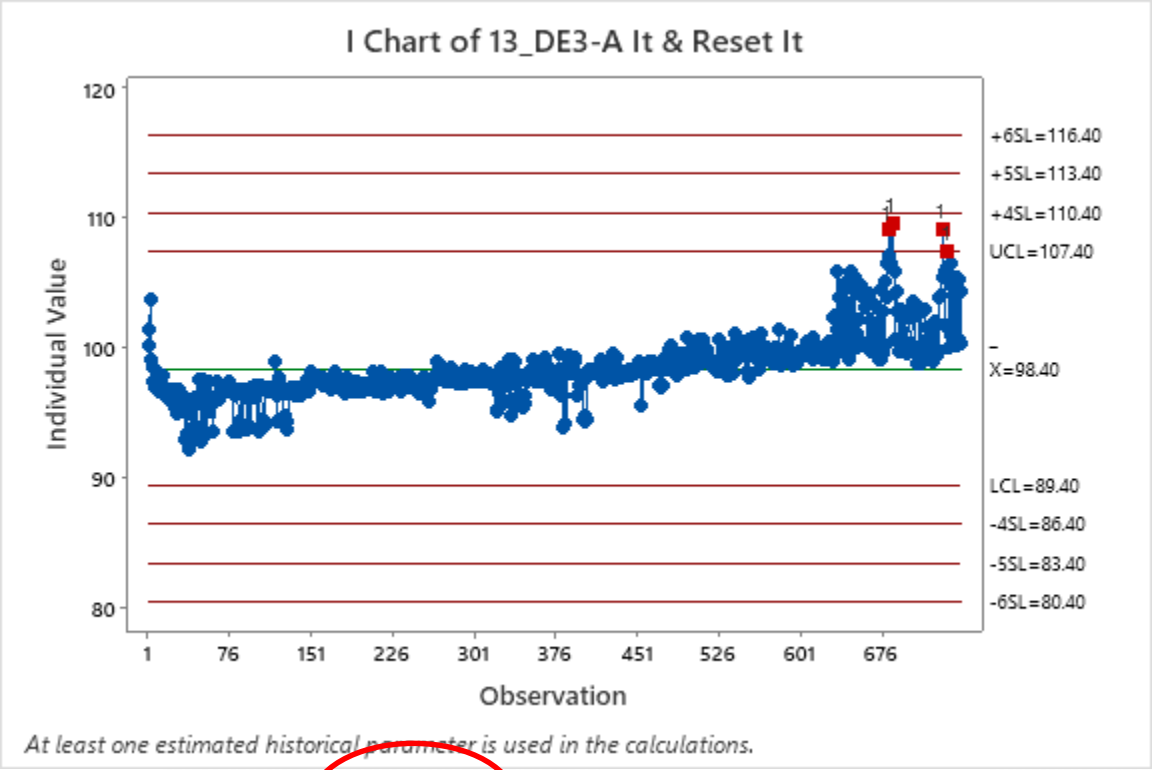


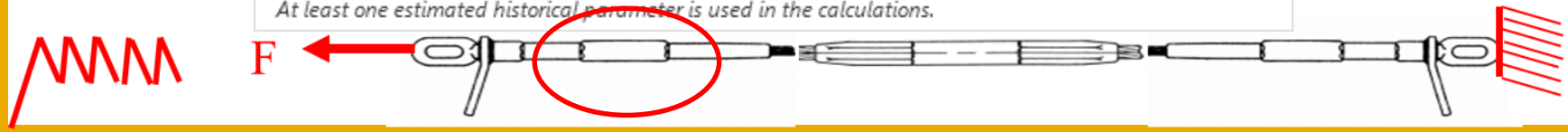
Resistance DE2-B / Set It & Forget It



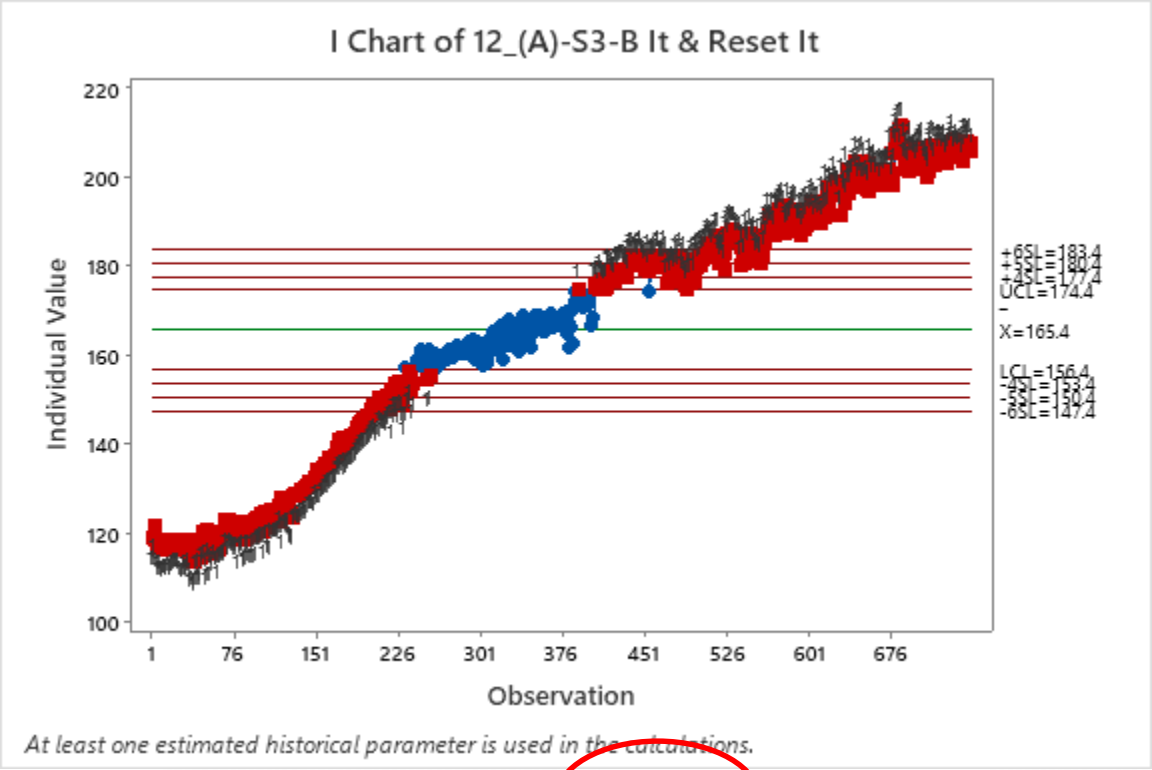


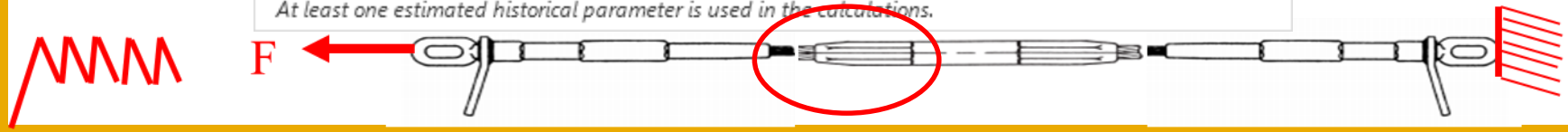
Temps DE3-A Set It & Reset It



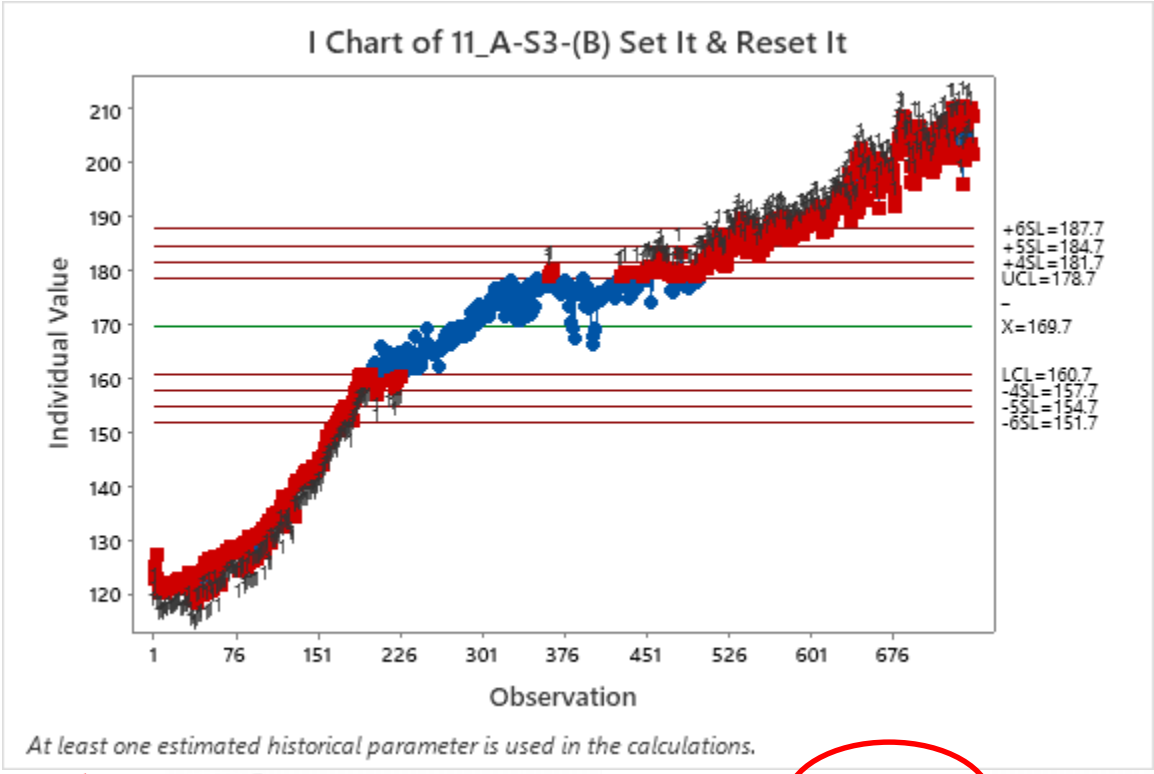


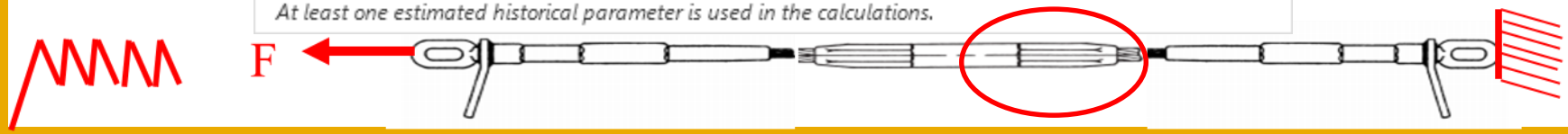
Temps S3-A Set It & Reset It



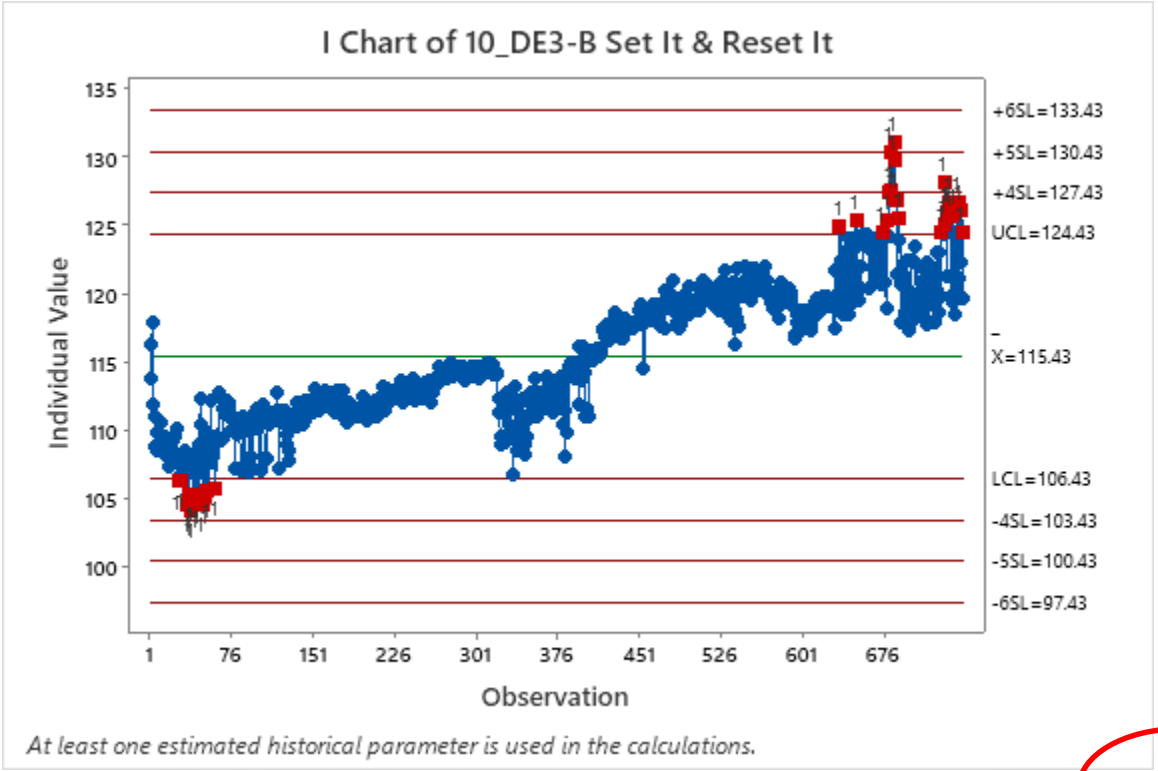


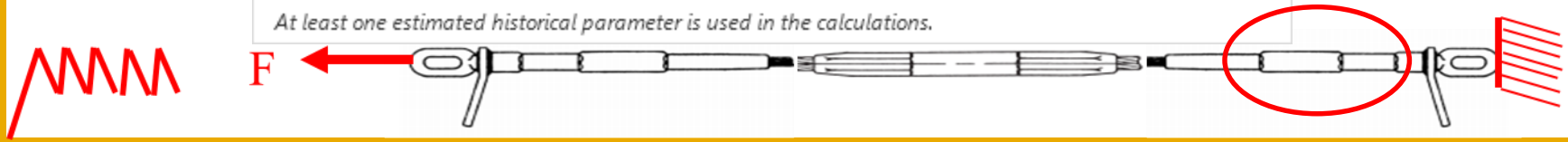
Temps S3-B Set It & Reset It



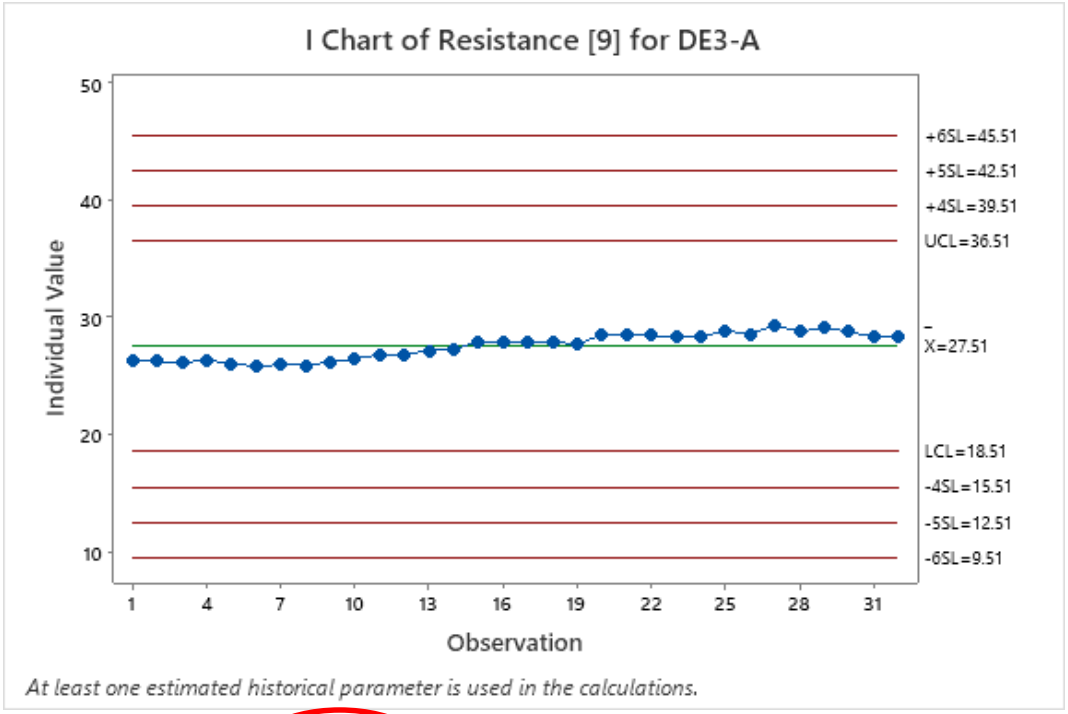


Temps DE3-B Set It & Reset It

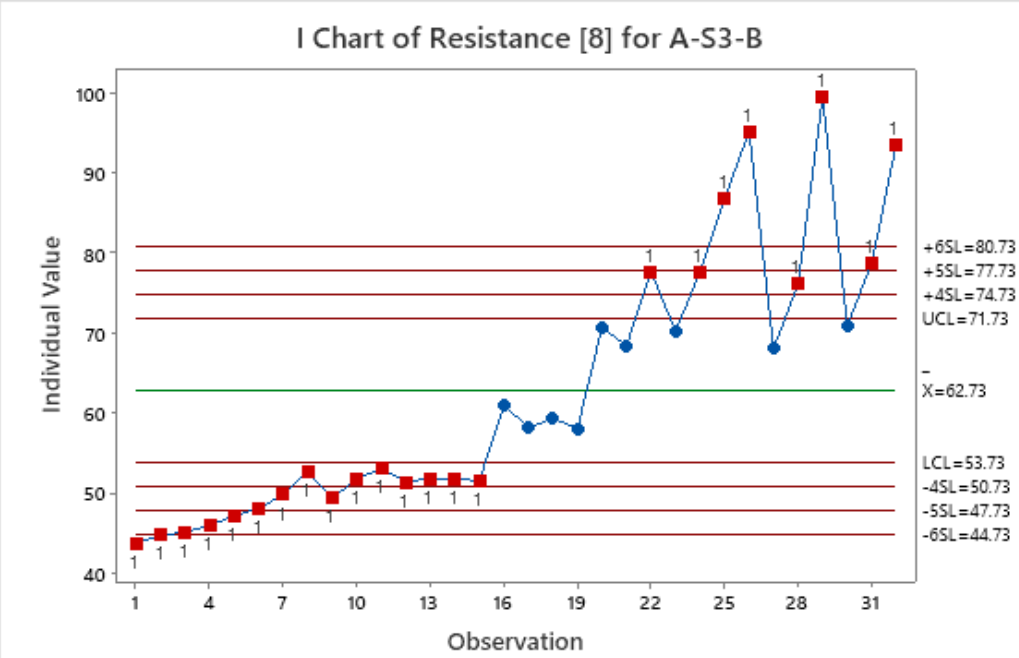




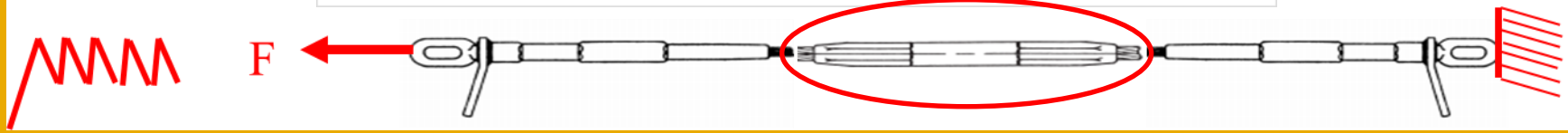
Resistance DE3-A / Set It & Reset It



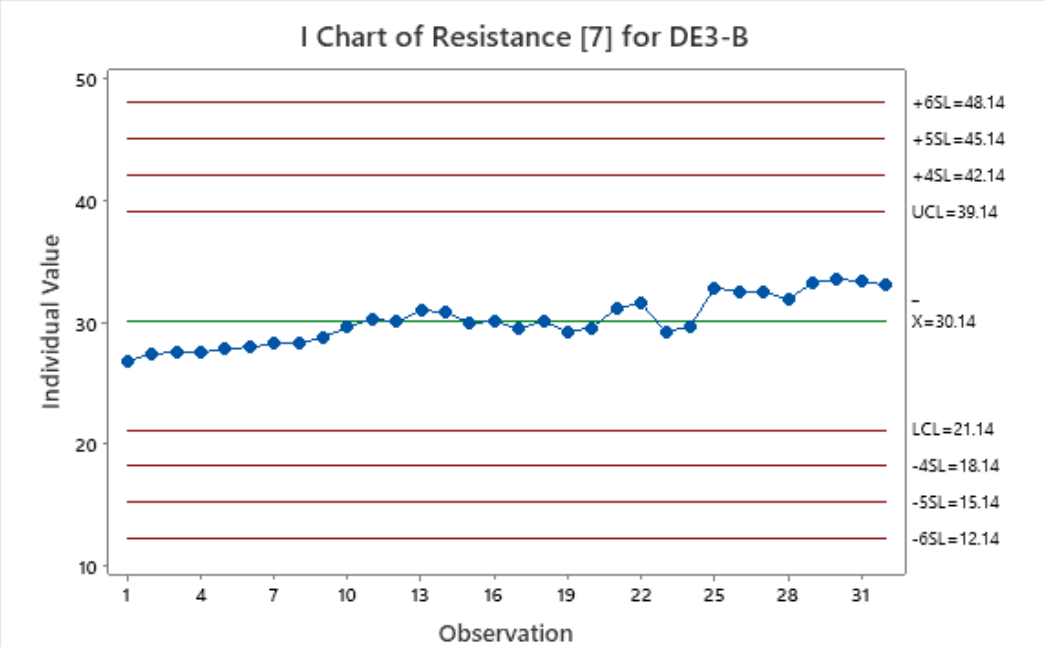
Resistance S3 / Set It & Reset It

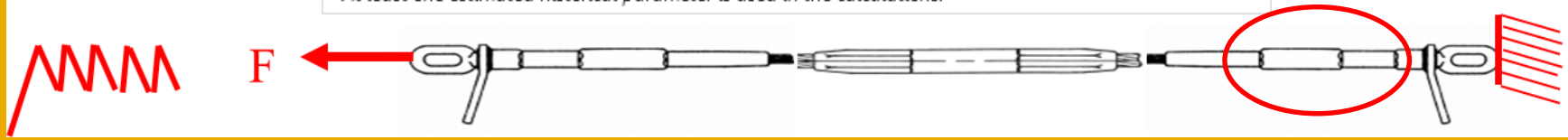


At least one estimated historical parameter is used in the calculations.

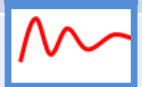


Resistance DE3-B / Set It & Reset It

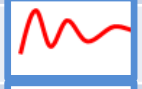




Ranking Tensioning Schemes

Tension Condition	# Connectors in Temperature Control	# Connectors in Resistance Control	Final Rank
	1	3	1
	0	0	3
	1	2	2

Ranking Tensioning Schemes

	C119.4 Rank	Control Chart Rank	Final Rank
	1	1	1
	3	3	3
	1	2	2

Presentation Agenda

Final Thoughts

What's Next

- We have enough information from Loop 2, and the C119.7 Committee and TA's advise completing this loop at 1000 cycles and starting Loop 3.

Schedule – End of Month Cycle Count

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	620	685	750	860	970	1000	110	220	330	440	550	660
2023	770	880	990									

Loop 1 Complete!

Loop 2

Loop 3

* Based on 1000 cycle loops.

On track