## 2B Assumptions

- Service – Desalted Crude vs Resid
- Tube ID Coating Thickness – 25 Microns (0.001 inch)
- Tube OD Coating Thickness – 25 Microns (0.001 inch)
- Coating Thermal Conductivity – 0.722 Btu/hr-ft-F
- Fuel Value -$3.50 per MBtu/hr. Note fuel prices in Asia can be 3X compared to US
- Furnace Efficiency = 0.9
- Network Factor = 0.85 [Part of the Duty Gain in the Exchanger Diminishes Heat Transfer on other Exchangers in the Preheat Train due to changes in temperature differentials]
- CO2 Reduction based on EPA Conversion Equations
- Heat Transfer Calculation performed with HTRI XIST
- Assumed Fouling Factor shown in the Comparison Tables below
- All bundles are cleaned yearly
- Assumed Inlet Operating
    - Crude Inlet Temp – 400 F
    - Crude Rate – 1,800 klb/hr
    - Resid Inlet Temp - 600 F
    - Resid Rate – 1,082 klb/hr

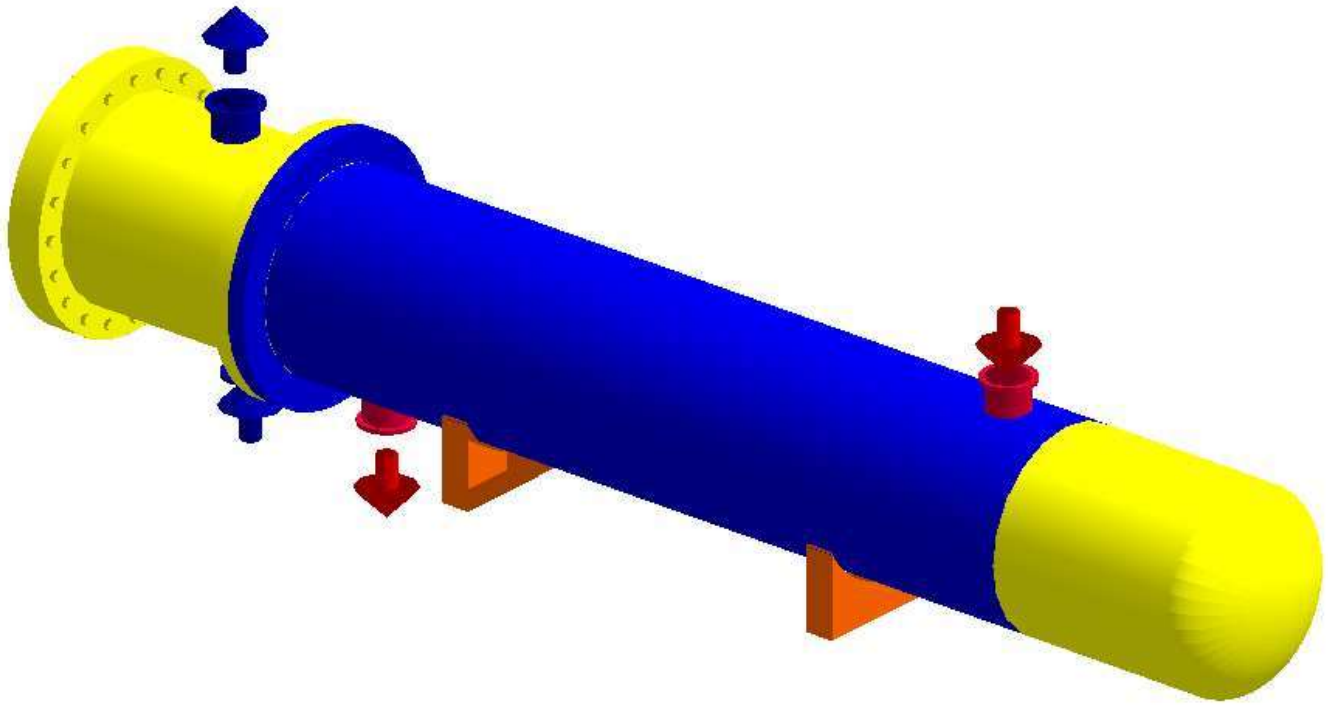
- Stream Properties

| Hot Shellside Fluid | | Inlet | Outlet |
|---|---|---|---|
| Fluid name | | Vac Resid | |
| Flow | (1000-lb/hr) | 1082.8 | |
| Temperature | (F) | 600.00 | 515.47 |
| Pressure | (psia) | 363.50 | 356.81 |
| Weight fraction vapor | (--) | 0.0000 | 0.0000 |
| **Vapor Properties** | | | |
| Flow | (1000-lb/hr) | -- | -- |
| Density | (lb/ft3) | -- | -- |
| Viscosity | (cP) | -- | -- |
| Conductivity | (Btu/hr-ft-F) | -- | -- |
| Heat capacity | (Btu/lb-F) | -- | -- |
| Molecular weight | (--) | -- | -- |
| **Liquid Properties** | | | |
| Flow | (1000-lb/hr) | 1082.8 | 1082.8 |
| Density | (lb/ft3) | 48.667 | 51.039 |
| Viscosity | (cP) | 1.5864 | 2.3593 |
| Conductivity | (Btu/hr-ft-F) | 0.0526 | 0.0542 |
| Heat capacity | (Btu/lb-F) | 0.7105 | 0.6729 |
| Molecular weight | (--) | -- | -- |
| Latent heat | (Btu/lb) | -- | -- |
| Surface tension | (dyne/cm) | 17.027 | 19.611 |

| Cold Tubeside Fluid | | Inlet | Outlet |
|---|---|---|---|
| Fluid name | | Crude | |
| Flow | (1000-lb/hr) | 1800.0 | |
| Temperature | (F) | 400.00 | 458.93 |
| Pressure | (psia) | 420.80 | 415.87 |
| Weight fraction vapor | (--) | 0.0000 | 0.0000 |
| **Vapor Properties** | | | |
| Flow | (1000-lb/hr) | -- | -- |
| Density | (lb/ft3) | -- | -- |
| Viscosity | (cP) | -- | -- |
| Conductivity | (Btu/hr-ft-F) | -- | -- |
| Heat capacity | (Btu/lb-F) | -- | -- |
| Molecular weight | (--) | -- | -- |
| **Liquid Properties** | | | |
| Flow | (1000-lb/hr) | 1800.0 | 1800.0 |
| Density | (lb/ft3) | 41.253 | 39.151 |
| Viscosity | (cP) | 0.5218 | 0.4066 |
| Conductivity | (Btu/hr-ft-F) | 0.0618 | 0.0595 |
| Heat capacity | (Btu/lb-F) | 0.6457 | 0.6771 |
| Molecular weight | (--) | -- | -- |
| Latent heat | (Btu/lb) | -- | -- |
| Surface tension | (dyne/cm) | 8.8330 | 47.488 |

## 2B Heat Exchanger Geometry

- TEMA – AET
- Shell Id = 54”
- 1130 Tubes
- 1” Tube OD
- 0.083” tube wall thickness
- 2 Tube Passes
- 20 ft length
- 11 Baffle Cross Passes, Single Vert Seg , 18.8% Cut



## 2B Results

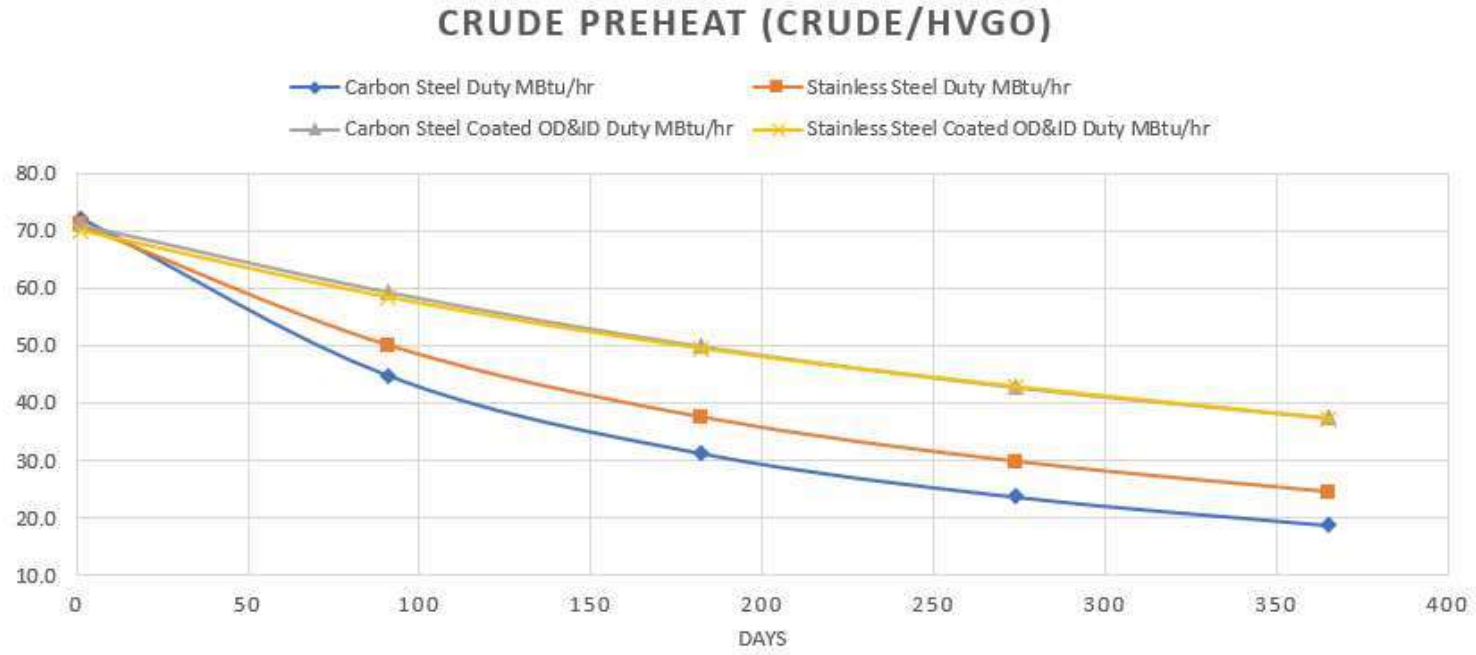
## Comparison Tables

| Carbon Steel | | | | | | |
|---|---|---|---|---|---|---|
| Days | Qactual MBtu/hr | Qclean MBtu/hr | Qact/Qclean | Tubeside DP psi | Tubeside Fouling Factor ft2-hr-F/Btu | Shellside Fouling Factor ft2-hr-F/Btu |
| 1 | 72.4 | 72.4 | 1.00 | 5.0 | 0.0000 | 0.0000 |
| 91 | 44.9 | 72.4 | 0.62 | 5.7 | 0.0050 | 0.0038 |
| 182 | 31.4 | 72.4 | 0.43 | 6.6 | 0.0100 | 0.0076 |
| 274 | 23.8 | 72.4 | 0.33 | 7.9 | 0.0150 | 0.0114 |
| 365 | 18.9 | 72.4 | 0.26 | 9.6 | 0.0200 | 0.0150 |

| Stainless Steel | | | | | | |
|---|---|---|---|---|---|---|
| Days | Qactual MBtu/hr | Qclean MBtu/hr | Qact/Qclean | Tubeside DP psi | Tubeside Fouling Factor ft2-hr-F/Btu | Shellside Fouling Factor ft2-hr-F/Btu |
| 1 | 71.2 | 71.2 | 1.00 | 4.9 | 0.0000 | 0.0000 |
| 91 | 50.2 | 71.2 | 0.70 | 5.4 | 0.0034 | 0.0030 |
| 182 | 37.7 | 71.2 | 0.53 | 5.9 | 0.0068 | 0.0060 |
| 274 | 29.9 | 71.2 | 0.42 | 6.6 | 0.0102 | 0.0090 |
| 365 | 24.6 | 71.2 | 0.35 | 7.4 | 0.0135 | 0.0120 |

| Carbon Steel Coated (0.001 inch) | | | | | | |
|---|---|---|---|---|---|---|
| Days | Qactual MBtu/hr | Qclean MBtu/hr | Qact/Qclean | Tubeside DP psi | Tubeside Fouling Factor ft2-hr-F/Btu | Shellside Fouling Factor ft2-hr-F/Btu |
| 1 | 71.4 | 71.4 | 1.00 | 5.0 | 0.0000 | 0.0000 |
| 91 | 59.5 | 71.4 | 0.83 | 5.2 | 0.0017 | 0.0015 |
| 182 | 50.1 | 71.4 | 0.70 | 5.4 | 0.0034 | 0.0030 |
| 274 | 42.9 | 71.4 | 0.60 | 5.7 | 0.0051 | 0.0045 |
| 365 | 37.5 | 71.4 | 0.53 | 6.0 | 0.0068 | 0.0060 |

| Stainless Steel Coated (0.001 inch) | | | | | | |
|---|---|---|---|---|---|---|
| Days | Qactual MBtu/hr | Qclean MBtu/hr | Qact/Qclean | Tubeside DP psi | Tubeside Fouling Factor ft2-hr-F/Btu | Shellside Fouling Factor ft2-hr-F/Btu |
| 1 | 70.1 | 70.1 | 1.00 | 4.9 | 0.0000 | 0.0000 |
| 91 | 58.5 | 70.1 | 0.83 | 5.1 | 0.0017 | 0.0015 |
| 182 | 49.6 | 70.1 | 0.71 | 5.4 | 0.0034 | 0.0030 |
| 274 | 42.9 | 70.1 | 0.61 | 5.6 | 0.0051 | 0.0045 |
| 365 | 37.4 | 70.1 | 0.53 | 5.9 | 0.0068 | 0.0060 |


CRUDE PREHEAT (CRUDE/HVGO)
Carbon Steel Duty MBtu/hr
Stainless Steel Duty MBtu/hr
Carbon Steel Coated OD&ID Duty MBtu/hr
Stainless Steel Coated OD&ID Duty MBtu/hr
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
50
100
150
200
250
300
350
400
DAYS

## 2B Economic & CO2 Reduction Benefit

1. Coated Versus Carbon Steel
    - Annualized Duty Reduction = 14 MBtu/hr
    - Energy benefit = $405k a year
    - CO2 Equivalent Benefit = 6,131 Tons a year
2. Coated Versus Stainless Steel
    - Annualized Duty Reduction = 9 MBtu/hr
    - Energy benefit = $260k a year
    - CO2 Equivalent Benefit = 3,937 Tons a year

Note if the Crude preheat furnace is limited and/or the Preheat Train is Hydraulically limited, the margin benefits could be significant more than the credits listed above.