Cokebusters

REMAINING LIFE ASSESSMENT

BA-1001

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Merlin
SMART PIGGING
INSPECTION TECHNOLOGY

SUMMARY

Cokebusters Ltd. were requested to carry out Level 2 Fitness for Service and Remaining Life Assessment on the process coils within heater BA-1001. All integrity analysis procedures were carried out in accordance with the methodologies described in API 579-1 / ASME FFS-1 2016.

From the Merlin Inspection data obtained it was evident that no significant metallic flaws were present within any pass, although some minor general metal loss was evident. None of the measured wall thickness values were seen to be below the Minimum Allowable Wall Thickness of 5.49mm (See Appendix A for full calculations). Remaining Life Assessments were carried out on every zone, of each process coil within the furnace. The Maximum Allowable Working Pressure (MAWP) approach used is described in API 579-1 / ASME FFS-1 2016 Section 4 and 5.

The historic data provided for the operating conditions of this furnace indicated the furnace has never entered the creep range and the pressures within the coils have never exceeded design pressure of the heater. Additionally, from the inspection data obtained, it can be seen that there is no evidence of any diametric growth. As a result, a remaining life assessment for equipment operating within the creep range was not necessary.

During the inspection is was evident that some internal fouling remained within the radiant tubing of the heater. Calculations have been made against the minimum wall thickness obtained during the intelligent pigging inspection. As reliable thickness data could not be obtained in the areas where the coke/internal fouling remained, these areas could not be taken into account in the assessment.

A remaining life assessment was carried out assuming the wall thickness at commissioning was at the nominal +12.5% throughout the heater and a uniform corrosion rate over the past 15 years. Based on a 600°F (316°C) operating temp the minimum calculated remaining life was **13.22 years** in 4” Convection Tube 14, Pass 1 and Pass 3. The corresponding remaining life for the same areas based on an operating temp of 900°F (482°C) is calculated to be **12.92 years** and **13.19 years** for a future operating temperature of 707°F (375°C).

A second remaining life assessment was also carried out using the supplied historic inspection data from 2013; a linear corrosion rate was assumed over the 4 years since this inspection. Based on a 600°F (316°C) operating temp the minimum calculated remaining life was **5.34 years** in Pass 2 4” Radiant Tube 16. The corresponding remaining life for the same areas based on an operating temp of 900°F (482°C) is calculated to be **5.29 years** and **5.34 years** for a future operating temperature of 707°F (375°C).

The remaining life values are listed in Table 1 and Table 2. Estimated remaining life was calculated for operating temperatures of 300°F (149°C), 600°F (316°C) and 900°F (482°C) to give a general overview of how different operating conditions will affect the remaining life of the heater. The estimated remaining life was also calculated for the specified future operating temperature of 707°F (375°C). These calculations do not account for increased coking as a result of higher temperatures and cannot accurately predict the formation of any hotspots as a result of coke formation or otherwise.

CONTENTS

1. ASSUMPTIONS

Historic inspection data was provided, however, only a single wall thickness value was provided for each tube. The value provided for each tube was considered to be the minimum wall thickness of that tube at the time of the inspection in 2013. A linear corrosion rate has been assumed over the previous 4 years since this inspection and the remaining life assessment conducted using the data collected by the Merlin Smart Pig IV.

A second remaining life assessment was also carried out assuming that the tube wall thickness was at the nominal +12.5% throughout the furnace at the time of commissioning and a linear corrosion rate over the past 15 years. Typically, the wall thickness tolerance for furnace tube manufacture of seamless pipe is +-12.5% due to mill tolerances - assuming the nominal wall thickness +12.5% at commissioning provides a more conservative remaining life and a “worst case” scenario.

In reality, the rate of corrosion in many instances accelerates with time. Using accurate historic wall thickness data, a regression would usually be carried out. This allows for a more accurate corrosion rate calculation. It will be viable to use this method after the next run period should the furnace be inspected using intelligent pigging technology, as there will be more comprehensive inspection data. This also highlights the importance of obtaining accurate furnace wall thickness data during heater commissioning/build and throughout the operating life of an asset.

The future operating conditions for this heater were provided as:

Max Operating Temp: 375°C (707°F)
Max Operating Pressure: 6.2kg/cm^2

2. RECOMMENDATIONS

Although the results of the remaining life assessments carried out for this report indicate that the furnace should be safe to run for at least the next 5.34 years without any tube repair or replacement required, it is strongly advised that the limitations and scope of this assessment should be taken into account. It is recommended that towards the end of the next run cycle IR thermography is carried out on the radiant tubes to try establish the actual tube metal temperature (TMT) for each tube, particularly the areas where there is coke remaining in the tubes; due to the insulating effect the coke/internal fouling has on the tubes the TMT is likely to be significantly higher in these areas. Using these temperatures will increase the accuracy of the assessment and most likely result in a more conservative outcome. In addition, obtaining actual inlet and outlet pressures towards the end of the cycle (pre-decoke) will be beneficial to increasing the accuracy of the assessment, as these are likely to increase over time. This will allow for a more accurate assessment to be carried out at a future date.

As mentioned in the previous section, it is recommended that as part of the continued asset integrity management plan for this furnace that intelligent pigging is carried out during the next furnace shutdown, so that an accurate corrosion rate can be calculated and further increase

the accuracy and validity of the assessment. If during the next turnaround the coke cannot be removed in its entirety, then it is recommended that these areas are checked using manual UT and the results from these areas used in conjunction with the data obtained from the Merlin Smart Pig as inputs into the RLA to more accurately calculate the corrosion rate.

3. MAXIMUM ALLOWABLE WORKING PRESSURE CALCULATION

The Maximum Allowable Working Pressure can be calculated using the formula shown below. The formula accounts for the maximum allowable stress in a material at a given temperature (values taken from ASME B31.3), the weld joint efficiency, the minimum wall thickness of the piping as measured by the Merlin Smart Pig IV, and the inner radius of the piping, also measured with the Merlin Smart Pig IV.

For the future operating temperature, a specific value for the maximum allowable stress is not available in ASME B31.3. In this instance a linear relationship between the given values is assumed and the respective maximum allowable stress calculated.

$$\text{MAWP} = \frac{\sigma E t}{Ri + (0.6t)}$$

MAWP = Maximum allowable working pressure
σ = Allowable stress
E = Weld joint efficiency
t = Minimum thickness
Ri = Inside radius

As can be seen from the formula, a higher allowable stress, increased weld efficiency and a greater remaining wall thickness will all improve the MAWP, whilst an increase in internal radius will reduce the MAWP.

As no previous wall thickness data was provided, a linear corrosion rate using the current wall thickness data and the nominal was used. Using this data, the MAWP can then be extrapolated and plotted over the next 40 years. By also plotting the maximum future operating pressure, the intersect of these can be calculated. The point where the MAWP and the maximum future operating pressure intersect is the remaining life value.

4. ESTIMATED MAXIMUM REMAINING LIFE VALUES BASED ON NOMINAL WALL THICKNESS +12.5%

Pass/Zone	Min WT(mm) and Tube reference Number	RL Years @ 300°F (149°C)	RL Years @ 600°F (316°C)	RL Years @ 707°F (375°C)	RL Years @ 900°F (482°C)
Pass 1, 4 Inch Convection	7.61, Tube 14	13.24	13.22	13.19	12.92
Pass 1, 4 Inch Radiant	7.73, Tube 14	14.62	14.60	14.56	14.28
Pass 1, 5 Inch Radiant	8.58, Tube 2	15.05	15.02	14.98	14.65
Pass 1, 6 Inch Radiant	10.21, Tube 1	18.11	18.07	18.02	17.64
Pass 1, 8 Inch Radiant	12.29, Tube 1	24.99	24.94	24.86	24.30
Pass 2, 4 Inch Convection	7.61, Tube 14	13.25	13.23	13.19	12.93
Pass 2, 4 Inch Radiant	7.81, Tube 11	15.64	15.62	15.57	15.28
Pass 2, 5 Inch Radiant	8.80, Tube 2	17.89	17.86	17.81	17.44
Pass 2, 6 Inch Radiant	9.83, Tube 1	14.02	13.99	13.95	13.63
Pass 2, 8 Inch Radiant	11.48, Tube 1	15.03	15.00	14.94	14.56
Pass 3, 4 Inch Convection	7.82, Tube 14	15.77	15.75	15.71	15.41
Pass 3, 4 Inch Radiant	7.77, Tube 18	15.12	15.10	15.06	14.77
Pass 3, 5 Inch Radiant	8.94, Tube 2	20.09	20.05	20.00	19.60
Pass 3, 6 Inch Radiant	10.27, Tube 1	18.89	18.86	18.80	18.41
Pass 3, 8 Inch Radiant	11.96, Tube 1	20.07	20.03	19.96	19.49
Pass 3, 4 Inch Convection	7.61, Tube 14	13.24	13.22	13.19	12.92
Pass 3, 4 Inch Radiant	7.79, Tube 19	15.38	15.35	15.31	15.02
Pass 3, 5 Inch Radiant	8.94, Tube 2	20.09	20.05	20.00	19.60
Pass 3, 6 Inch Radiant	10.09, Tube 1	16.66	16.63	16.58	16.22
Pass 3, 8 Inch Radiant	12.81, Tube 1	37.33	37.27	37.16	36.40

5. ESTIMATED MAXIMUM REMAINING LIFE VALUES BASED ON HISTORIC INSPECTION DATA

Pass/Zone	Min WT(mm) and Tube reference Number	RL Years @ 300°F (149°C)	RL Years @ 600°F (316°C)	RL Years @ 707°F (375°C)	RL Years @ 900°F (482°C)
*Pass 1, 4 Inch Convection	7.61, Tube 14	N/A	N/A	N/A	N/A
Pass 1, 4 Inch Radiant	7.73, Tube 14	5.61	5.60	5.60	5.54
Pass 1, 5 Inch Radiant	8.58, Tube 2	7.33	7.32	7.30	7.18
Pass 1, 6 Inch Radiant	10.21, Tube 1	21.46	21.43	21.37	20.99
Pass 1, 8 Inch Radiant	12.29, Tube 1	21.26	21.22	21.16	20.75
*Pass 2, 4 Inch Convection	7.61, Tube 14	N/A	N/A	N/A	N/A
Pass 2, 4 Inch Radiant	7.81, Tube 11	5.35	5.34	5.34	5.29
Pass 2, 5 Inch Radiant	8.80, Tube 2	8.95	8.94	8.92	8.77
Pass 2, 6 Inch Radiant	9.83, Tube 1	10.03	10.01	9.99	9.81
Pass 2, 8 Inch Radiant	11.48, Tube 1	6.55	6.54	6.53	6.40
*Pass 3, 4 Inch Convection	7.82, Tube 14	N/A	N/A	N/A	N/A
Pass 3, 4 Inch Radiant	7.77, Tube 18	6.75	6.75	6.74	6.65
Pass 3, 5 Inch Radiant	8.94, Tube 2	9.23	9.22	9.20	9.05
Pass 3, 6 Inch Radiant	10.27, Tube 1	24.02	23.99	23.93	23.50
Pass 3, 8 Inch Radiant	11.96, Tube 1	10.63	10.61	10.58	10.37
*Pass 3, 4 Inch Convection	7.61, Tube 14	N/A	N/A	N/A	N/A
Pass 3, 4 Inch Radiant	7.79, Tube 19	5.92	5.91	5.90	5.83
Pass 3, 5 Inch Radiant	8.94, Tube 2	14.22	14.20	14.17	13.93
Pass 3, 6 Inch Radiant	10.09, Tube 1	15.08	15.06	15.02	14.75
Pass 3, 8 Inch Radiant	12.81, Tube 1	17.54	17.51	17.46	17.14

*No historic inspection data provided.

6. APPENDIX A: MINIMUM ALLOWABLE WALL THICKNESS (ALL PASSES)

6.1 Convection Tubes

Assessment Inputs

Component Name	4 Inch Convection Tubing
Material Specification Number and Grade	A335-P9
Design temperature	587°C
Minimum Temperature	10°C
Design Pressure	1.860MPa
Nominal Outside Diameter	114.3mm
Nominal Thickness	8.6mm
Supplemental Thickness	0.0mm
Longitudinal Weld Joint Efficiency	1
Mechanical Allowances - MA	1.075mm
Internal Future Corrosion Allowance	0.132mm
External Future Corrosion Allowance	0.0mm
Internal Uniform Metal Allowance	0.99mm
External Uniform Metal Allowance	0.0mm

Assessment Results

Allowable Stress	**22.7527MPa**
Minimum Required Thickness	**5.4941mm**

Calculations based on data from ASME B31.3 2006 and Supplied Operating Data using TWI Integriwise software.

6.2 Radiant 4 Inch Tubes

Assessment Inputs

Component Name	4 Inch Radiant Tubing
Material Specification Number and Grade	A335-P9
Design temperature	587°C
Minimum Temperature	10°C
Design Pressure	1.860MPa
Nominal Outside Diameter	114.3mm
Nominal Thickness	8.6mm
Supplemental Thickness	0.0mm
Longitudinal Weld Joint Efficiency	1
Mechanical Allowances - MA	1.075mm
Internal Future Corrosion Allowance	0.101mm
External Future Corrosion Allowance	0.0mm
Internal Uniform Metal Allowance	0.76mm
External Uniform Metal Allowance	0.0mm

Assessment Results

Allowable Stress	**22.7527MPa**
Minimum Required Thickness	**5.4941mm**

Calculations based on data from ASME B31.3 2006 and Supplied Operating Data using TWI Integriwise software.

6.3 Radiant 5 Inch Tubes

Assessment Inputs

Component Name	5 Inch Radiant Tubing
Material Specification Number and Grade	A335-P9
Design temperature	587°C
Minimum Temperature	10°C
Design Pressure	1.860MPa
Nominal Outside Diameter	141.3mm
Nominal Thickness	9.5mm
Supplemental Thickness	0.0mm
Longitudinal Weld Joint Efficiency	1
Material Specification Number and Grade	A335-P9
Internal Future Corrosion Allowance	0.123mm
External Future Corrosion Allowance	0.0mm
Internal Uniform Metal Allowance	0.92mm
External Uniform Metal Allowance	0.0mm

Assessment Results

Allowable Stress	**22.7527MPa**
Minimum Required Thickness	**6.6504mm**

Calculations based on data from ASME B31.3 2006 and Supplied Operating Data using TWI Integriwise software.

6.4 Radiant 6 Inch Tubes

Assessment Inputs

Component Name	6 Inch Radiant tubing
Material Specification Number and Grade	A335-P9
Design temperature	587°C
Minimum Temperature	10°C
Design Pressure	1.860MPa
Nominal Outside Diameter	168.3mm
Nominal Thickness	11.0mm
Supplemental Thickness	0.0mm
Longitudinal Weld Joint Efficiency	1
Material Specification Number and Grade	A335-P9
Internal Future Corrosion Allowance	0.156mm
External Future Corrosion Allowance	0.0mm
Internal Uniform Metal Allowance	1.17mm
External Uniform Metal Allowance	0.0mm

Assessment Results

Allowable Stress	**22.7527MPa**
Minimum Required Thickness	**7.8818mm**

Calculations based on data from ASME B31.3 2006 and Supplied Operating Data using TWI Integriwise software.

6.5 Radiant 8 Inch Tubes

Assessment Inputs

Component Name	8 Inch Radiant Tubing
Material Specification Number and Grade	A335-P9
Design temperature	587°C
Minimum Temperature	10°C
Design Pressure	1.860MPa
Nominal Outside Diameter	219.1mm
Nominal Thickness	12.7mm
Supplemental Thickness	0.0mm
Longitudinal Weld Joint Efficiency	1
Material Specification Number and Grade	A335-P9
Internal Future Corrosion Allowance	0.163mm
External Future Corrosion Allowance	0.0mm
Internal Uniform Metal Allowance	1.2mm
External Uniform Metal Allowance	0.0mm

Assessment Results

Allowable Stress	**22.7527MPa**
Minimum Required Thickness	**10.0583mm**

Calculations based on data from ASME B31.3 2006 and Supplied Operating Data using TWI Integriwise software.

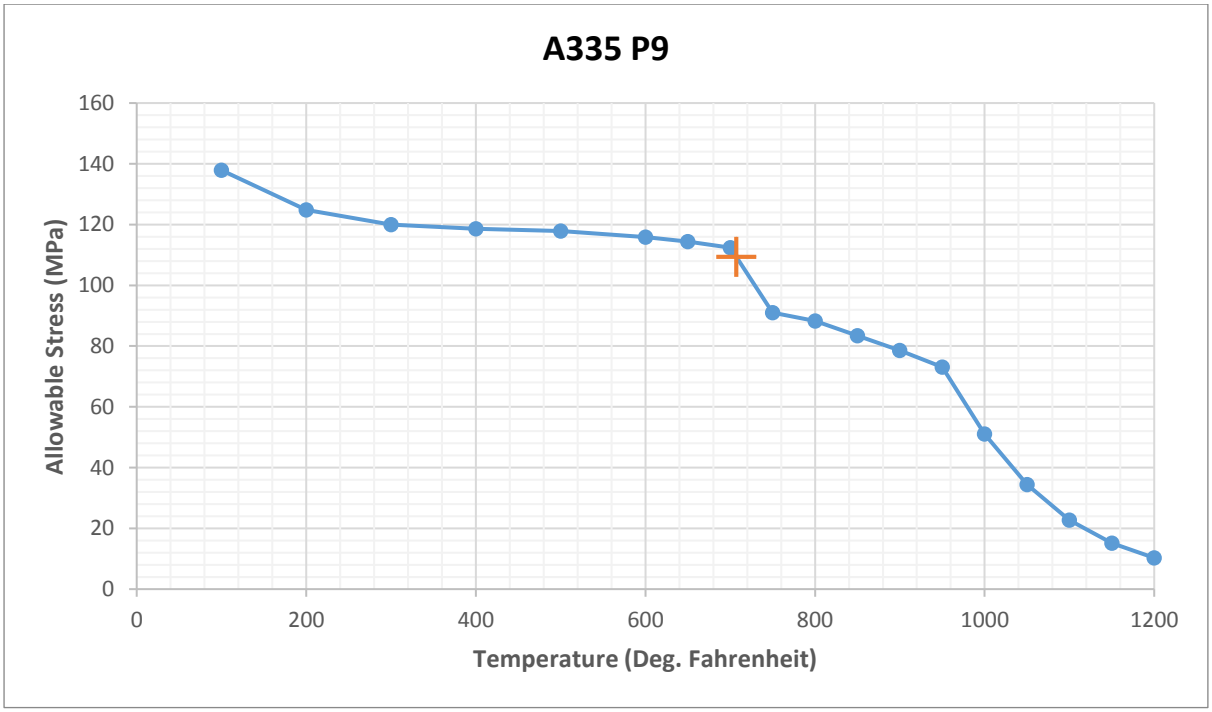
7. APPENDIX B: ALLOWABLE STRESSES FOR A335 P9 TO ASME B31.3

Maximum Allowable Stress @ 300°F (149°C): 119.97 MPa

Maximum Allowable Stress @ 600°F (316°C): 115.83 MPa

Maximum Allowable Stress @ 900°F (482°C): 78.6 MPa

Maximum Allowable Stress @ 707°F (375°C): 109.39 MPa



8. APPENDIX C: PASS 1 REMAINING LIFE CALCULATIONS (BASED ON MAWP)

8.1 Pass 1, Convection Coil, Maximum Allowable Future Operating Pressure

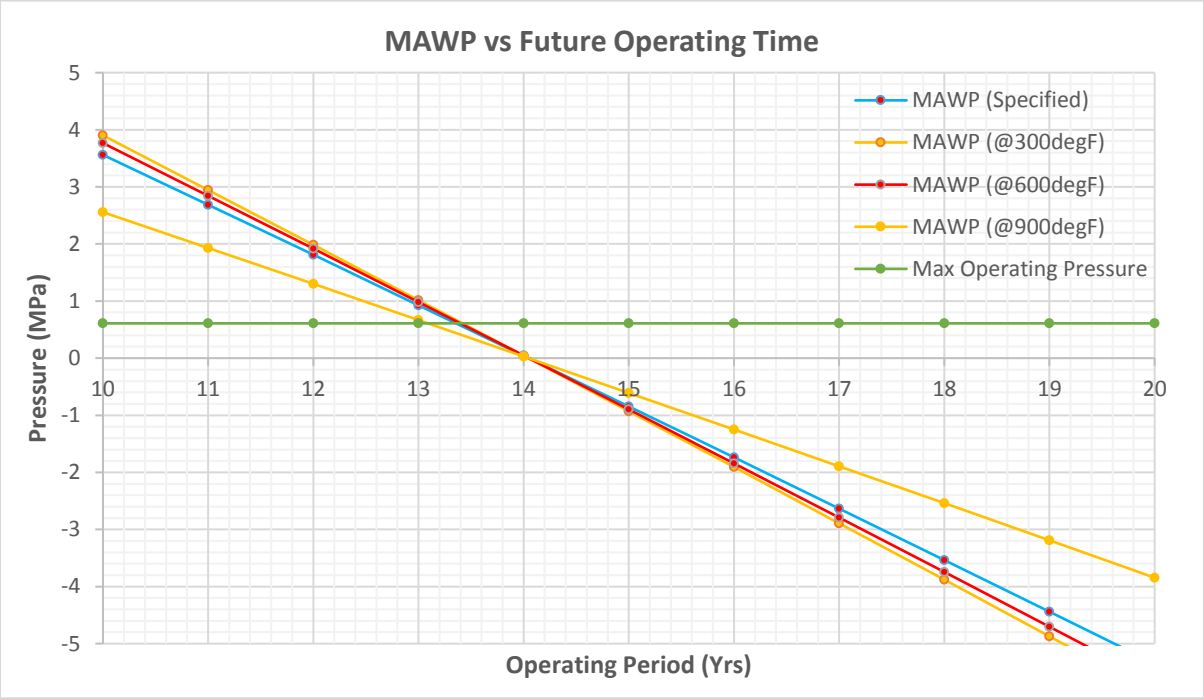
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 8.6mm+12.5% (9.68mm)

Supplied Data Wall Thickness: N/A

Nominal ID: 97.1mm

Minimum Measured Wall Thickness: 7.61mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	13.24	N/A
600°F (316°C)	13.22	N/A
707°F (375°C)	13.19	N/A
900°F (482°C)	12.92	N/A

8.2 Pass 1, 4 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

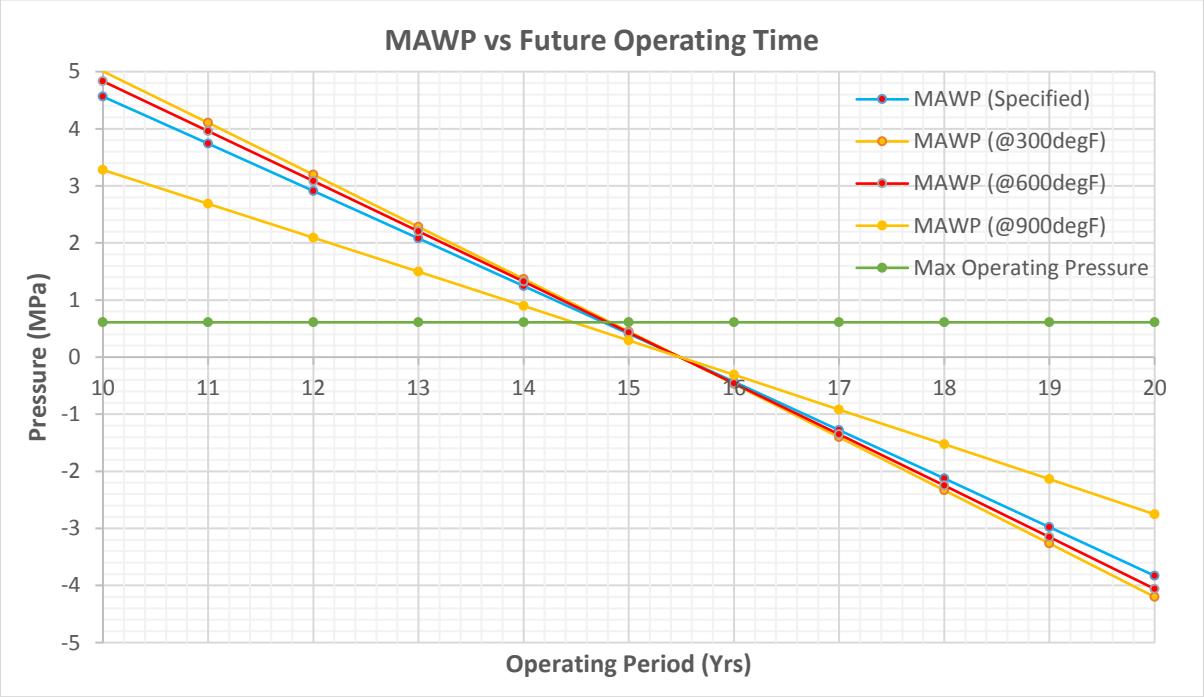
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 8.6mm+12.5% (9.68mm)

Supplied Data Wall Thickness: 9.7mm

Nominal ID: 97.1mm

Minimum Measured Wall Thickness: 7.73mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	14.62	5.61
600°F (316°C)	14.60	5.61
707°F (375°C)	14.56	5.60
900°F (482°C)	14.28	5.54

8.3 Pass 1, 5 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

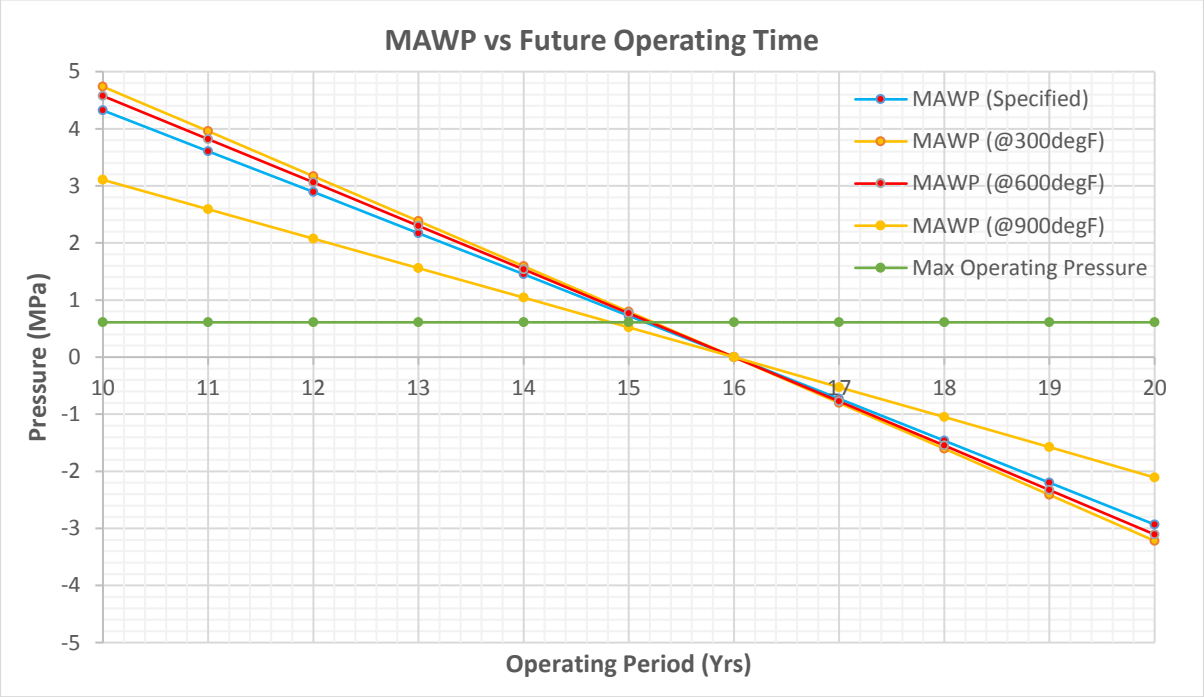
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 9.5mm+12.5% (10.69mm)

Supplied Data Wall Thickness: 10mm

Nominal ID: 122.3mm

Minimum Measured Wall Thickness: 8.58mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	15.05	7.33
600°F (316°C)	15.02	7.32
707°F (375°C)	14.98	7.30
900°F (482°C)	14.65	7.18

8.4 Pass 1, 6 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

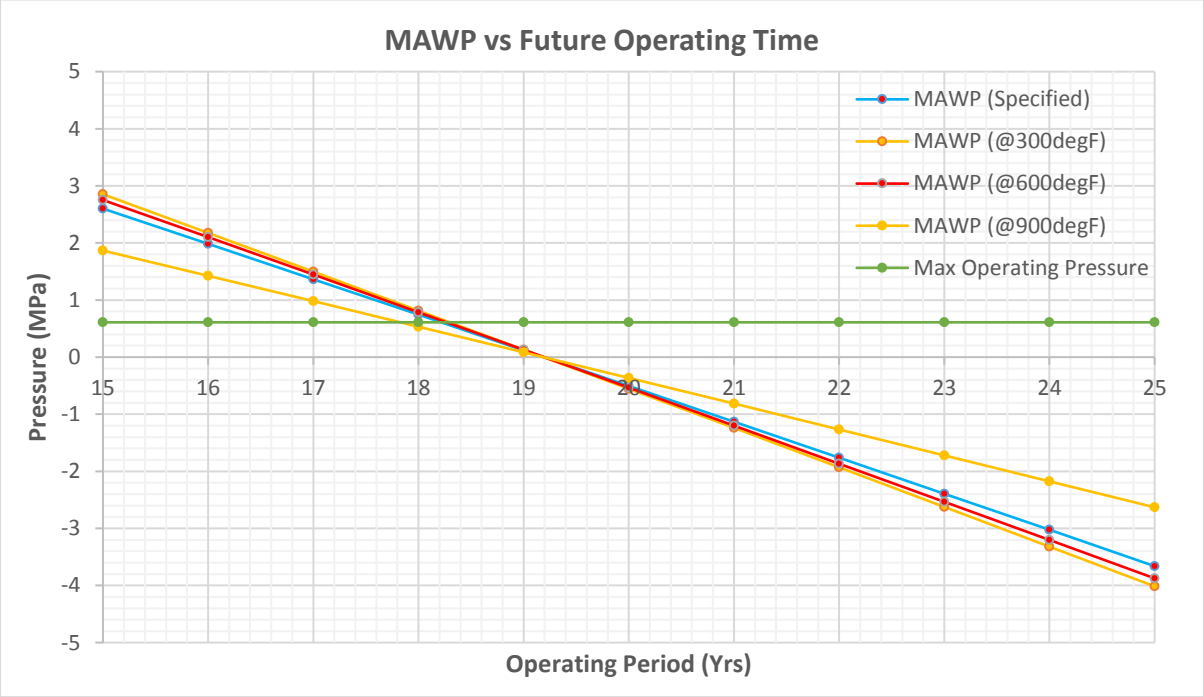
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 11.0mm+12.5% (12.38mm)

Supplied Data Wall Thickness: 10.86mm

Nominal ID: 146.3mm

Minimum Measured Wall Thickness: 10.21mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	18.11	21.46
600°F (316°C)	18.07	21.43
707°F (375°C)	18.02	21.37
900°F (482°C)	17.64	20.99

8.5 Pass 1, 8 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

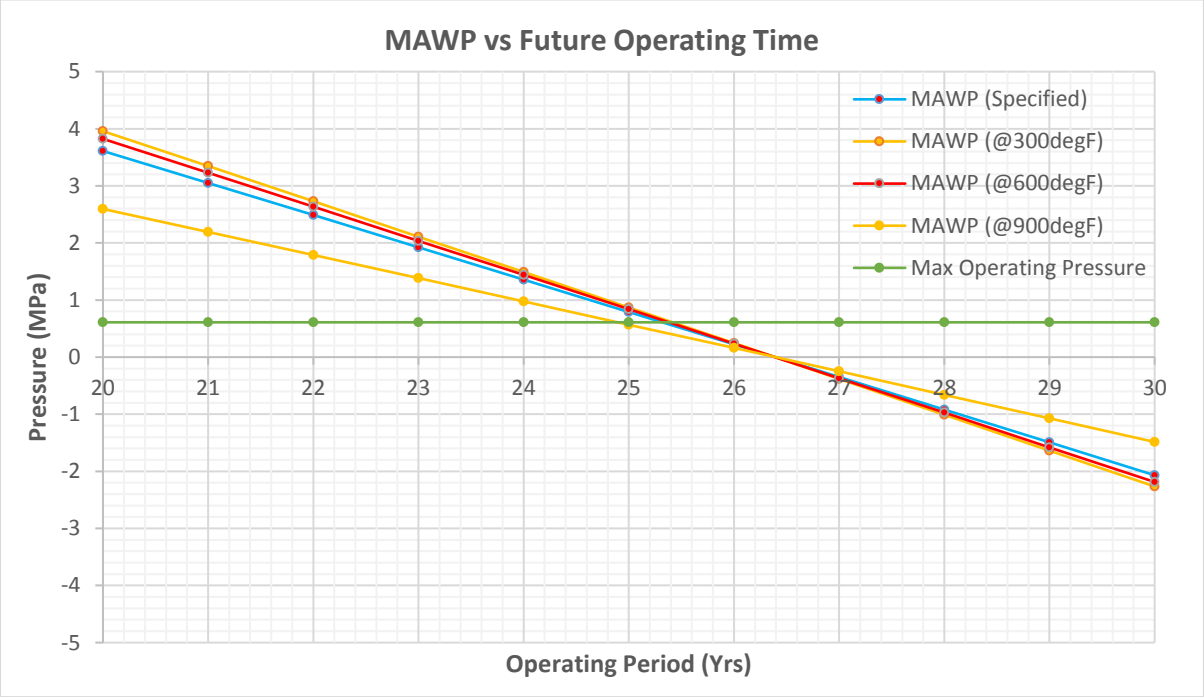
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 12.7mm+12.5% (14.29mm)

Supplied Data Wall Thickness: 13mm

Nominal ID: 193.7mm

Minimum Measured Wall Thickness: 12.29mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	24.99	21.26
600°F (316°C)	24.94	21.22
707°F (375°C)	24.86	21.16
900°F (482°C)	24.30	20.75

9. APPENDIX D: PASS 2 REMAINING LIFE CALCULATIONS (BASED ON MAWP)

9.1 Pass 2, Convection Coil, Maximum Allowable Future Operating Pressure

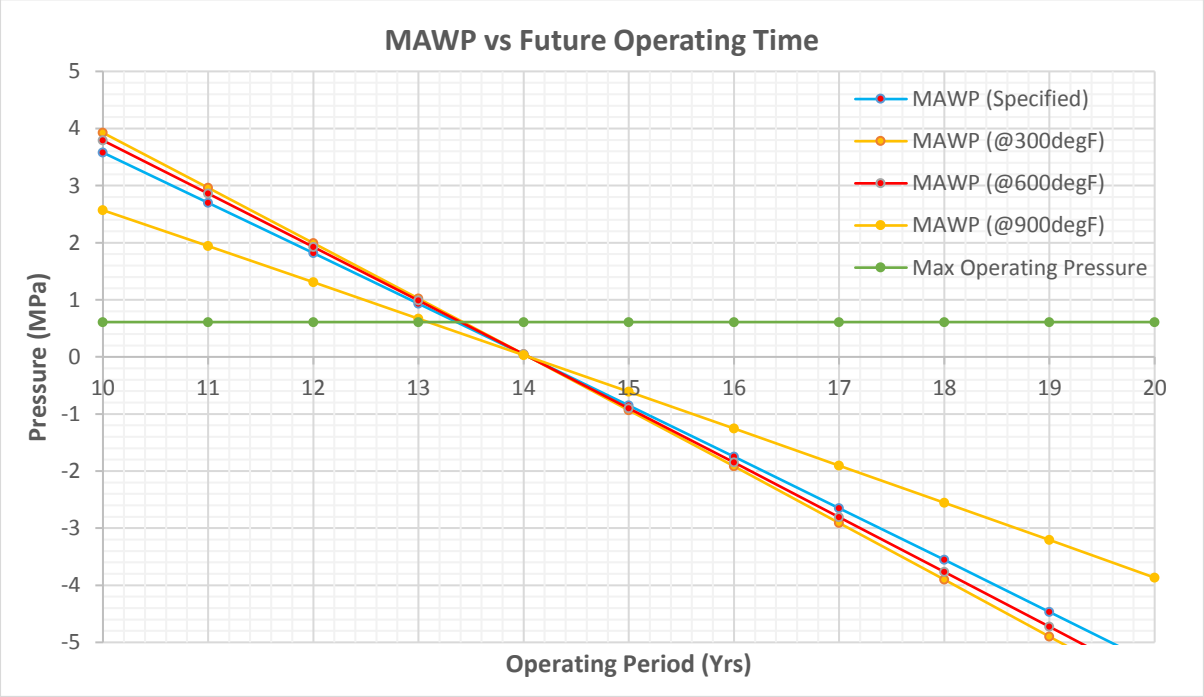
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 8.6mm+12.5% (9.68mm)

Supplied Data Wall Thickness: N/A

Nominal ID: 97.1mm

Minimum Measured Wall Thickness: 7.61mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	13.25	N/A
600°F (316°C)	13.23	N/A
707°F (375°C)	13.19	N/A
900°F (482°C)	12.93	N/A

9.2 Pass 2, 4 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

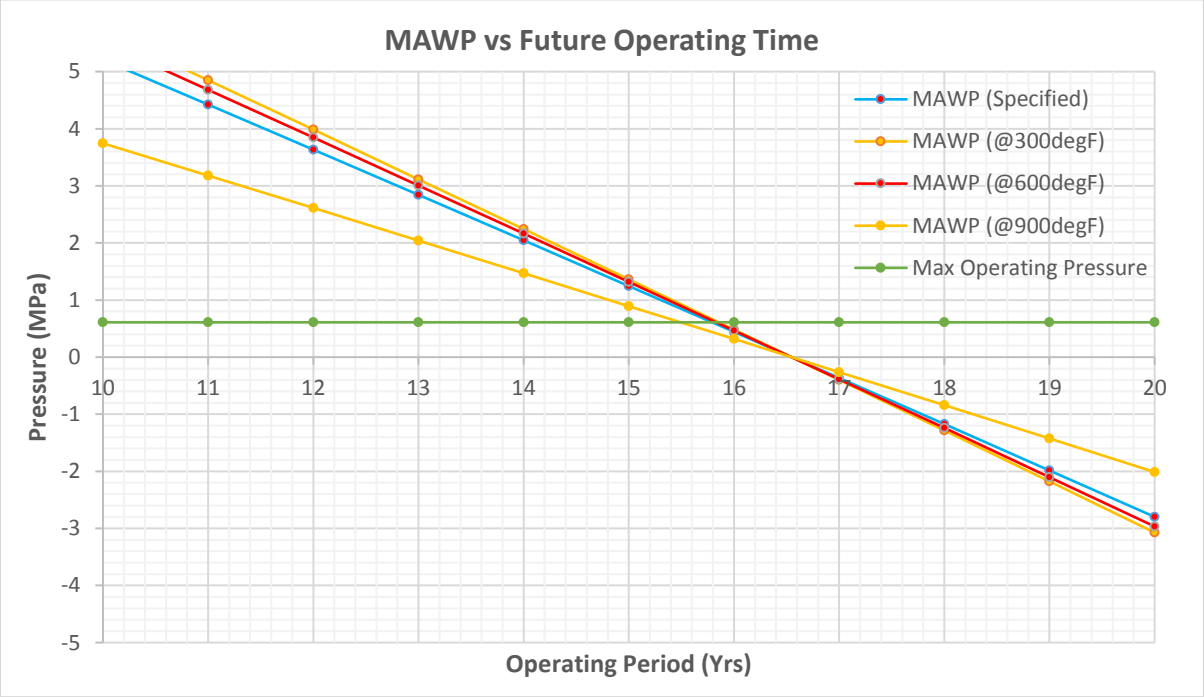
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 8.6mm+12.5% (9.68mm)

Supplied Data Wall Thickness: 10mm

Nominal ID: 97.1mm

Minimum Measured Wall Thickness: 7.81mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	15.64	5.35
600°F (316°C)	15.62	5.34
707°F (375°C)	15.57	5.34
900°F (482°C)	15.28	5.29

9.3 Pass 2, 5 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

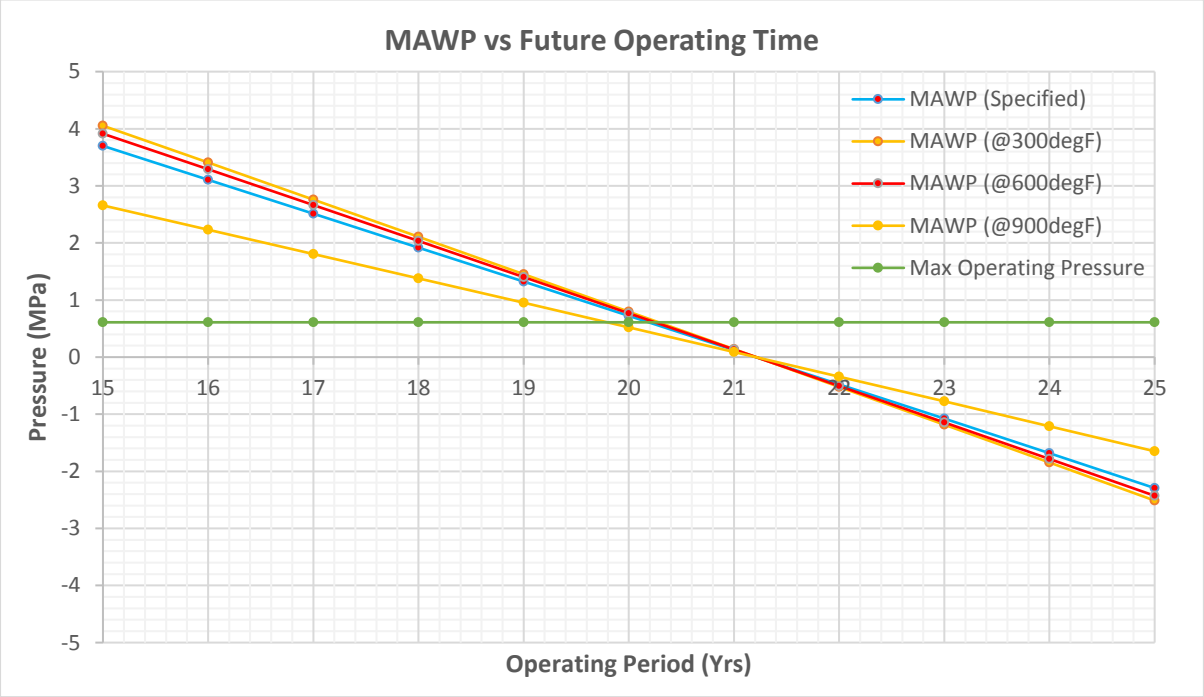
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 9.5mm+12.5% (10.69mm)

Supplied Data Wall Thickness: 10mm

Nominal ID: 122.3mm

Minimum Measured Wall Thickness: 8.80mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	17.89	8.95
600°F (316°C)	17.86	8.94
707°F (375°C)	17.81	8.92
900°F (482°C)	17.44	8.77

9.4 Pass 2, 6 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

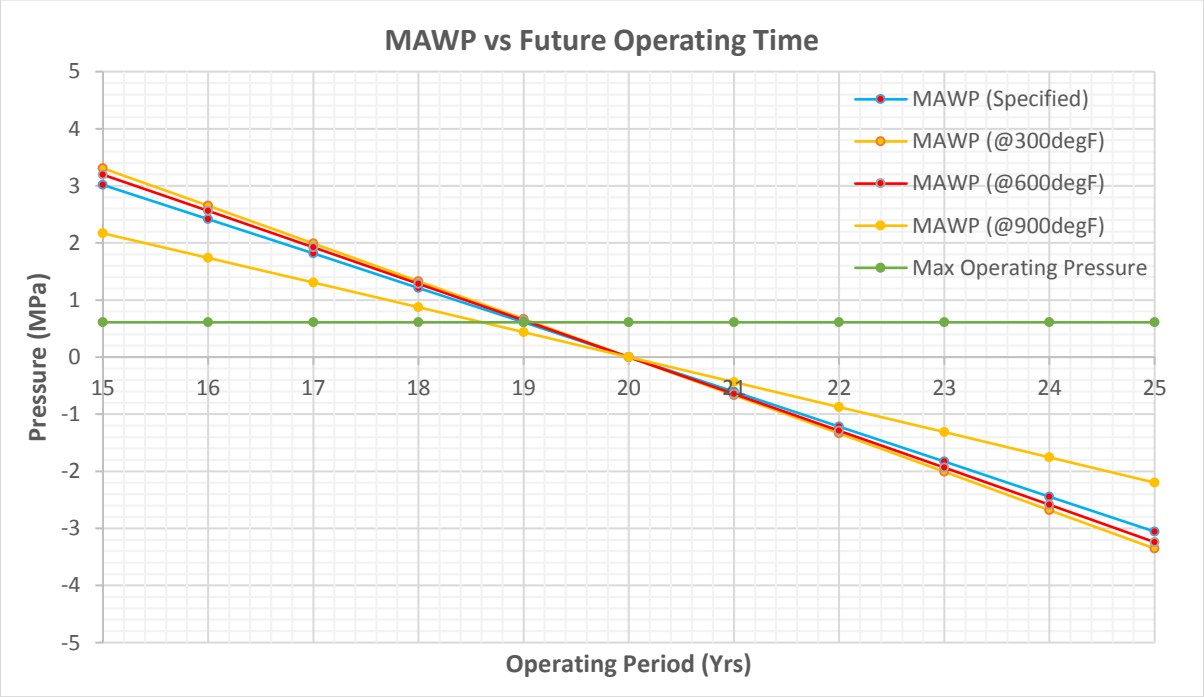
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 11.0mm+12.5% (12.38mm)

Supplied Data Wall Thickness: 11mm

Nominal ID: 146.3mm

Minimum Measured Wall Thickness: 9.83mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	14.02	10.03
600°F (316°C)	13.99	10.01
707°F (375°C)	13.95	9.99
900°F (482°C)	13.63	9.81

9.5 Pass 2, 8 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

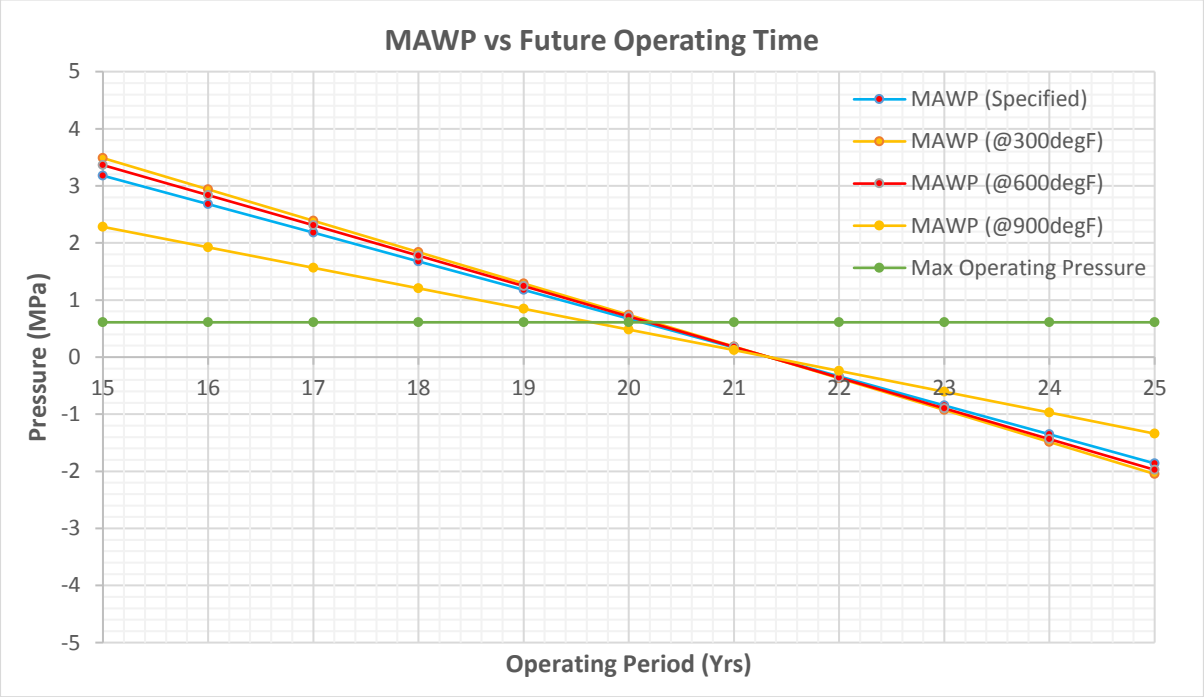
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 12.7mm+12.5% (14.29mm)

Supplied Data Wall Thickness: 13.6mm

Nominal ID: 193.7mm

Minimum Measured Wall Thickness: 11.48mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	15.03	6.55
600°F (316°C)	15.00	6.54
707°F (375°C)	14.94	6.53
900°F (482°C)	14.56	6.40

10. APPENDIX E: PASS 3 REMAINING LIFE CALCULATIONS (BASED ON MAWP)

10.1 Pass 3, Convection Coil, Maximum Allowable Future Operating Pressure

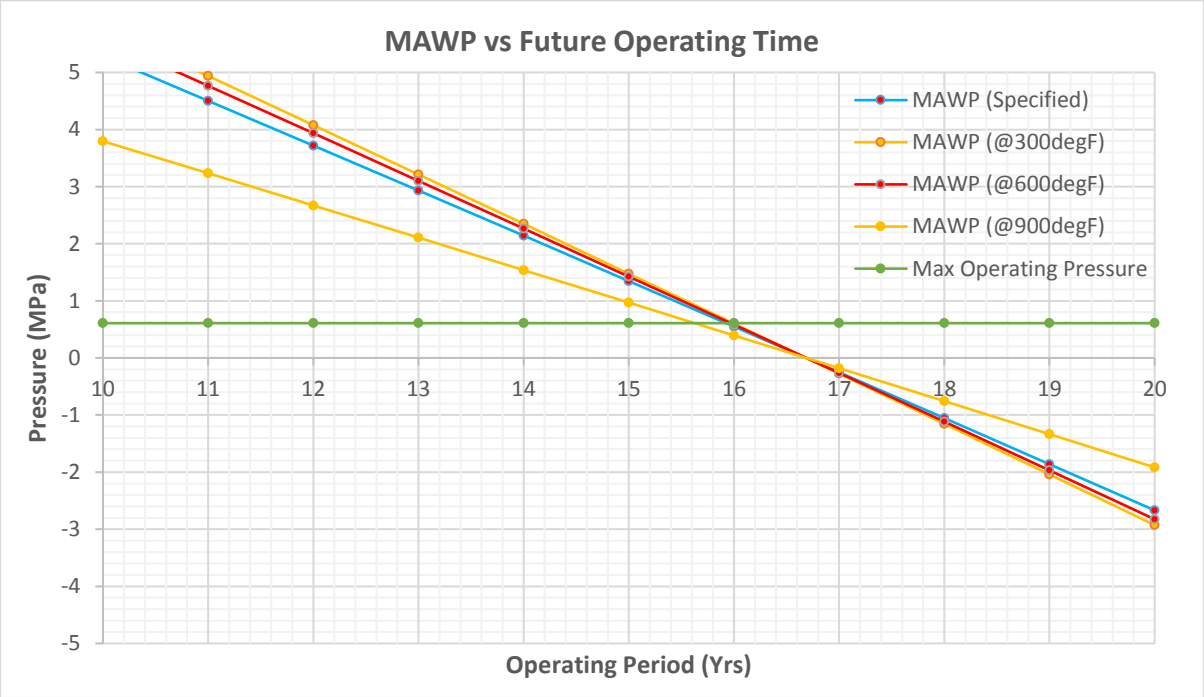
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 8.6mm+12.5% (9.68mm)

Supplied Data Wall Thickness: N/A

Nominal ID: 97.1mm

Minimum Measured Wall Thickness: 7.82mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	15.77	N/A
600°F (316°C)	15.75	N/A
707°F (375°C)	15.71	N/A
900°F (482°C)	15.41	N/A

10.2 Pass 3, 4 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

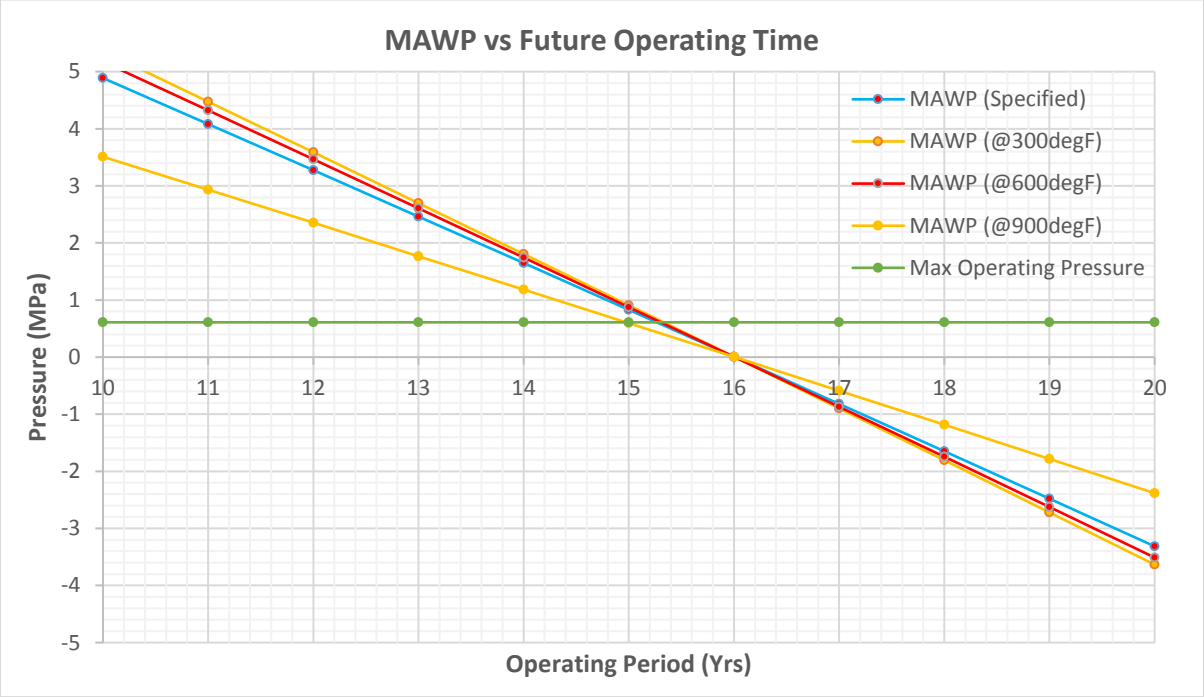
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 8.6mm+12.5% (9.68mm)

Supplied Data Wall Thickness: 9.3mm

Nominal ID: 97.1mm

Minimum Measured Wall Thickness: 7.77mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	15.12	6.75
600°F (316°C)	15.10	6.75
707°F (375°C)	15.06	6.74
900°F (482°C)	14.77	6.65

10.3 Pass 3, 5 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

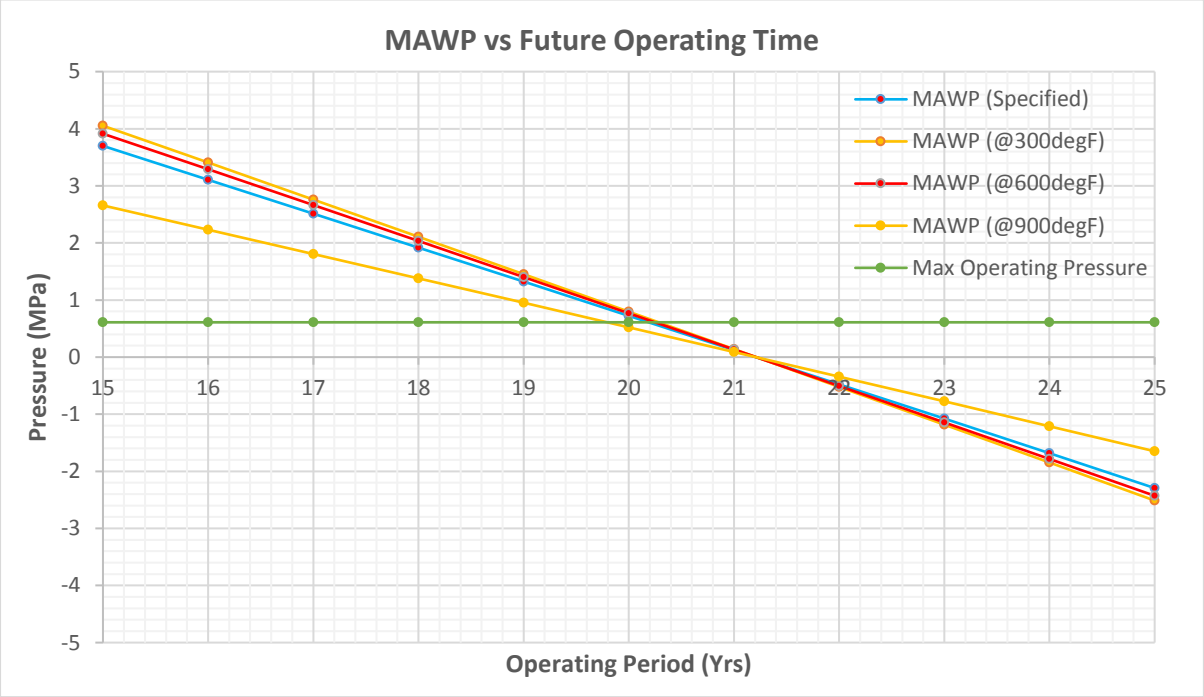
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 9.5mm+12.5% (10.69mm)

Supplied Data Wall Thickness: 10.1mm

Nominal ID: 122.3mm

Minimum Measured Wall Thickness: 8.94mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	20.09	9.23
600°F (316°C)	20.05	9.22
707°F (375°C)	20.00	9.20
900°F (482°C)	19.60	9.05

10.4 Pass 3, 6 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

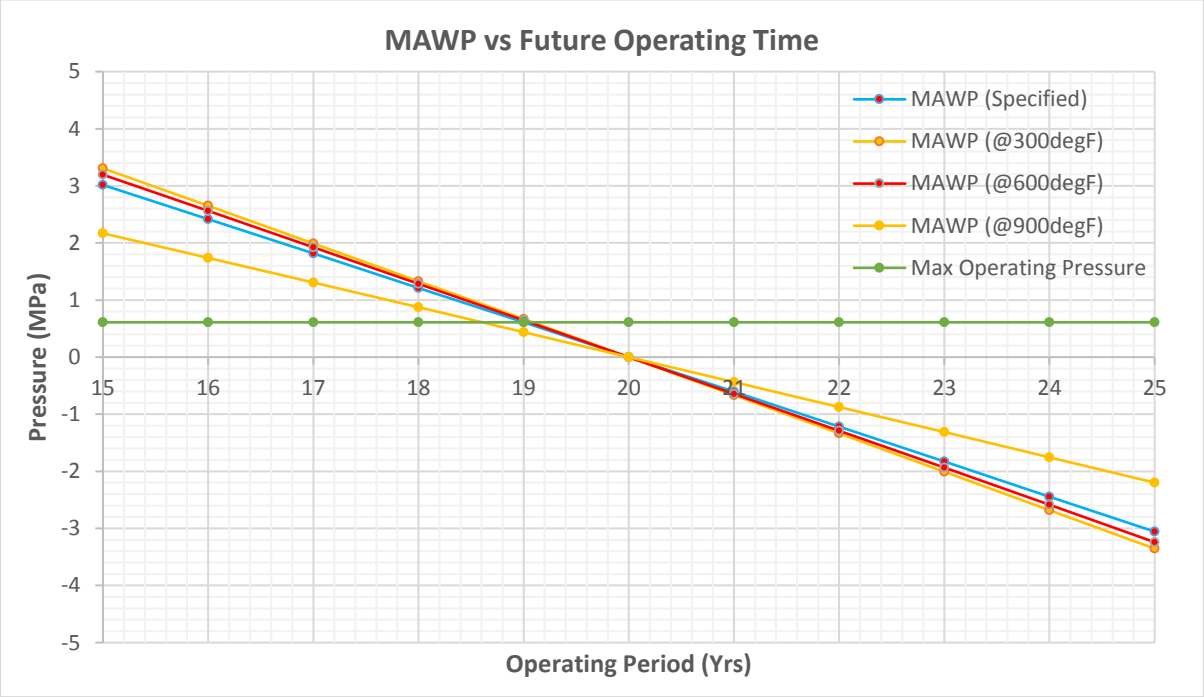
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 11.0mm+12.5% (12.38mm)

Supplied Data Wall Thickness: 10.8mm

Nominal ID: 146.3mm

Minimum Measured Wall Thickness: 10.27mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	18.89	24.02
600°F (316°C)	18.86	23.99
707°F (375°C)	18.80	23.93
900°F (482°C)	18.41	23.50

10.5 Pass 3, 8 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

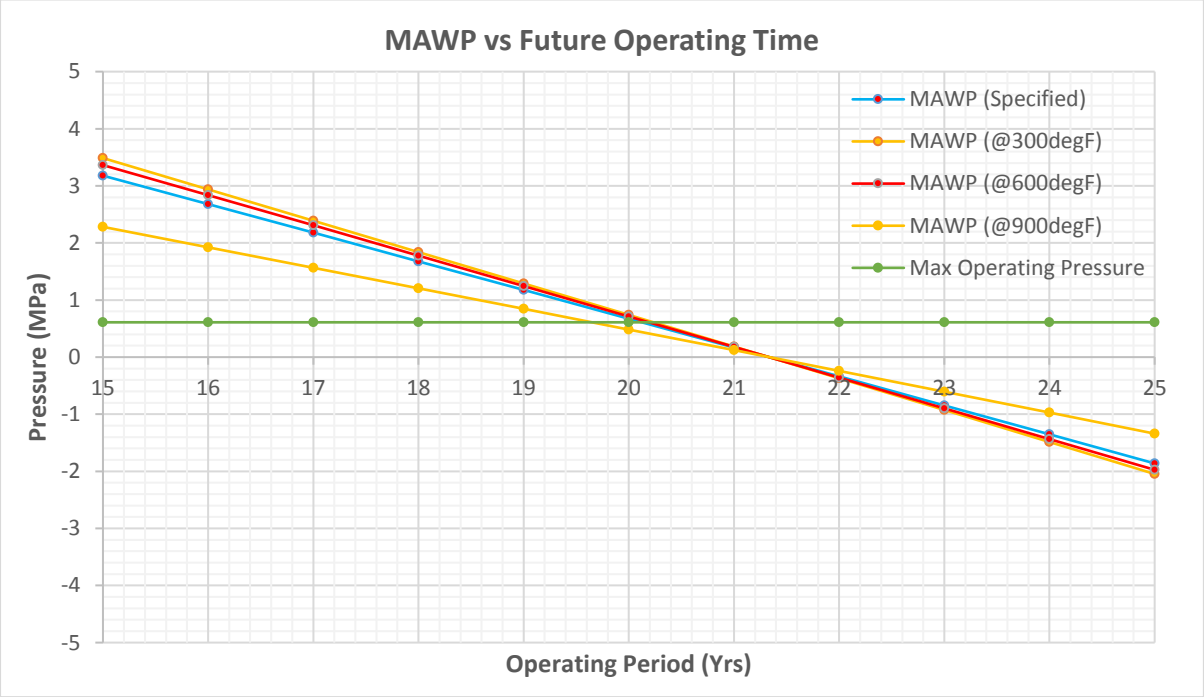
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 12.7mm+12.5% (14.29mm)

Supplied Data Wall Thickness: 13.30mm

Nominal ID: 193.7mm

Minimum Measured Wall Thickness: 11.96mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	20.07	10.63
600°F (316°C)	20.03	10.61
707°F (375°C)	19.96	10.58
900°F (482°C)	19.49	10.37

11. APPENDIX F: PASS 4 REMAINING LIFE CALCULATIONS (BASED ON MAWP)

11.1 Pass 4, Convection Coil, Maximum Allowable Future Operating Pressure

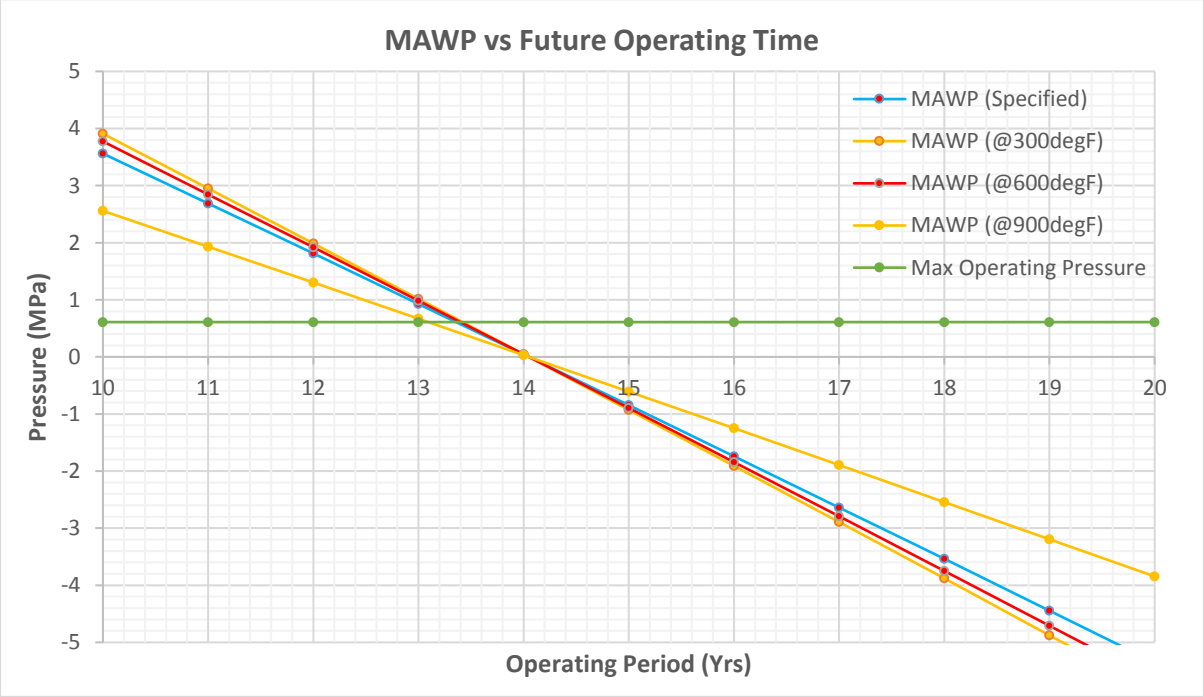
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 8.6mm+12.5% (9.68mm)

Supplied Data Wall Thickness: N/A

Nominal ID: 97.1mm

Minimum Measured Wall Thickness: 7.61mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	13.24	N/A
600°F (316°C)	13.22	N/A
707°F (375°C)	13.19	N/A
900°F (482°C)	12.92	N/A

11.2 Pass 4, 4 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

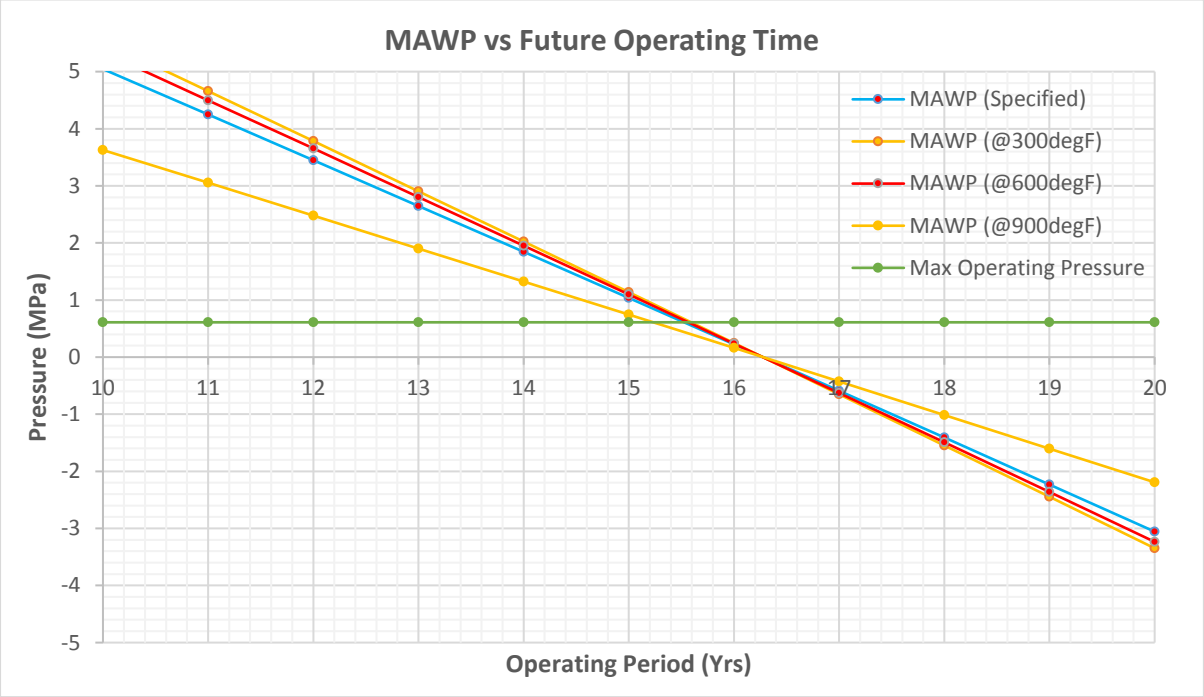
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 8.6mm+12.5% (9.68mm)

Supplied Data Wall Thickness: 9.6mm

Nominal ID: 97.1mm

Minimum Measured Wall Thickness: 7.79mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	15.38	5.92
600°F (316°C)	15.35	5.91
707°F (375°C)	15.31	5.90
900°F (482°C)	15.02	5.83

11.3 Pass 4, 5 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

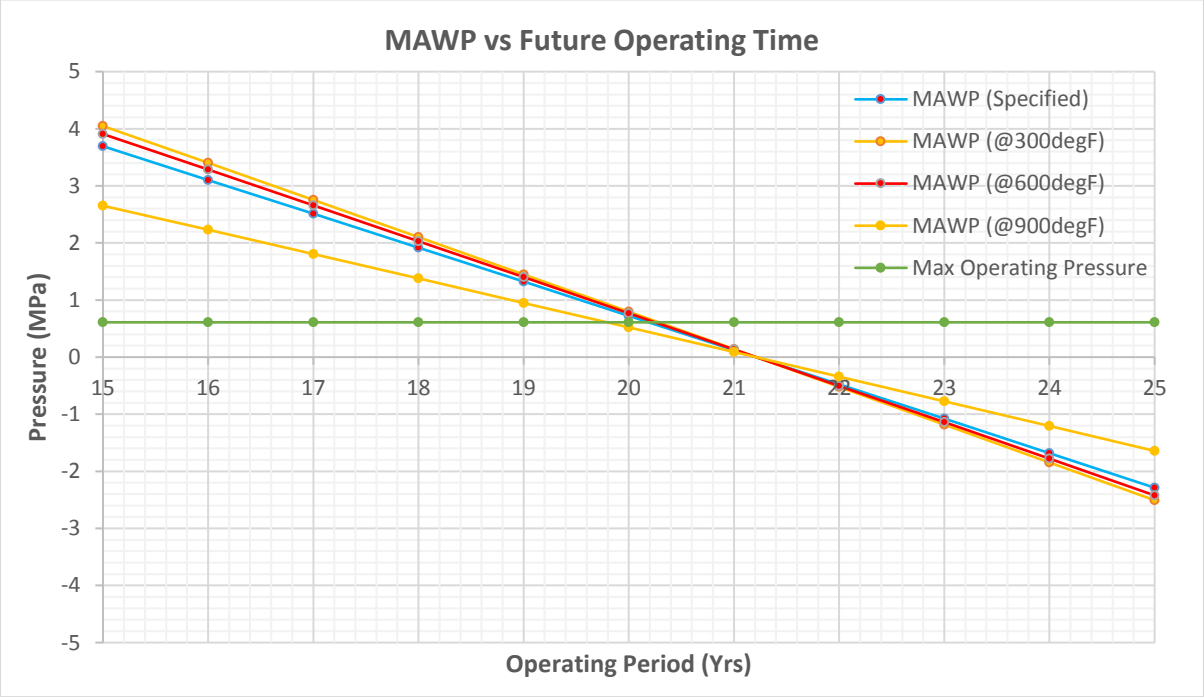
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 9.5mm+12.5% (10.69mm)

Supplied Data Wall Thickness: 9.7mm

Nominal ID: 122.3mm

Minimum Measured Wall Thickness: 8.94mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	20.09	14.22
600°F (316°C)	20.05	14.20
707°F (375°C)	20.00	14.17
900°F (482°C)	19.60	13.93

11.4 Pass 4, 6 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

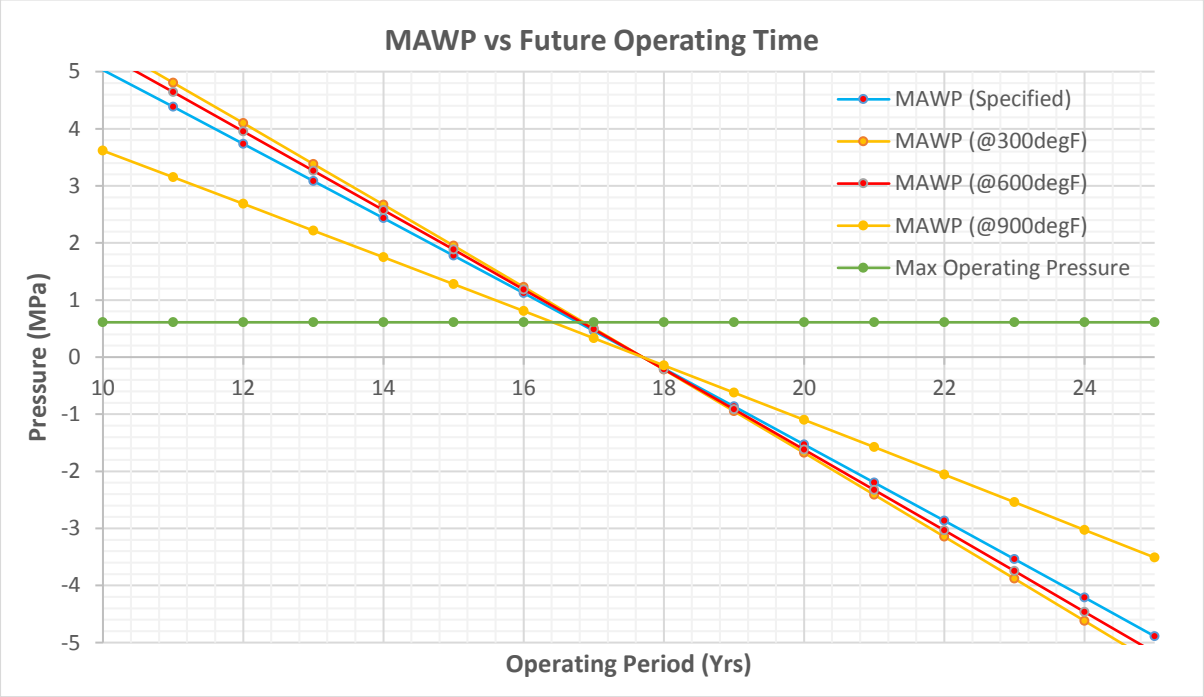
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 11.0mm+12.5% (12.38mm)

Supplied Data Wall Thickness: 10.9mm

Nominal ID: 146.3mm

Minimum Measured Wall Thickness: 10.09mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	16.66	15.08
600°F (316°C)	16.63	15.06
707°F (375°C)	16.58	15.02
900°F (482°C)	16.22	14.75

11.5 Pass 4, 8 Inch Radiant Coil, Maximum Allowable Future Operating Pressure

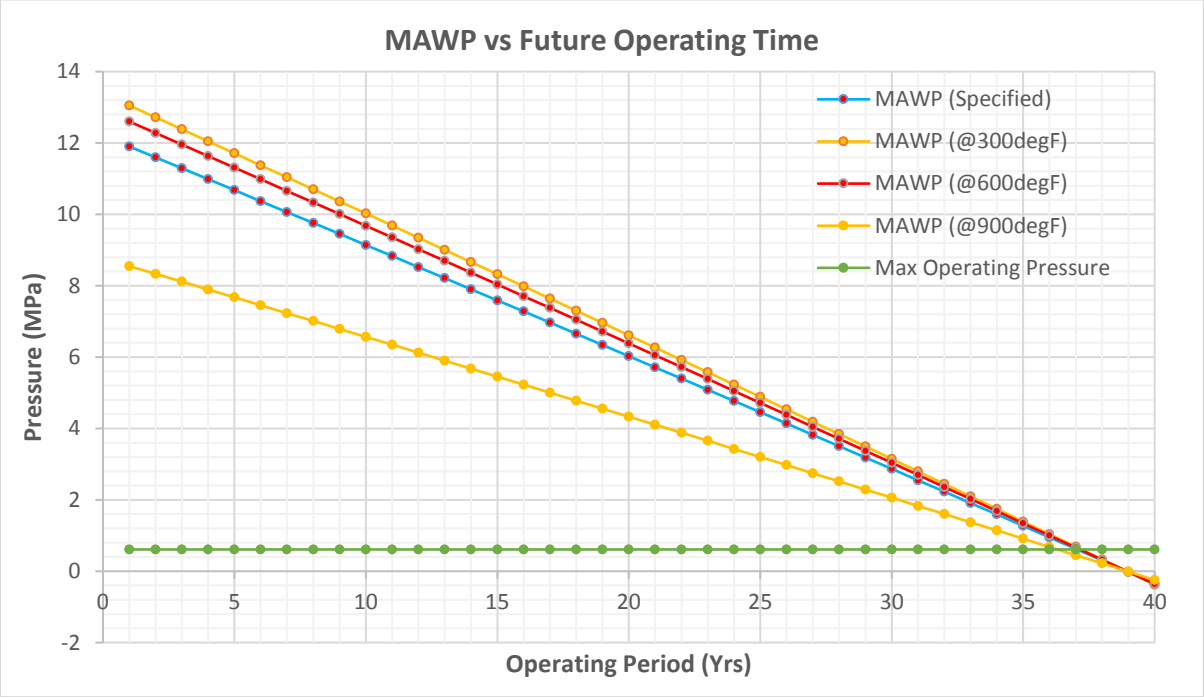
Assuming Nominal Wall Thickness +12.5% at Installation and a Uniform Corrosion Rate

Nominal Wall Thickness: 12.7mm+12.5% (14.29mm)

Supplied Data Wall Thickness: 13.7mm

Nominal ID: 193.7mm

Minimum Measured Wall Thickness: 12.81mm



Operating Temperature	Remaining Life Using Nominal Wall Thickness +12.5% (Years)	Remaining Life Using Supplied Historic Data (Years)
300°F (149°C)	37.33	17.54
600°F (316°C)	37.27	17.51
707°F (375°C)	37.16	17.46
900°F (482°C)	36.40	17.14

DISCLAIMER

Due to the nature of a remaining life assessment it is important that the scope of the assessment is understood. The calculations involved within a remaining life assessment are heavily dependent on past inspection data and inspection data recorded at time of the assessment. As more data is available the remaining life assessment will become more accurate and provide a more realistic remaining life of an asset.

Cokebusters Limited will not accept responsibility for any metallurgic flaw, defect or anomaly contained within the process coil(s) tubing and/or return bends.

Merlin Technology Inspection Service, Fitness for Service and Remaining Life Assessment provided by Cokebusters Limited is for advisory purposes only. Cokebusters Limited will not accept responsibility for any geometric anomaly, flaw or defect which may have gone undetected from the inspection procedure.

The accuracy, resolution and technical capabilities of the Merlin Mark IV In-line Inspection Tool are described within Appendix A of the Field and Final Inspection Reports. Cokebusters Limited will not accept responsibility for any misinterpretation of data or reporting.

Cokebusters Limited will not accept responsibility for any process anomalies, accidents or disruptions following the inspection service and remaining life assessment.