HEAT EXCHANGER WORLD
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# RELAXATION OF THE BOLTED FLANGE JOINT

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# Understanding Relaxation Behavior In Temperature Cycling Environments

- This study researches and monitors bolt stress readings for different gasket styles in multiple temperature cycling environments over a long time period.
- The information generated from this study and further developments will provide a better understanding of when a flanged joint may be at risk and the relaxation factor for a given gasket style in service. This can then be implemented into the bolt up procedure and torque value of the flange joint to ensure a leak free start up and long-term service performance.

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# Understanding Relaxation Behavior In Temperature Cycling Environments

This presentation follows on from a previous study I conducted – *PVP2020-21002 Relaxation Of The Bolted Flange Connection*. The study monitored bolt stress / relaxation values in temperature cycling environments for different gasket styles, the readings were only taken at ambient temperature after each temperature cycle due to intelligent bolt limitations.

With developments in intelligent bolting technology it was decided to conduct further work on this project to understand bolt stress values throughout the temperature cycling test.

# Understanding Relaxation Behavior In Temperature Cycling Environments

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| | |
|---|---|
| Standard | ASME B16.20 |
| NPS | 4" |
| Pressure Class | 300# |
| Pipe Sch | 80 |

| | | | |
|---|---|---|---|
| Gasket Type | | | SWG |
| Flange Material | | | A182 F11 Cl. 2 |
| **FLANGE DETAIL** | | | |
| Flange OD | A | in | 10.000 |
| Flange ID | B | in | 3.826 |
| BCD | C | in | 7.880 |
| Raised Flange / Recessed Dia | FOD | in | 6.190 |
| Pipe Wall Thickness | go (in) | | 0.337 |
| Hub Thk at Flange Ring | g1 | in | 0.962 |
| Flange Thk | t | in | 1.190 |
| Hub Height | h | in | 2.130 |
| Pipe Outside Diameter | Pipe OD | in | 4.500 |
| Hub OD | X | in | 5.750 |
| Distance - BCD to Hub | R | in | 1.065 |
| **BOLTING DETAIL** | | | |
| Bolt Material | | | A193 B7 |
| Bolt Diameter | φb | in | 3/4 |
| No of Bolts | nb | | 8 |
| Bolt Area | Root | in2 | 0.302 |
| **GASKET DETAIL** | | | |
| Gasket ID | G ID | in | 5.000 |
| Gasket OD | G OD | in | 5.880 |
| Gasket Area | | in2 | 7.52 |
| Additional Gasket Area | | in2 | - |
| m | | | 3.00 |
| y | | psi | 10,000 |
| **DESIGN CONDITIONS** | | | |
| Temperature | | Deg F | 500 |
| Pressure | | psi | 500 |
| Corrosion Factor | Ca | in | - |
| **STRESS VALUES** | | | |
| Flange (According to ASME B31.3-2020) | Sf (Amb) | psi | 40,000 |
| | Sf (Oper) | psi | 19,400 |
| Bolt (According to ASME B31.3-2020) | Sa | psi | 25,000 |
| | Sb | psi | 25,000 |
| | Sb Sel | psi | 64,000 |
| Bolt Yield | | psi | 105,000 |
| Flange Youngs Mod | E | psi | 2.94E+07 |
| Poissons Ratio | | | 0.3 |
| Flange Stress (Operating) | | % | 37% |
| Flange Stress (Assembly) | | % | 76% |
| Max BS (Assembly) - Calculated | | psi | 124,000 |
| Max BS - (Assembly) Min of Calc -Sbmax | | psi | 84,000 |

Note: 3S Superior Sealing Services LLC produces torque calculations from given information, either from relevant standards or information from our customers. 3S Superior Sealing Service LLC doesn't accept responsibility for misuse of this information.

## ASME SECTION VIII - DIV 1 APPENDIX 2 WELD NECK FLANGE ANALYSIS - WRC538 METHOD IN ASSEMBLY

### Torque Chart - ASME PCC-1 Appendix O Method

| | | | |
|---|---|---|---|
| | SgT | 20,562 | Gasket Stress |
| Sb sel | O-1 | 64,000 | Bolt Stress |
| Tb | O-2 | 205 | Torque |
| Sbsel | O-4 | TRUE | Bolt Upper Limits |
| Sbsel | O-5 | TRUE | Bolt Lower Limits |
| Sbsel | O-6 | TRUE | Flange Limits |
| Sg | O-7 | TRUE | Gasket Assembly Seating Stress |
| | O-8 | TRUE | Gasket Operating Stress Maintained |
| | O-9 | TRUE | Gasket Max Stress |

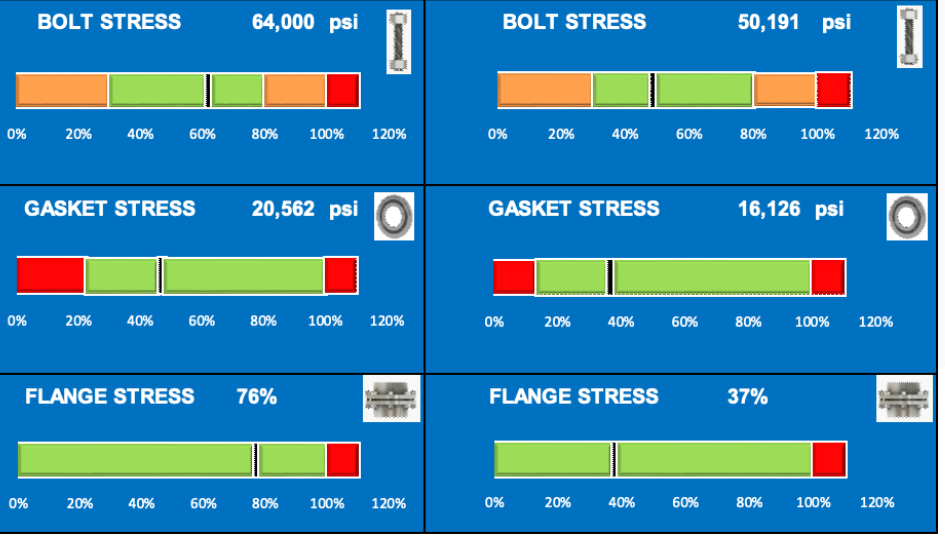
| | | | |
|---|---|---|---|
| Sg-min-O | 6,000 | Relaxation Factor | 0.70 |
| Sg-min-s | 10,000 | $\theta$gmax | 1.00 |
| Sg-max | 45,000 | | |

| | | |
|---|---|---|
| Sbmax | 84,000 | 80% |
| Sbmin | 31,500 | 30% |
| K Factor | 0.17 | |

| Max Operating Pressure (psi) | |
|---|---|
| Flange | 1358 |
| Bolt | 1287 |

| TORQUE (ft/lbs) | |
|---|---|
| Flange Alignment | 21 |
| 1st Pass - ft/lbs | 53 |
| 2nd Pass - ft/lbs | 105 |
| 3rd Pass - ft/lbs | 158 |
| Final Pass - ft/lbs | 210 |
| **Tb (O-2) - ft/lbs** | **210** |

| ASSEMBLY | OPERATING / HYDROTEST |
|---|---|
| BOLT STRESS 64,000 psi | BOLT STRESS 50,191 psi |
| GASKET STRESS 20,562 psi | GASKET STRESS 16,126 psi |
| FLANGE STRESS 76% | FLANGE STRESS 37% |



# Test Equipment

Temperature Control Unit / Flange Assembly / Insulation


4” 300lb RF WN Flanges to ASME B16.5

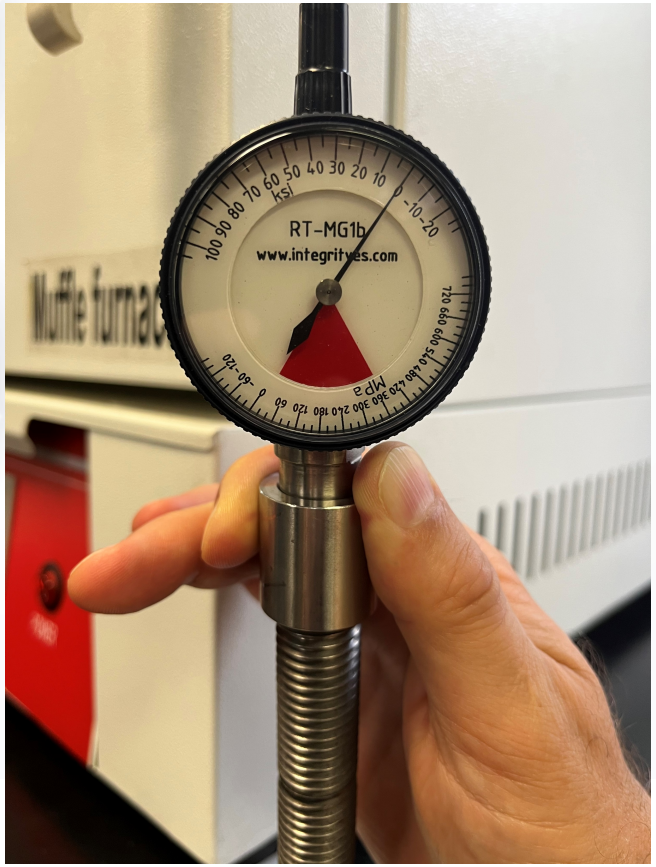

Flange Setup / Intelligent Bolting

## Test Temperature Details

- Temperature Control Unit: RS 340-083
- Thermocouple: Type K
- Thermocouple Data Collection: MC USB-TC / SN 202C8A7
- Channel Count: 1
- Scan Rate: 0.016667 (1 reading per minute)
- Temperature Control Set Value: 500 Deg F
- Heating Rate: 212 Deg F / Hour

# Test Equipment

Intelligent Bolt & Gauge




Ceramic Dial Gauge

# Test Equipment

Using the intelligent bolting with the ceramic dial gauge enables bolt stress reading to be taken at any point within the test procedure.

Bolt grade used for the first stage of this project was ASTM A193 B7.
Nut grade used ASTM A194 Gr. 2H
Hardened Washers.

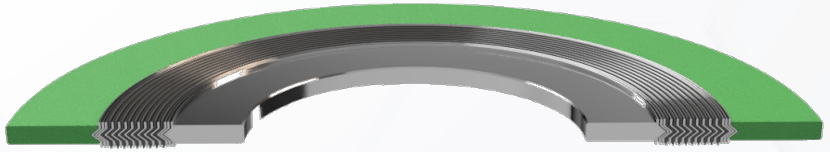
High temperature bolt lubricant with a K factor of 0.17

All tests had a target assembly bolt stress of 58,000 psi

# Test Gaskets

All gaskets are sized to suit ASME B16.5 – 4” 300lb RF  Flanges
Core / Winding material – 316L SS
Filler / Facing Material – Flexible Graphite

Gasket 1

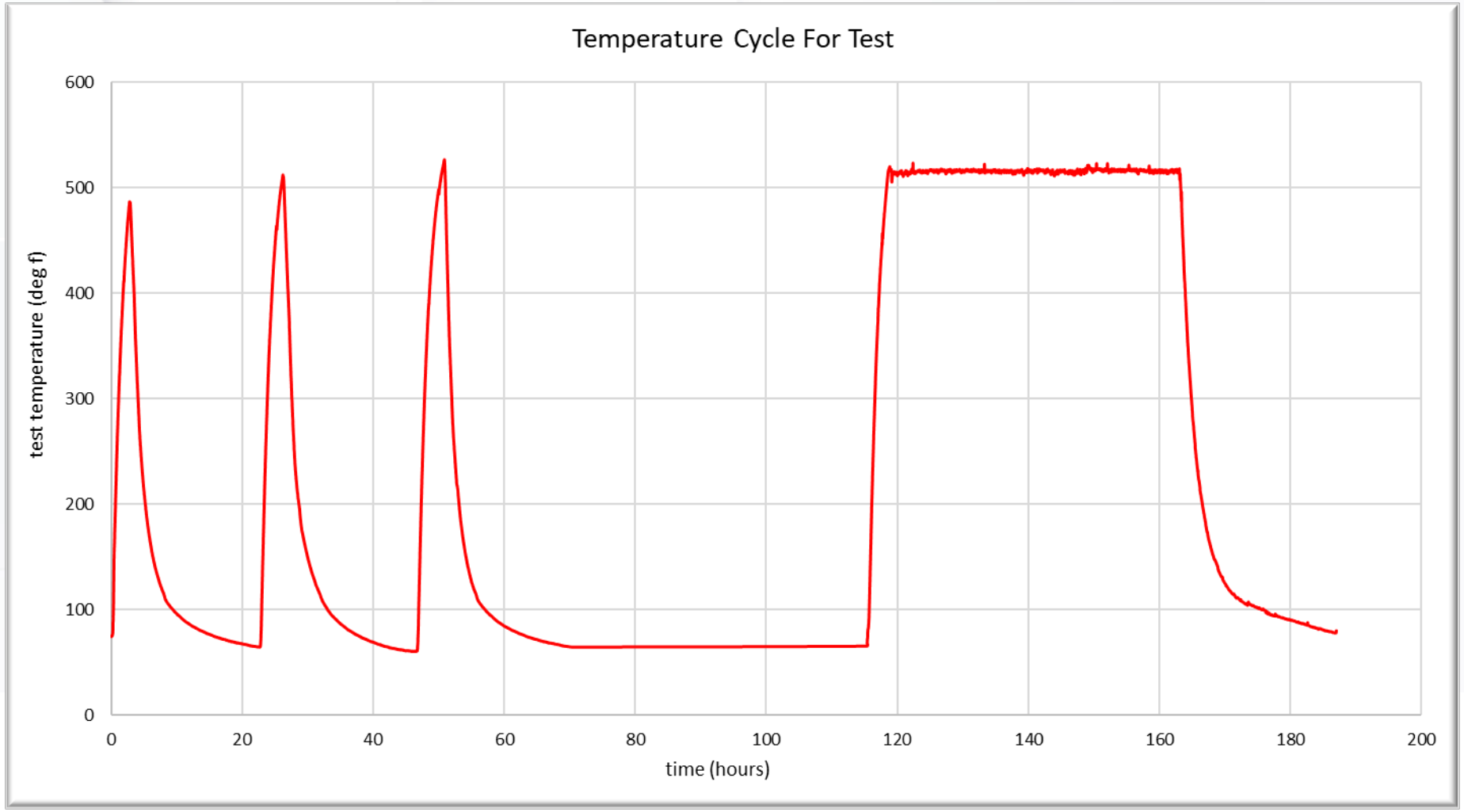


Gasket 2

Gasket 3

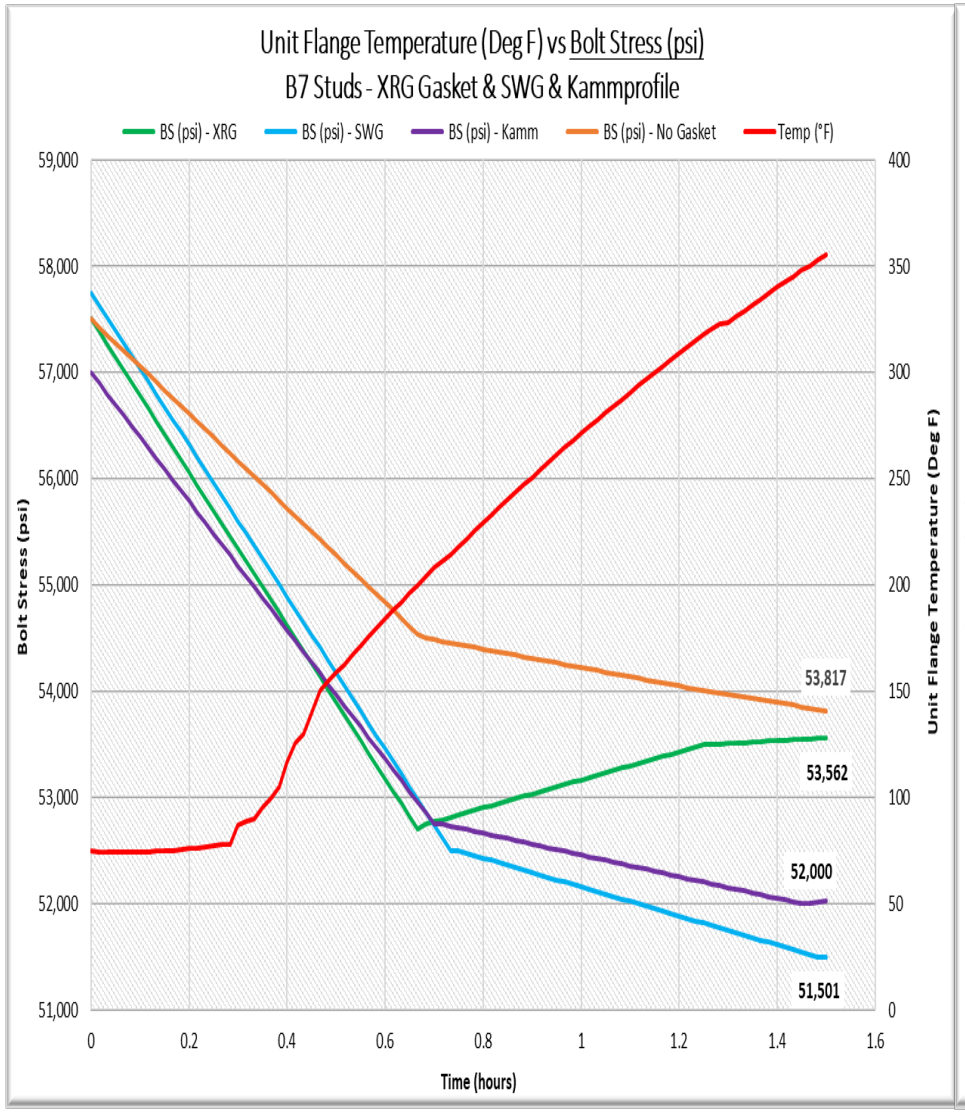
# Temperature Cycling

Each test follows the below temperature cycle with bolt stress readings taken through the test period.

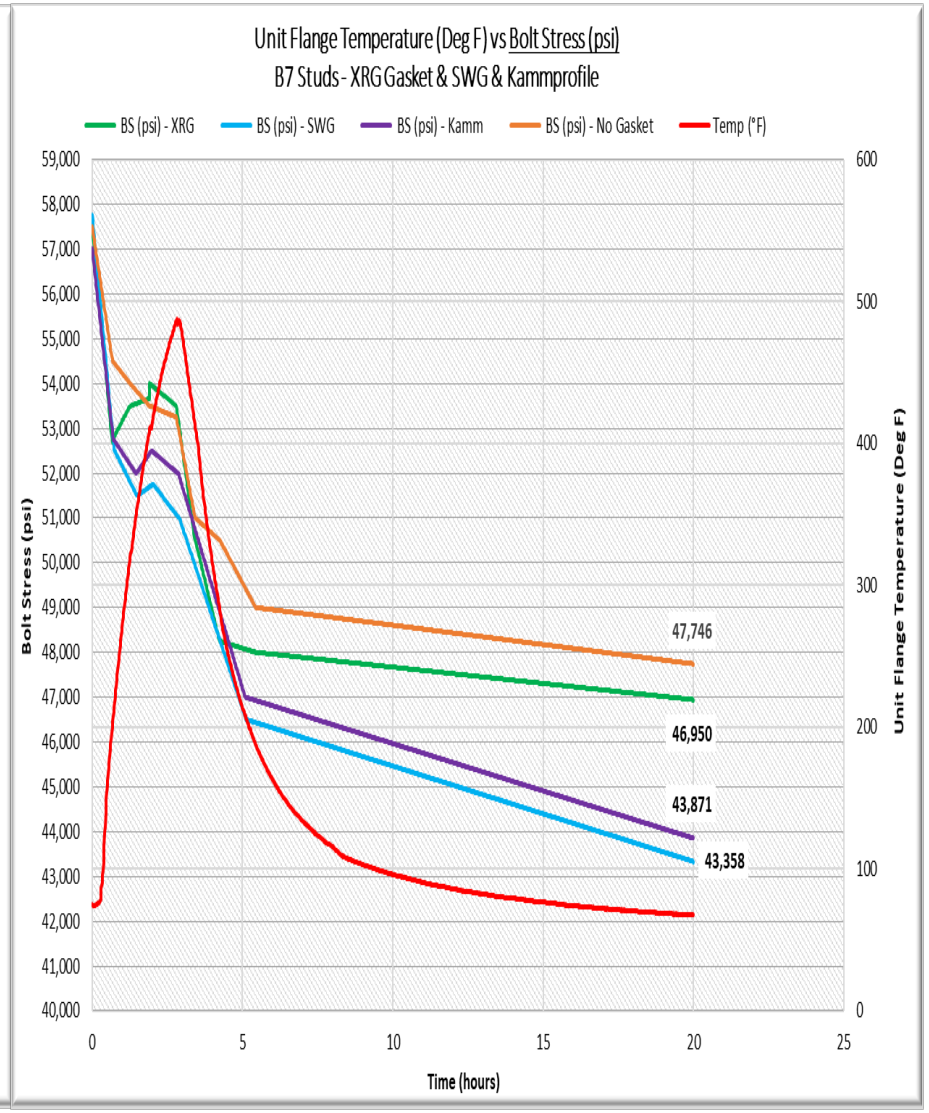


# Initial Reduction In Bolt Stress

The below graph shows the initial relaxation of the three gaskets over a 1 ½ hour Period

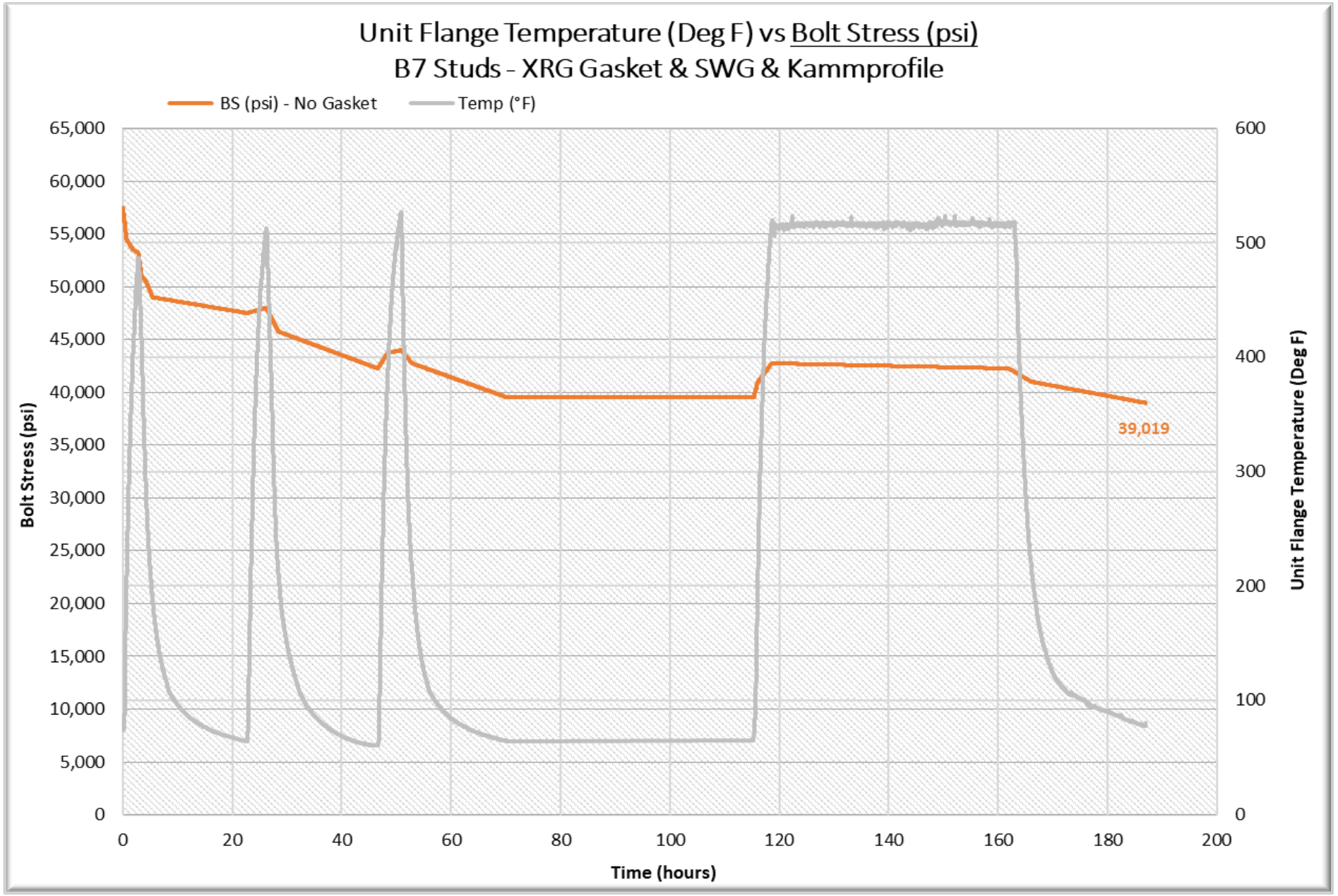



The below graph shows the initial relaxation of the three gaskets over the first temperature cycle



# Reduction In Bolt Stress Over The Full Test Period

The below graph shows the bolt stress readings across the full test.



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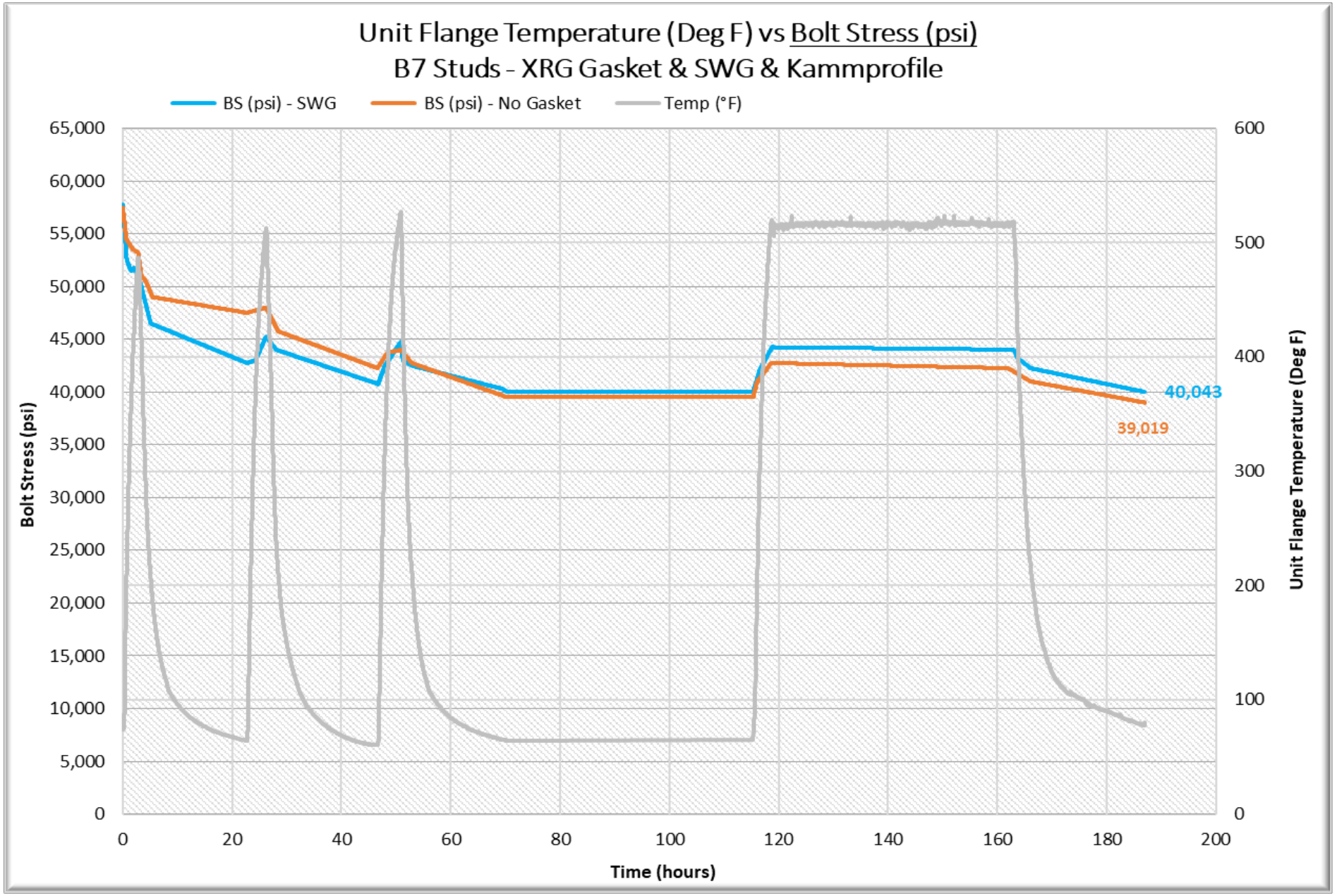

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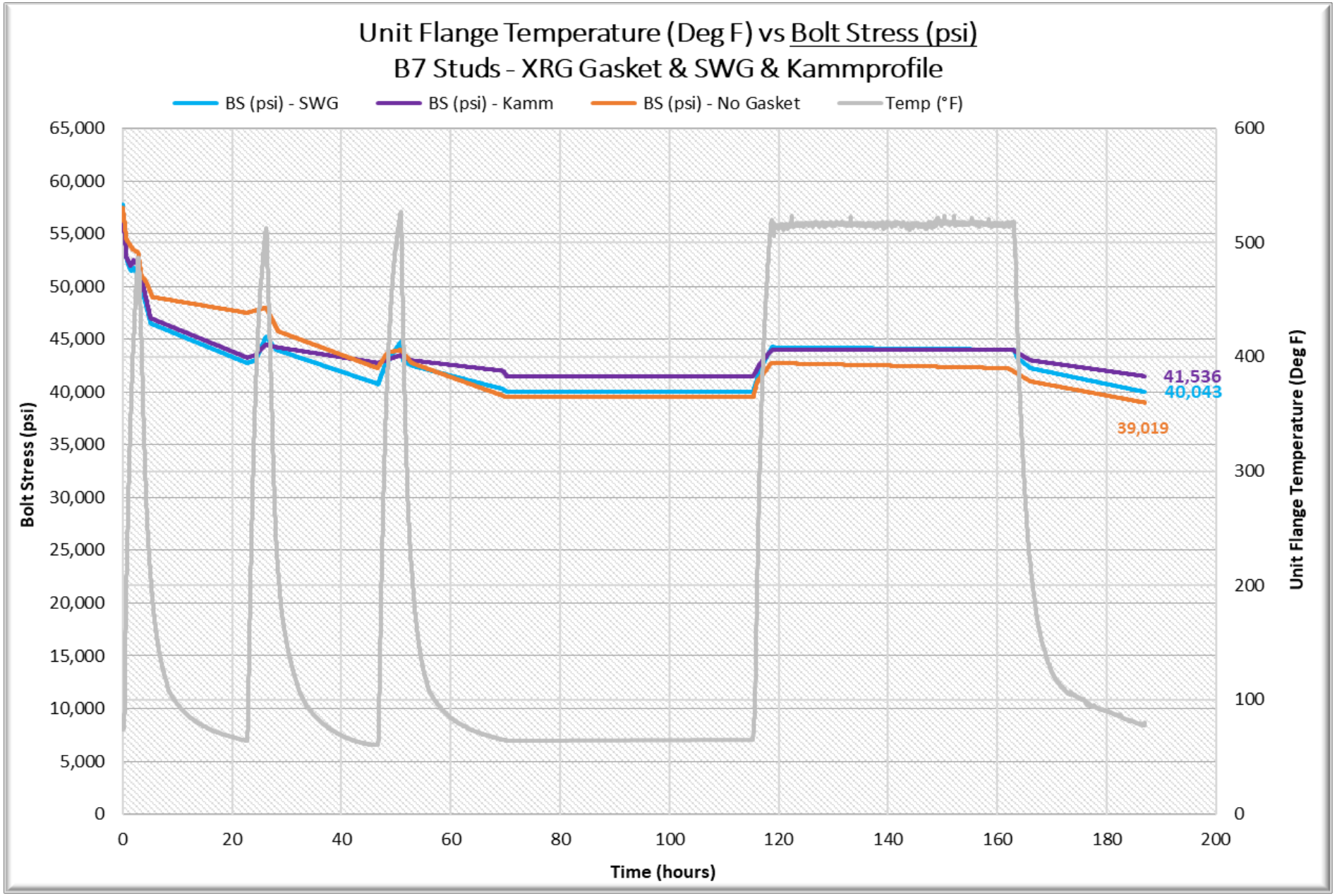

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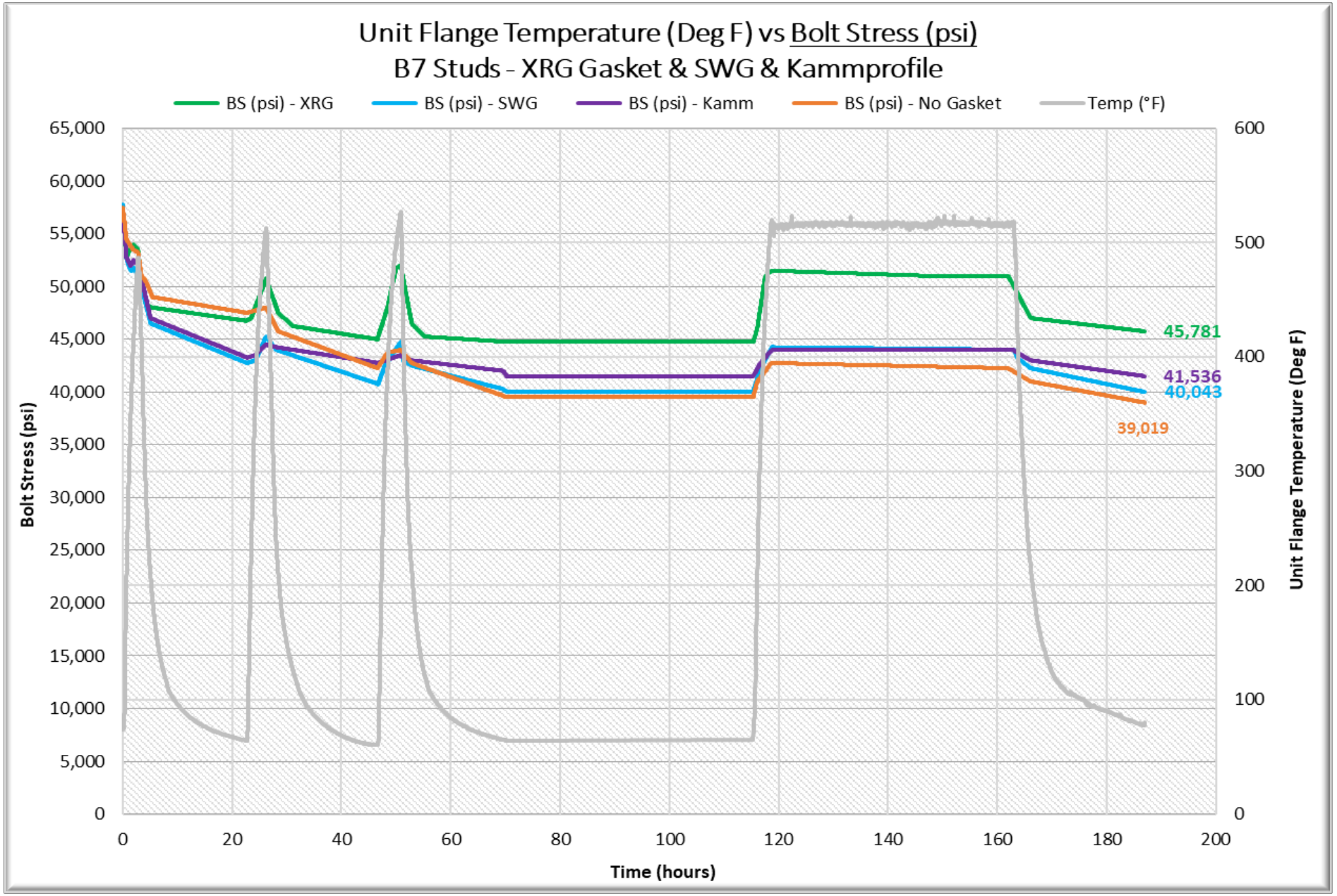
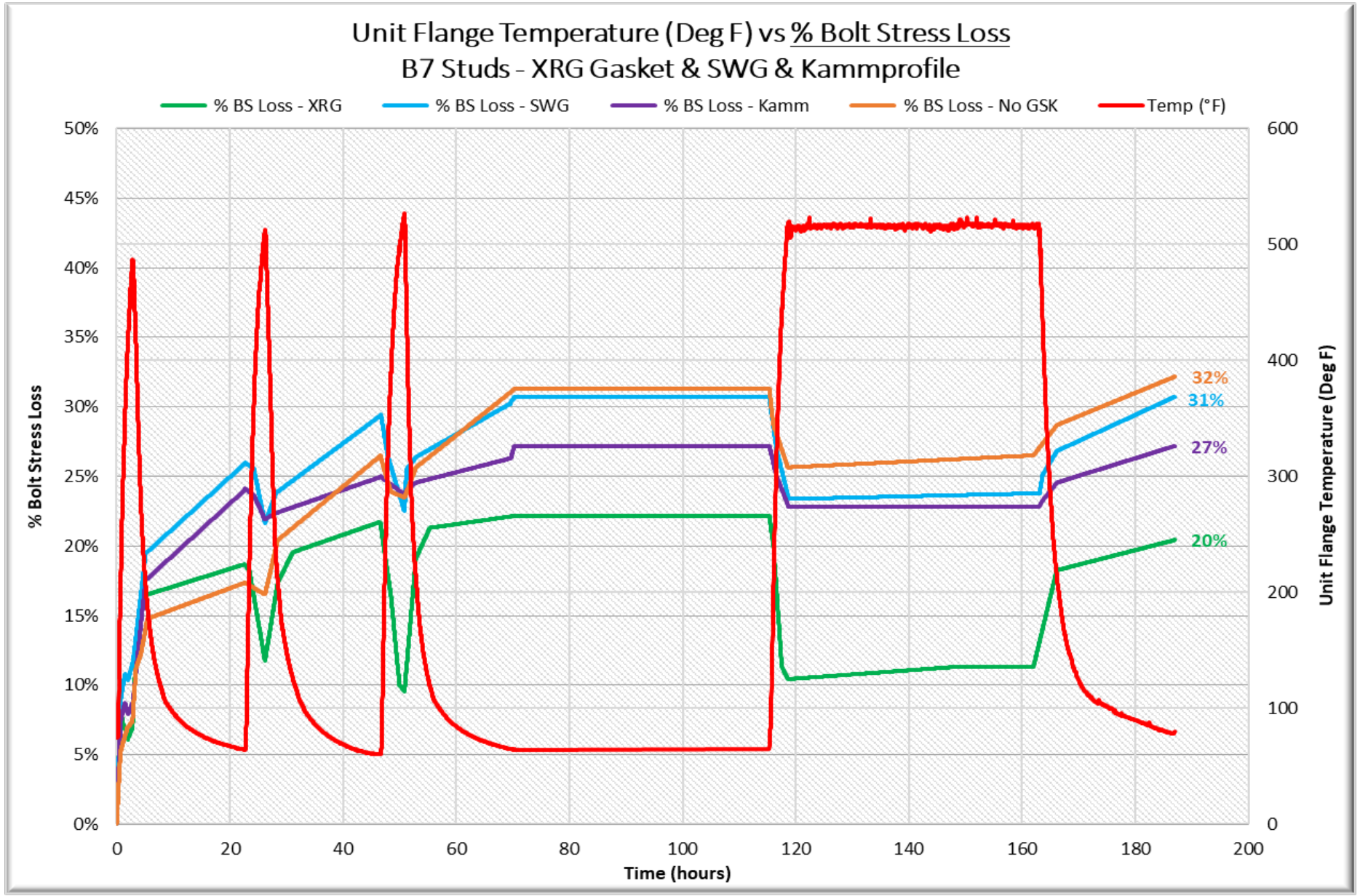


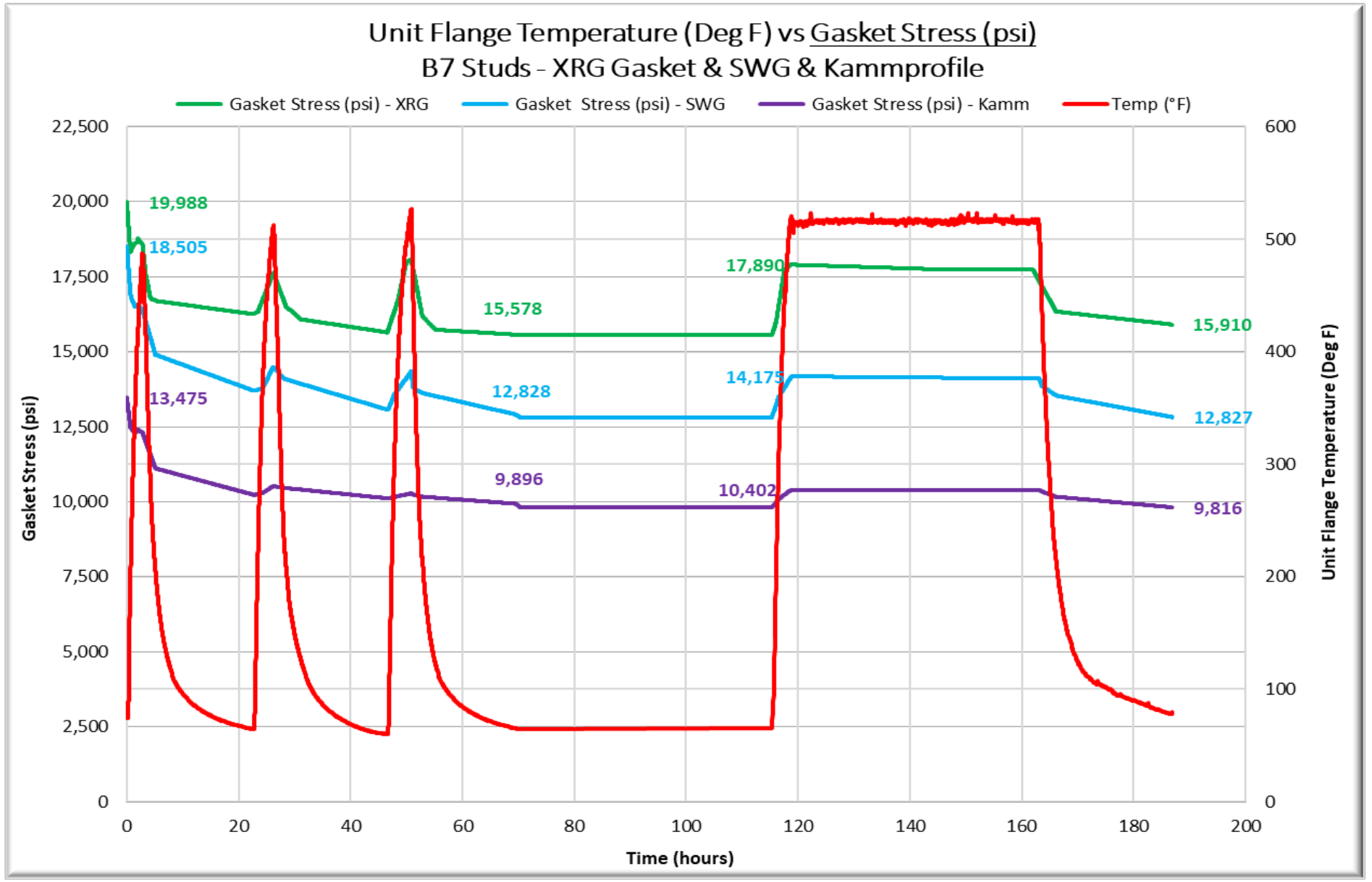
# % Relaxation Values Over The Full Test Period

As expected the relaxation values increase and decrease as the flange temperature cycles.



# Gasket Stress Values Over The Full Test Period

Gasket stress values are worked out from the bolt stress values as standard.



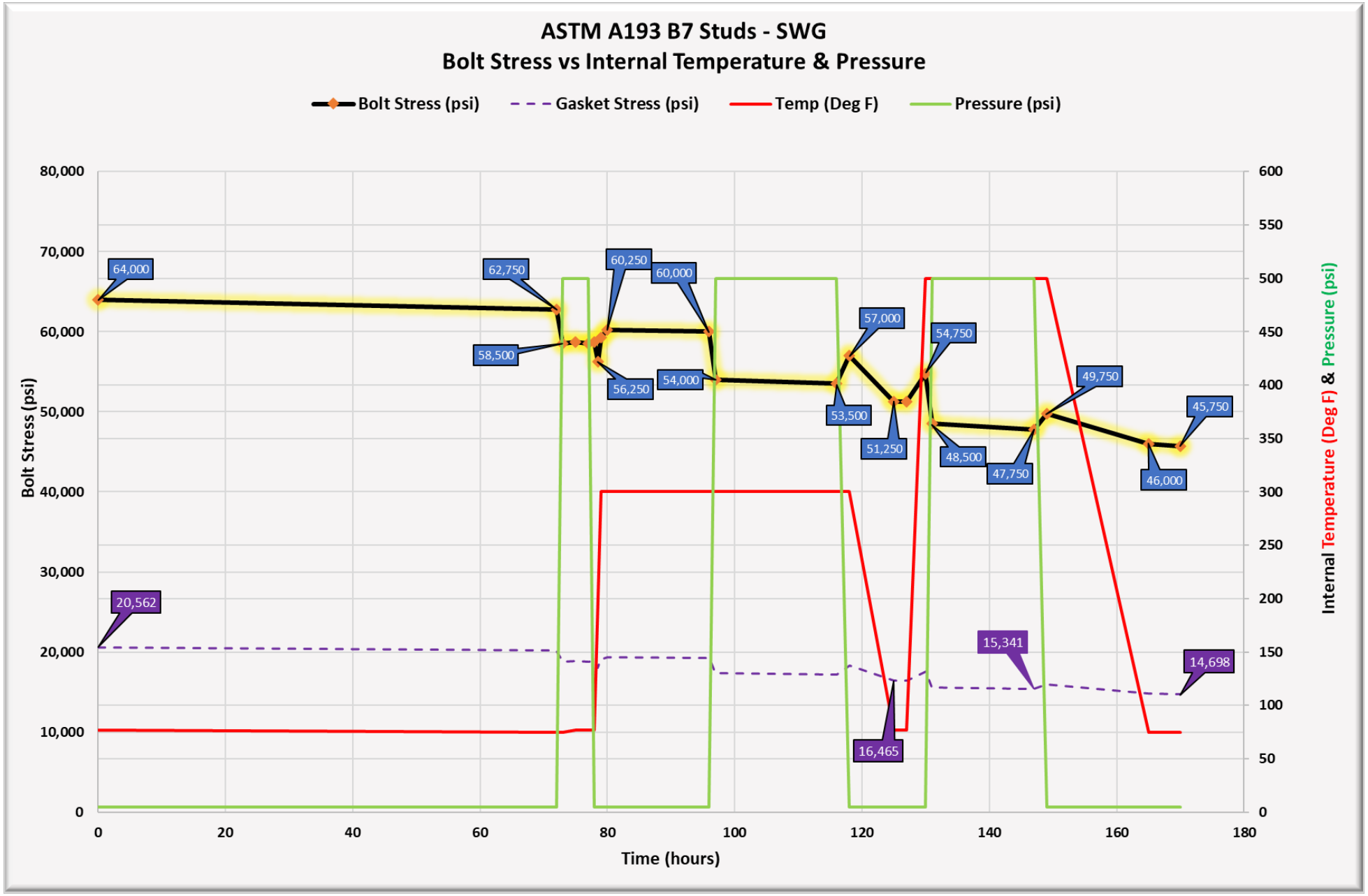
## Further Work To Be Conducted

- Repeat testing but introduce internal pressure into the test fixture. How will the hydrostatic end forces change the bolt stress readings?
- Repeat testing with different bolt grades.
- Suggestions?

## Conclusions

- Bolt stress readings increase as the temperature increases after the first temperature cycle.
- Minimal relaxation occurs after the first two temperature cycles.
- No relaxation was evident when left at ambient temperature for 2.5 days after the initial three temperature cycles.
- The gasket style does affect the amount of relaxation through temperature cycling.

# Further Work To Be Conducted



# Further Work To Be Conducted