Crude Preheat Tube Coating Analysis Study 2

Objectives 2A:

Following up to Study 1, for coated cases, evaluate cleaning at a 2 year frequency instead of 1 year. Quantify the benefits from the longer run length (avoiding one cleaning). Include credits for avoiding the maintenance cost and potential rate cuts required for cleaning.

This study evaluates a Crude preheat exchanger service heat transfer performance with the following tube material and coatings and estimates the energy savings and CO2 Emissions Reduction:

- Carbon Steel
- Stainless Steel
- Carbon Steel Tube ID Coated
- Stainless Steel Tube ID Coated

Assumptions 2A:

- Service – Desalted Crude vs Heavy Vacuum Gas Oil (HVGO)
- Tube ID 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 = 0.75 [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
- Coated bundles are cleaned at 2 year frequency
- Non coated bundles are cleaned yearly
- Assumed Inlet Operating
    - Crude Inlet Temp – 370 F
    - Crude Rate – 650 klb/hr
    - HVGO Inlet Temp - 505 F
    - HVGO Rate – 675 klb/hr
- 7 Days Oil Out to Oil In for Exchanger Cleaning
- Maintenance Cost for Cleaning - $40k
- Margin Cost Per Day During Cleaning – Approx $15k per day

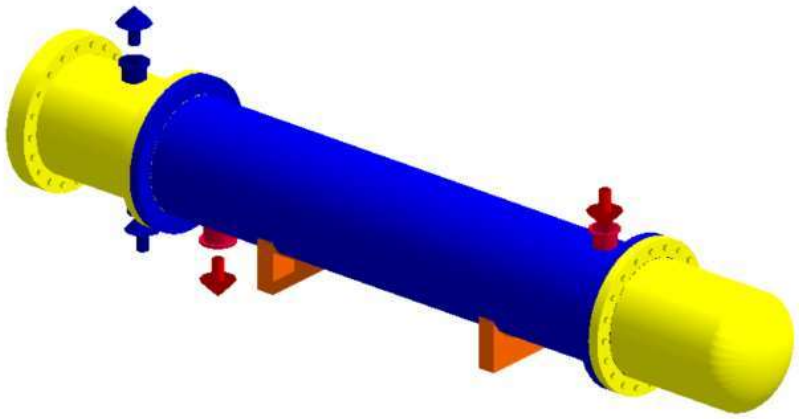
- Stream Properties

Hot Shellside Fluid		Inlet	Outlet
Fluid name		VHGO	
Flow	(1000-lb/hr)	675.00	
Temperature	(F)	505.00	475.18
Pressure	(psia)	111.67	107.09
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)	675.00	675.00
Density	(lb/ft3)	46.741	47.559
Viscosity	(cP)	1.4807	1.5337
Conductivity	(Btu/hr-ft-F)	0.0528	0.0537
Heat capacity	(Btu/lb-F)	0.6831	0.6657
Molecular weight	(--)	--	--
Latent heat	(Btu/lb)	--	--
Surface tension	(dyne/cm)	0.0000	0.0000

Cold Tubeside Fluid		Inlet	Outlet
Fluid name		Crude	
Flow	(1000-lb/hr)	650.00	
Temperature	(F)	370.00	402.61
Pressure	(psia)	381.37	372.57
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)	650.00	650.00
Density	(lb/ft3)	44.085	42.918
Viscosity	(cP)	0.8648	0.6984
Conductivity	(Btu/hr-ft-F)	0.0671	0.0646
Heat capacity	(Btu/lb-F)	0.6233	0.6342
Molecular weight	(--)	--	--
Latent heat	(Btu/lb)	--	--
Surface tension	(dyne/cm)	0.0000	0.0000

2A Heat Exchanger Geometry

- TEMA – AES
- Shell ID = 50”
- 1054 Tubes
- 1” Tube OD
- 0.083” tube wall thickness
- 4 Tube Passes
- 20 ft length
- 11 Baffle Cross Passes, Single Vert Seg , 20.9% Cut



2A Results

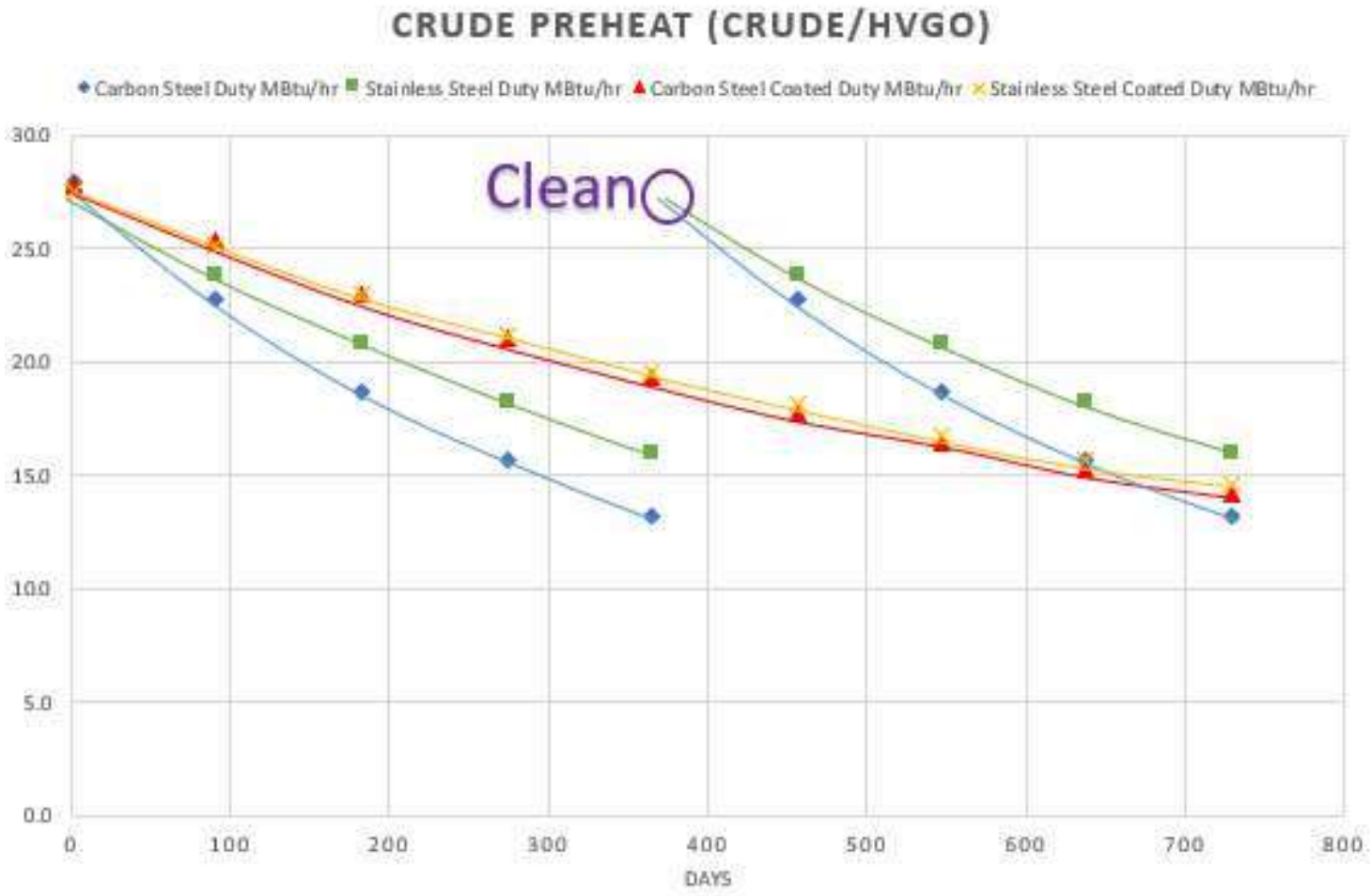
Comparison Tables

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	27.9	27.9	1.00	3.9	0.0000	0.0000
91	22.7	27.9	0.81	4.7	0.0044	0.0013
182	18.7	27.9	0.67	5.8	0.0088	0.0025
274	15.6	27.9	0.56	7.1	0.0131	0.0038
365	13.2	27.9	0.47	8.8	0.0175	0.0050

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	27.6	27.6	1.00	3.9	0.0000	0.0000
91	23.8	27.6	0.86	4.5	0.0030	0.0010
182	20.8	27.6	0.75	5.1	0.0060	0.0020
274	18.2	27.6	0.66	5.1	0.0090	0.0030
365	16.0	27.6	0.58	6.7	0.0120	0.0040

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	27.8	27.8	1.00	3.9	0.0000	0.0000
91	25.3	27.8	0.91	4.2	0.0015	0.0013
182	23.0	27.8	0.83	4.5	0.0030	0.0025
274	21.0	27.8	0.75	4.8	0.0045	0.0038
365	19.3	27.8	0.69	5.1	0.0060	0.0050
456	17.7	27.8	0.64	5.5	0.0075	0.0063
547	16.4	27.8	0.59	5.9	0.0090	0.0075
638	15.2	27.8	0.55	6.3	0.0105	0.0088
730	14.2	27.8	0.51	6.8	0.0120	0.0100

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	27.5	27.5	1.00	3.9	0.0000	0.0000
91	25.2	27.5	0.91	4.2	0.0015	0.0010
182	23.0	27.5	0.84	4.5	0.0030	0.0020
274	21.1	27.5	0.77	4.8	0.0045	0.0030
365	19.5	27.5	0.71	5.1	0.0060	0.0040
456	18.1	27.5	0.66	5.5	0.0075	0.0050
547	16.8	27.5	0.61	5.9	0.0090	0.0060
638	15.7	27.5	0.57	6.3	0.0105	0.0070
730	14.6	27.5	0.53	6.8	0.0120	0.0080



2A Economic & CO2 Reduction Benefit

3. Coated Carbon Steel (cleaned 2yr interval) Versus Carbon Steel (cleaned yearly)
    - Annualized Duty Reduction = 0.6 MBtu/hr
    - Energy benefit = $28k over 2 years
    - Margin + Maintenance benefit from increasing cleaning interval = $105k+$40k=$145k
    - CO2 Equivalent Benefit = 423 Tons over 2 years
    - Overall Benefit = $28k + $145 k = **$173k**
4. Coated Stainless Steel Versus Stainless Steel
    - Annualized Duty Reduction = -0.9 MBtu/hr
    - Energy benefit = -$46.8k over 2 years
    - Margin + Maintenance benefit from increasing cleaning interval = $96.8k+$40k=$136.7k
    - CO2 Equivalent **Increase Emissions** = 708 Tons over 2 years
    - Overall Benefit = -$46.8k + $136.7k = **$89.9k**

Objectives 2B:

Repeat of Study 1, but it assumes anti-fouling coating on both tube OD & ID.

This study evaluates a Crude preheat exchanger service heat transfer performance with the following tube material and coatings and estimates the energy savings and CO2 Emissions Reduction:

- Carbon Steel
- Stainless Steel
- Carbon Steel Tube ID & OD Coated
- Stainless Steel Tube ID & OD Coated