| MEG ENERGY | CHRISTINA LAKE REGIONAL PROJECT<br>Phase 3A EPC for Central Plant Facilities<br>SLI Project No. 511036 | SNC·LAVALIN |
|---|---|---|

SNC·LAVALIN

Vendor's drawing review for conformity with specifications and design drawing.

This review does not relieve the vendor of his responsibility for errors in design and detailing as detailed in his contract.

| | |
|---|---|
| ☐ A1 | Not suitable to initiate fabrication. modify as noted, resubmit for review |
| ☐ B1 | Suitable to initiate fabrication as noted. modify as noted, resubmit for review |
| ☐ C1 | Suitable to fabricate to completion as noted. submit final documents including as-builts as required |
| ☐ D1 | Suitable to fabricate to completion. submit final documents including as-built documents as required |
| ☐ E1 | Not suitable as final documents as noted. modify as noted and resubmit. |
| ☒ F1 | Suitable as final documents. no further resubmittal required (unless revised by vendor) |

| | | | |
|---|---|---|---|
| Vendor: Sewon Cellontech Co. Ltd. - P00007 | No.: E0351-3AE325-P-02 | Rev: 2 | Date Rec'd<br>2013-10-02 |
| Doc. Title: L53.51, L53.53 - THERMAL DESIGN CALCULATION - Tag:3A-E-325A/B | | | |
| Client Code: | Project: MEG Phase 3A EPC | | |
| Reviewed by: SS<br>Date: 2-Oct-2013 | Document No<br>P-5310-01-0039 | | Submittal<br>03 |

| SEWON CELLONTECH | DOCUMENT FOR EQUIPMENT | SWC JOB NO | E-0351 |
|---|---|---|---|
| | | ITEM NO. | 3A-E-325A/B |
| | | SWC DOC. NO. | E0351-3AE325-P-02 |

ASME-U

| MEG Energy Corp. | SNC·LAVALIN |
|---|---|
| P.O NO. | P-5310-01 |
| PROJECT NAME | CLRP Phase 3A Central Plant Facility: EPC |
| PROJECT NO. | 511036 |
| DOCUMENT TITLE | THERMAL DESIGN CALCULATION |
| ITEM NO. | ITEM DESCRIPTION |
| 3A-E-325A/B | BLOWDOWN DISPOSAL / GLYCOL EXCHANGER |

SEWON CELLONTECH CORP. ISSUED 2013.09.30 2BU KOREA

- Total Sheet : 24 Sheet (Including This Cover)

| | | | | |
|---|---|---|---|---|
| | | | | |
| | | | | |
| 2 | M.K.PARK 9/26/13 | T.W.KIM 9/27/13 | Y.S.JI 9/30/2013 | THIRD ISSUE |
| 1 | M.K.PARK | T.W.KIM | Y.S.JI | SECOND ISSUED |
| 0 | M.K.PARK | T.W.KIM | Y.S.JI | FIRST ISSUED |
| REV | PREPARED BY | REVIEWED BY | APPROVED BY | DESCRIPTION |

**SEWON CELLONTECH CO.,LTD.**

SEWON CELLONTECH

# TUBULAR HEAT EXCHANGER

SHEET 2 OF 21

| | |
|---|---|
| CUSTOMER | MEG Energy Corp. |
| LOCATION | CANADA |
| JOB NO. | 511036 |
| SERVICE | Blowdown Disposal / Glycol Exchanger |
| ITEM NO. | 3A-E-325A/B (Max Duty Case) |

| REV | MADE BY | CHECKED BY | APPROVED BY | DATE |
|---|---|---|---|---|
| 0 | - | - | - | 07-01-2013 |
| 1 | - | - | - | 08-14-2013 |
| 2 | - | - | - | 09-26-2013 |

Total 2 Shells, Connected in 1 Parallel 2 Series Shells | Install ■ Hor. □ Vert. | Size 1,120.0 ID - 6,096.0 L

Code ASME Sec.VIII Div.1 (STAMP), TEMA, API660 TEMA Type AFU (Note 13) | TEMA Class R | Effective Area 301.34 m² /Shell

## PERFORMANCE OF ONE BATTERY

| | | | SHELL SIDE | | TUBE SIDE | |
|---|---|---|---|---|---|---|
| | | | INLET | OUTLET | INLET | OUTLET |
| Fluid Circulated | | | TEG/Water(60/40 wt%) | | MP Blowdown | |
| Total Fluid | kg/hr | | 205102 | | 207611 | |
| Vapor | kg/hr | MW | | | | |
| Liquid | kg/hr | MW | 205102 | 205102 | 207611 | 207611 |
| Steam | kg/hr | | | | | |
| Water | kg/hr | | | | 207611 | 207611 |
| Noncondendable | kg/hr | MW | | | | |
| Operating Temperature | ℃ | | 40.00 | 85.00 | 95.00 | 60.00 |
| Operating Pressure | kPaa | | 994.015 | | 1455.02 | |
| Density | kg/m3 | L / V | 1078.0 | 1044.0 | 962.00 | 983.00 |
| Viscosity | cP | L / V | 4.6610 | 1.7770 | 0.2940 | 0.4630 |
| Thermal Conductivity | W/m·℃ | L / V | 0.3281 | 0.3381 | 0.6782 | 0.6532 |
| Specific Heat | kJ/kg·℃ | L / V | 3.2231 | 3.3841 | 4.2081 | 4.1831 |
| Latent Heat | kJ/kg | | | | | |
| Bubble / Dew Point | ℃ | | / | / | / | / |
| Critical Press. / Temp. | kPaa / ℃ | | / | / | / | / |
| Velocity | m/sec | | 0.62 | | 1.68 | |
| Pressure Drop | kPa. | | Allow. 120.000 | Calc. 107.133 | Allow. 165.000 | Calc. 163.508 |
| Fouling Resistance | m2·℃/kW | | 0.088 | | 0.176 | |
| Film Coefficient | W/m2·K | | 2,482.86 | | 8,993.31 | |
| Overall Coefficient | W/m2·K | | Clean 1756.50 | Calc. 1161.58 | Design 1092.47 | |
| Heat Duty | KW | | 8,469.00 | | LMTD ℃ | MTD 12.9 ℃ |

## CONSTRUCTION

| | | | | | |
|---|---|---|---|---|---|
| Design Pressure / Design Temperature | 1500.0 / FV kPa.G | -29 / 214 ℃ | 1950.0 / FV kPa.G | -29 / 214 ℃ | |
| No. of Passes | 2 | | 8 | | |
| Tubes No. 238U / Shell, Size 31.75 mm, Thickness 2.11 (Min.) mm | ( BWG : 14 ) | Length 6,096.0 mm | | | |
| Shell 1120 mm ID | Tube Pitch 39.69 mm, Layout angle 45 °, Leffective - mm | | | | |
| Baffles Cross Baffle 11+1S (Note 2) ea / Shell, Type Single Seg. (Vert.), Cut 26.0 % Dia., Spacing c/c 470.0 mm, End - mm | | | | | |
| ρv² Inlet Nozzle 641.90, Entrance 1,530.45 | Outlet Nozzle 662.81 kg/m·sec2 | | Impingement plate None | | |
| Material Tube SA 179 Seamless | Shell & Cover SA 516 GR. 70N | | Channel & Cover SA 516 GR. 70N | | |
| Material Tube Sheet SA 266 GR.2 | Baffle Carbon Steel | | Expansion Joint N/A | | |
| Estimated Weight Empty Weight kg | Bundle Weight - kg | | Full Water Weight kg | | |
| Corrosion Allowance Shell side 3.2 mm | Tube side 3.2 mm | | Tube Joints : Rolled (two grooves) and Expanded | | |
| Insulation Shell side 64 mm | Tube side 64 mm | | | | |

| MEAN METAL TEMPERATURE | Temperature, ℃ | | Pressure, kPa.G | |
|---|---|---|---|---|
| | Shell | Tube | Shell | Tube |
| Normal Operating | - | - | - | - |
| Startup | - | - | - | - |

| NOZZLE | SHELL SIDE | | | | TUBE SIDE | | | |
|---|---|---|---|---|---|---|---|---|
| | Tag | No | NPS | Remarks | Tag | No | NPS | Remarks |
| Inlet | S1 | 1 | 12 | | T1 | 1 | 8 | |
| Outlet | S2 | 1 | 12 | | T2 | 1 | 8 | |
| Vent | | | | (Note 8 & 9) | | | | (Note 9) |
| Drain | | | | (Note 8 & 9) | | | | (Note 9) |
| Thermowell | | | | | | | | |
| Util. Con. | | | | | | | | |
| RATING | RFWN 300# | | | | RFWN 300# | | | |

Remarks

1) Seller shall verify and guarantee thermal rating of the unit.
2) Full support at the U-bend tangent line shall be trimmed beyond the top and the bottom tube rows as much as possible.
3) Exchanger is to be designed for future field hydrotest in the fully corroded condition.
4) Exchangers to be designed for liquid full condition at S.G. = 1.079
5) Seller is to design and install electrical heat tracing for hold temperature of 10℃. CSA approval is required for electric components and installation. The heat exchanger is located in a non-hazardous area.
7) Seller is to supply and install 64mm thick mimeral fiber insulation.
8) Each shell and channel shall be provided with a NPS 2" (300#, RFWN or RFLWN) vent and drain. Channel vent & drain between shells shall be provided with a 90° elbow. Vents and drains shall come complete with blind flange, gasket, bolts & nuts.
9) Each process nozzle shall be provided with one 1" 300# RFLWN (complete with blind flange, gasket, bolts & nuts).
10) Exchangers shall be stacked. Per API 660, exchangers shall be hydrotested stacked.
11) During normal operation 3A-E-325 is not operating. 3A-E-325 operates only when MVC evaporator is down.
12) EHT design shall use voltage of 277 VAC.
13) Bundles shall be removable.

# SEWON CELLONTECH

# TUBULAR HEAT EXCHANGER

SHEET 3 OF 21

| | |
|---|---|
| CUSTOMER | MEG Energy Corp. |
| LOCATION | CANADA |
| JOB NO. | 511036 |
| SERVICE | Blowdown Disposal / Glycol Exchanger |
| ITEM NO. | 3A-E-325A/B (Min Duty Case) |

| REV | MADE BY | CHECKED BY | APPROVED BY | DATE |
|---|---|---|---|---|
| 0 | - | - | - | 07-01-2013 |
| 1 | - | - | - | 08-14-2013 |
| 2 | - | - | - | 09-26-2013 |

Total 2 Shells, Connected in 1 Parallel 2 Series Shells | Install ■ Hor. □ Vert. | Size 1,120.0 ID - 6,096.0 L

Code ASME Sec.VIII Div.1 (STAMP), TEMA, API660 TEMA Type AFU | TEMA Class R | Effective Area 301.34 m² /Shell

## PERFORMANCE OF ONE BATTERY

| | | | SHELL SIDE | | TUBE SIDE | |
|---|---|---|---|---|---|---|
| | | | INLET | OUTLET | INLET | OUTLET |
| Fluid Circulated | | | TEG/Water(60/40 wt%) | | MP Blowdown | |
| Total Fluid | kg/hr | | 152546 | | 154412 | |
| Vapor | kg/hr | MW | | | | |
| Liquid | kg/hr | MW | 152546 | 152546 | 154412 | 154412 |
| Steam | kg/hr | | | | | |
| Water | kg/hr | | | | 154412 | 154412 |
| Noncondendable | kg/hr | MW | | | | |
| Operating Temperature | ℃ | | 40.00 | 85.00 | 95.00 | 60.00 |
| Operating Pressure | kPaa | | 994.015 | | 1455.02 | |
| Density | kg/m3 | L / V | 1078.0 | 1044.0 | 962.00 | 983.00 |
| Viscosity | cP | L / V | 4.6610 | 1.7770 | 0.2940 | 0.4630 |
| Thermal Conductivity | W/m·℃ | L / V | 0.3281 | 0.3381 | 0.6782 | 0.6532 |
| Specific Heat | kJ/kg·℃ | L / V | 3.2231 | 3.3841 | 4.2081 | 4.1831 |
| Latent Heat | kJ/kg | | | | | |
| Bubble / Dew Point | ℃ | | / | / | / | / |
| Critical Press. / Temp. | kPaa / ℃ | | / | / | / | / |
| Velocity | m/sec | | 0.47 | | 1.25 | |
| Pressure Drop | kPa. | | Allow. 100.000 | Calc. 62.465 | Allow. 100.000 | Calc. 93.264 |
| Fouling Resistance | m2·℃/kW | | 0.088 | | 0.176 | |
| Film Coefficient | W/m2·K | | 2,118.10 | | 7,114.33 | |
| Overall Coefficient | W/m2·K | | Clean 1487.03 | Calc. 1037.21 | Design 813.03 | |
| Heat Duty | KW | | 6,299.00 | | LMTD ℃ | MTD 12.9 ℃ |

## CONSTRUCTION

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Design Pressure | Design Temperature | / kPa.G | / ℃ | / kPa.G | / ℃ | | |
| No. of Passes | | | | | | | |
| Tubes No. | / Shell, Size | mm , Thickness | (Min.) mm | ( BWG : ) | Length | mm | |
| Shell | mm ID | Tube Pitch | mm , Layout angle | ° , Leffective | - mm | | |
| Baffles Cross Baffle | ea / Shell , Type | , Cut | - % Dia. , Spacing c/c | mm , End | - mm | | |
| ρv² | Inlet Nozzle 355.08 , Entrance 851.35 | Outlet Nozzle 366.65 | kg/m·sec2 | Impingement plate | | | |
| Material | Tube | Shell & Cover | | Channel & Cover | | | |
| | Tube Sheet | Baffle | | Expansion Joint | | | |
| Estimated Weight | Empty Weight kg | Bundle Weight | kg | Full Water Weight | kg | | |
| Corrosion Allowance | Shell side mm | Tube side | mm | Tube Joints : | | | |
| Insulation | Shell side mm | Tube side | mm | | | | |

| MEAN METAL TEMPERATURE | Temperature, ℃ | | Pressure, kPa.G | |
|---|---|---|---|---|
| | Shell | Tube | Shell | Tube |
| Normal Operating | - | - | - | - |
| Startup | - | - | - | - |

| NOZZLE | SHELL SIDE | | | | TUBE SIDE | | | |
|---|---|---|---|---|---|---|---|---|
| | Tag | No | NPS | Remarks | Tag | No | NPS | Remarks |
| Inlet | | | | | | | | |
| Outlet | | | | | | | | |
| Vent | | | | | | | | |
| Drain | | | | | | | | |
| Liquid Outlet | | | | | | | | |
| Thermowell | | | | | | | | |
| Util. Con. | | | | | | | | |
| RATING | | | | | | | | |

**Blowdown Disposal Water Analysis**

| Water Analysis (mg/l as ion unless noted) | Normal | Max. |
|---|---|---|
| $Ca^{++}$ | 0.36 | 0.44 |
| $Mg^{++}$ | 0.36 | 0.44 |
| $Na^{+}$ | 3707 | 10709 |
| $K^{+}$ | 5.92 | 36.12 |
| $Fe^{++}$ | 4.47 | 8.29 |
| $Cu^{++}$ | 0.22 | 0.75 |
| $Ba^{++}$ | 0.31 | 3.04 |
| $Sr^{++}$ | 0.89 | 8.22 |
| $HCO_3^-$ | 0.0 | 0.0 |
| $CO_3^{--}$ | 127 | 333 |
| $OH^-$ | 305 | 775 |
| $SO_4^{--}$ | 18.81 | 39.60 |
| $Cl^-$ | 4929 | 14529 |
| Silica ppm as $SiO_2$ | 214.1 | 262.1 |
| Sulphides ppm as $S^{--}$ | 0.0 | 0.0 |
| TOC ppm as TOC | 0.48 | 4.83 |
| TDS ppm as ion | 9314 | 26706 |
| TSS ppm TSS | 0.0 | 0.0 |
| Oil & Grease ppm oil in water | 0.0 | 0.0 |
| Total Hardness ppm as $CaCO_3$ | 2.36 | 2.89 |
| P-Alk (ppm as $CaCO_3$) | 1004 | 2559 |
| M-Alk (ppm as $CaCO_3$) | 1111 | 2837 |
| Dissolved $O_2$ | - | - |
| Estimated pH | 12.16 | 12.61 |

SEWON CELLONTECH

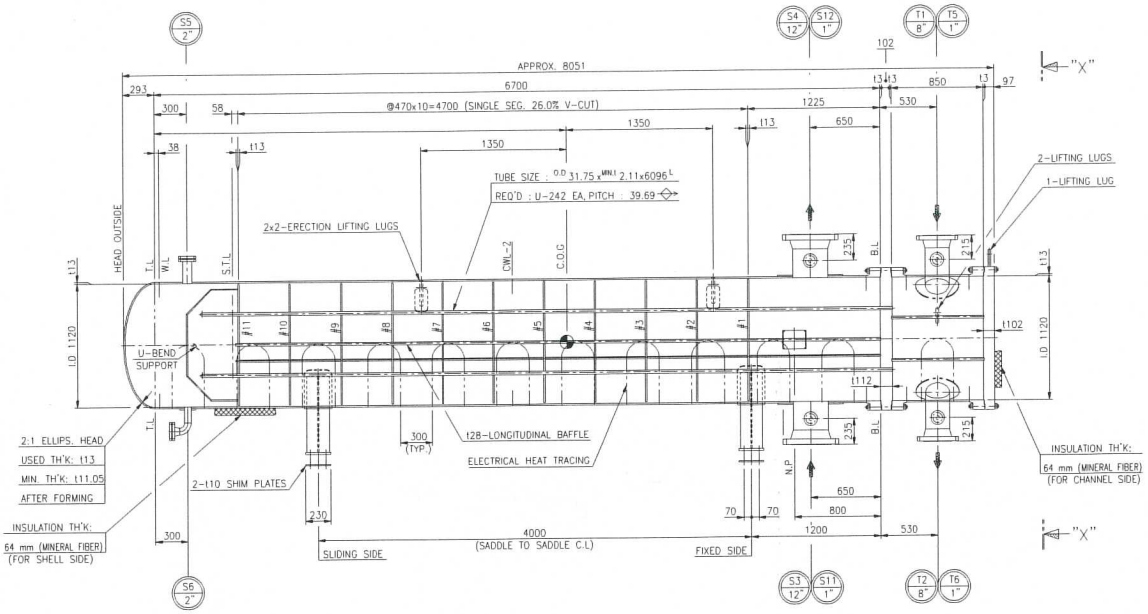
# TUBULAR HEAT EXCHANGER

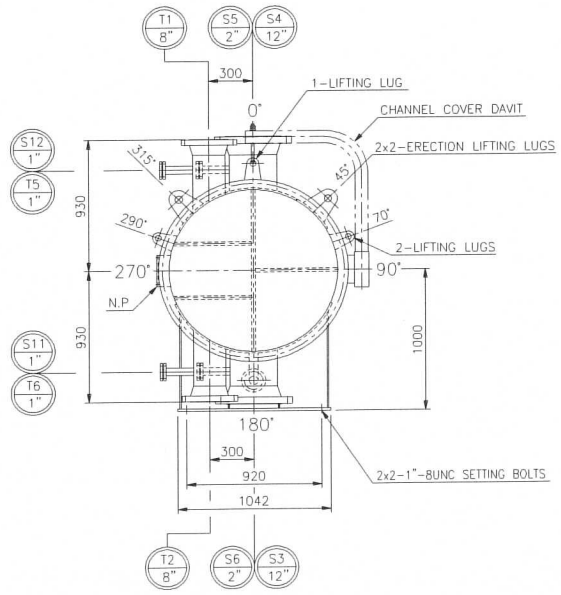
SHEET 4 OF 21

| | |
|---|---|
| CUSTOMER | MEG Energy Corp. |
| LOCATION | CANADA |
| JOB NO. | 511036 |
| SERVICE | Blowdown Disposal / Glycol Exchanger |
| ITEM NO. | 3A-E-325A/B |

| REV | MADE BY | CHECKED BY | APPROVED BY | DATE |
|---|---|---|---|---|
| 0 | - | - | - | 07-01-2013 |
| 1 | - | - | - | 08-14-2013 |
| 2 | - | - | - | 09-26-2013 |
| | | | | |
| | | | | |

## Shell 1



SEWON CELLONTECH

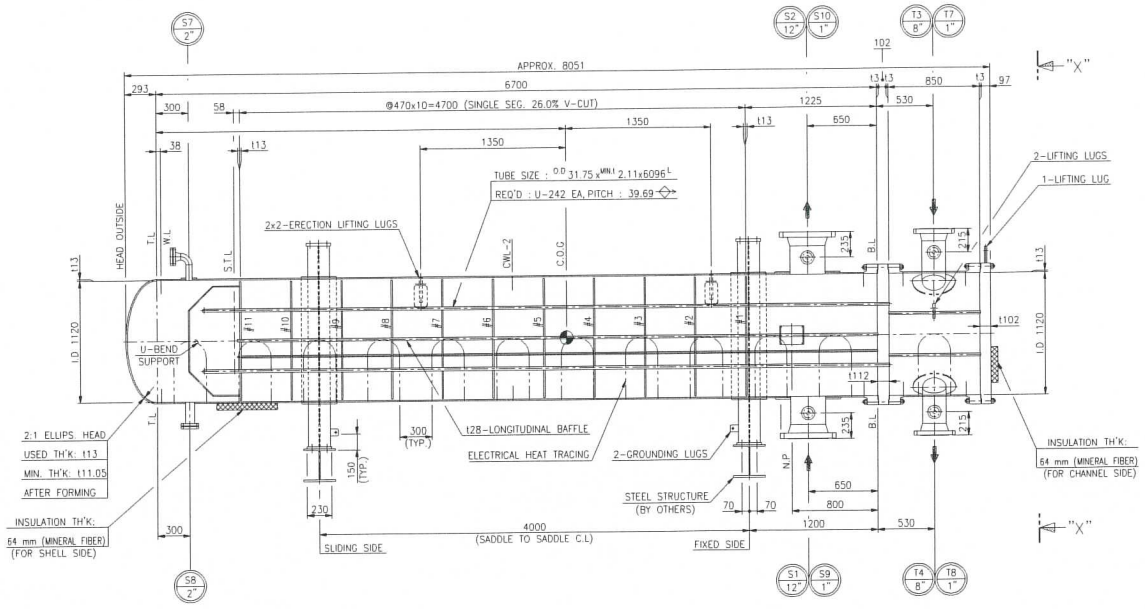
# TUBULAR HEAT EXCHANGER

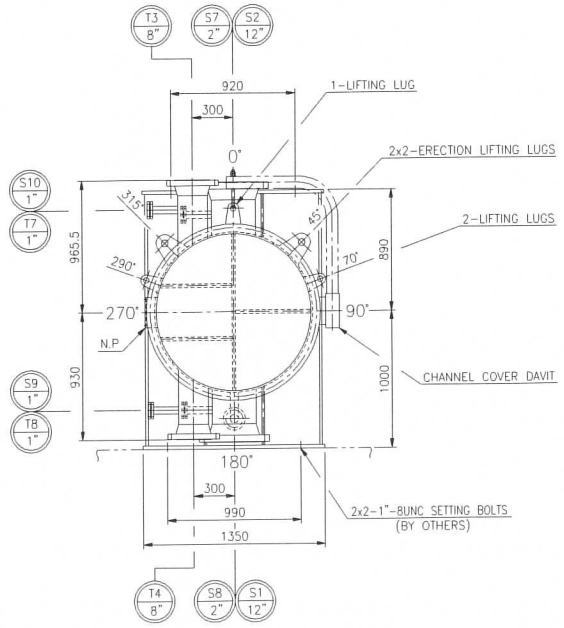
SHEET 5 OF 21

| | |
|---|---|
| CUSTOMER | MEG Energy Corp. |
| LOCATION | CANADA |
| JOB NO. | 511036 |
| SERVICE | Blowdown Disposal / Glycol Exchanger |
| ITEM NO. | 3A-E-325A/B |

| REV | MADE BY | CHECKED BY | APPROVED BY | DATE |
|---|---|---|---|---|
| 0 | - | - | - | 07-01-2013 |
| 1 | - | - | - | 08-14-2013 |
| 2 | - | - | - | 09-26-2013 |
| | | | | |

## Shell 2



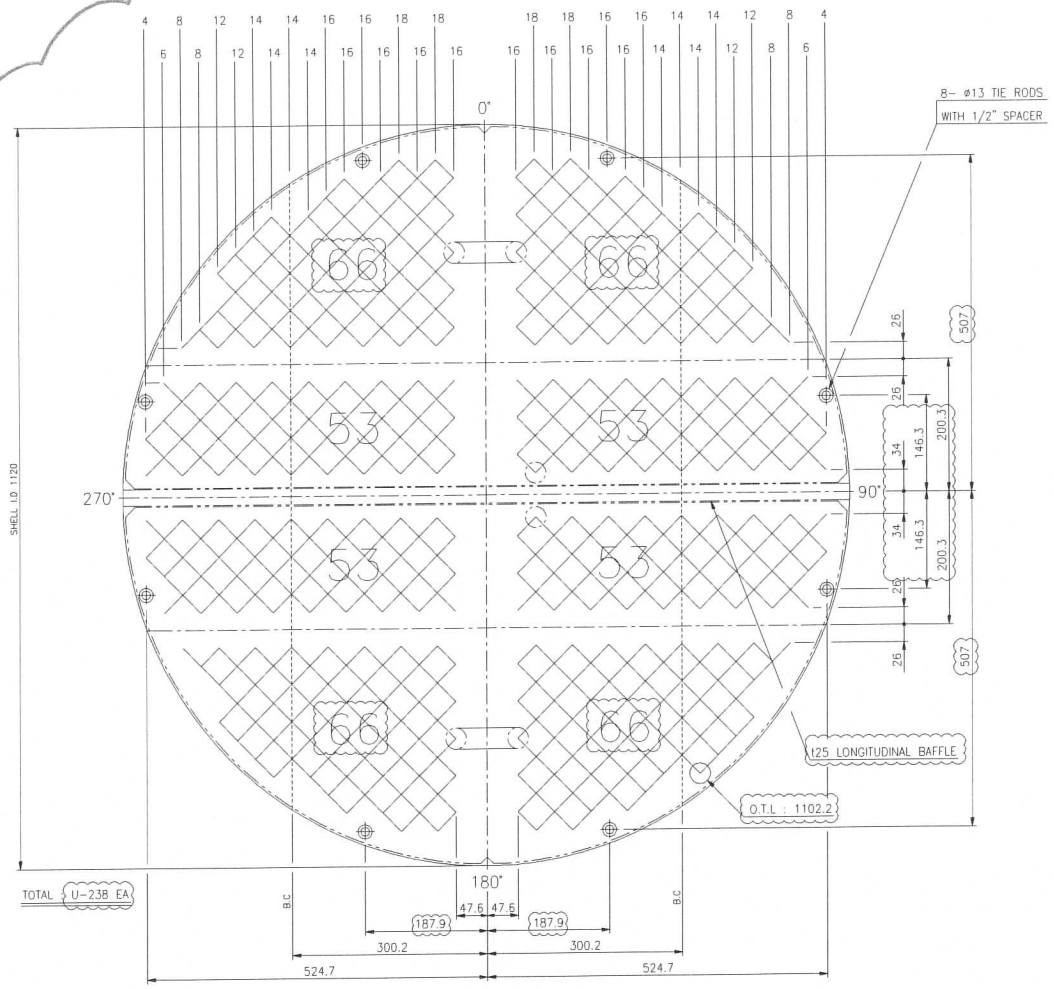
SEWON CELLONTECH

# TUBULAR HEAT EXCHANGER

SHEET 6 OF 21

| | |
|---|---|
| CUSTOMER | MEG Energy Corp. |
| LOCATION | CANADA |
| JOB NO. | 511036 |
| SERVICE | Blowdown Disposal / Glycol Exchanger |
| ITEM NO. | 3A-E-325A/B |

| REV | MADE BY | CHECKED BY | APPROVED BY | DATE |
|---|---|---|---|---|
| 0 | - | - | - | 07-01-2013 |
| 1 | - | - | - | 08-14-2013 |
| 2 | - | - | - | 09-26-2013 |




3A-E-325

1/5

| | | |
|---|---|---|
| I.D.-SHELL | 1,120.0 ID | (AFU) |
| ALLOWABLE O.T.L | 1102.2 | mm |
| ACTUAL O.T.L | 1102.2 | mm |
| SEAL STRIP | N/A | Pairs |
| SEAL Rod | N/A | ea |

TOTAL 238U HOLES FOR 31.75 OD TUBES ON 39.69 SQUARE PITCH.
8 PASSES. BAFFLE CUT SINGLE SEGM. 26% DIA.

*Remarks*

7/21

# Thermal/Hydraulic/ Vibration Verification Report

(Rev.2)

## 3A-E-325A/B

| | |
|---|---|
| Client : | MEG Energy Corp. |
| Project : | MEG Energy Christina Lake Regional Project<br>Phase 3A-Central Plant Facilities |
| Date : | 09-26-2013 |

# 3A-E-325A/B (Max Duty Case)

The Thermal/Hydraulic/Vibration calculations are perfomed by using HTRI Xist Ver. 6.00 SP3.

The process condiiton and the physical properties are based on Buyer data sheet.

For the design result ( the geometry data), please refer to the Equopment data sheet and Fabrication drawing.

1. Thermal and Hydraulic performance

| | | | | | | |
|---|---|---|---|---|---|---|
| - Thermal performance : | | **6.33** | % Over - Design Case | | ---------- | O.K. |
| - Pressure drop : | | | | | | |
| | Shell-side | **107.133** | < | **120.000 kPa** | ---------- | O.K |
| | tube-side | **163.508** | < | **165.000 kPa** | ---------- | O.K |

2. Vibration Analysis

| | | | | | |
|---|---|---|---|---|---|
| - Fluidelastid instability : | characteristic values | << | criteria | ---------- | O.K. |
| - Acoustic vibration : | characteristic values | << | criteria | ---------- | O.K. |
| - Tube vibration check: | characteristic values | << | criteria | ---------- | O.K. |
| - Bundle Entrance/Exit : | characteristic values | << | criteria | ---------- | O.K. |
| - Shell Entrance /Exit: | characteristic values | << | criteria | ---------- | O.K. |

# 3A-E-325A/B (Max Duty Case) - Shell 1

Used Program : HTRI Xist Ver.6.00 SP.3 Vibration Analysis

| VALUE TO BE CHECKED | Inlet | Center | U-Bend | RECOMMEND LIMIT | CONCLUSION |
|---|---|---|---|---|---|
| Unsupported span (mm) | 1690. | 940. | 908. | 2235 (By TEMA) | O.K |
| Length / TEMA maximum span | 0.756 | 0.421 | 0.478 | < 1.0 TEMA | O.K |
| Fluidelastic Instability Check | | | | | |
| Baffle tip cross velocity ratio | 0.1033 | 0.0874 | 0.1926 | < 0.8 | O.K |
| Ave. crossflow velocity ratio | 0.0966 | 0.0817 | 0.1801 | < 0.8 | O.K |
| Acoustic Vibration Check | | | | | |
| Vortex shedding ratio | - | - | - | - | - |
| Tubulent buffeting ratio | - | - | - | - | - |
| Tube Vibration Check | | | | | |
| Vortex shedding ratio | 0.077 | 0.207 | 0.184 | < 0.5 | O.K |
| Tubulent buffeting ratio | - | - | - | - | - |
| Bundle Entance / Exit | | Entrance | Exit | | |
| Fluidelastic Instability ratio | | 0.158 | 0.160 | < 0.8 | O.K |
| Vortex shedding ratio | | 0.194 | 0.197 | < 0.5 | O.K |
| Shell Entrance / Exit | | | | | |
| Velocity (m/sec) | | 1.20 | 1.22 | < If velocity is exceed 2.38 / 2.39 | O.K. |
| ρv2 (kg/m-s2) | | 1530.45 | 1551.53 | < 5953 by TEMA | O.K. |

# Vibration Analysis

Released to the following HTRI Member Company:

*sewon*

*M.K.Park*

Xist Ver. 6.00 SP3 2013/09/13 10:47 SN: 1500213869 — **MEG Energy Units**

Max.Duty Case : Shell 1

Rating - Horizontal Multipass Flow TEMA AFU Shell With Single-Segmental Baffles

| | | | | | |
|---|---|---|---|---|---|
| 1 | Shellside condition | | Sens. Liquid | (Level 2.3) | |
| 2 | Axial stress loading | (MPa) | 0.000 | Added mass factor | 1.517 |
| 3 | Beta | | 3.745 | | |

| | Position In The Bundle | | Inlet | Center | U-Bend |
|---|---|---|---|---|---|
| 5 | Length for natural frequency | (mm) | 1690. | 940. | 908. |
| 6 | Length/TEMA maximum span | (--) | 0.756 | 0.421 | 0.478 |
| 7 | Number of spans | (--) | 6 | 6 | 2 |
| 8 | Tube natural frequency | (Hz) | 35.6 | 68.6 | 27.9 + |
| 9 | Shell acoustic frequency | (Hz) | | | |
| 10 | **Flow Velocities** | | **Inlet** | **Center** | **U-Bend** |
| 11 | Window parallel velocity | (m/s) | 0.78 | 0.78 | 0.78 |
| 12 | Bundle crossflow velocity | (m/s) | 0.15 | 0.40 | 0.28 |
| 13 | Bundle/shell velocity | (m/s) | 0.14 | 0.37 | 0.26 |
| 14 | **Fluidelastic Instability Check** | | **Inlet** | **Center** | **U-Bend** |
| 15 | Log decrement | HTRI | 0.100 | 0.096 | 0.100 |
| 16 | Critical velocity | (m/s) | 2.38 | 7.56 | 2.39 |
| 17 | Baffle tip cross velocity ratio | (--) | 0.1033 | 0.0874 | 0.1926 |
| 18 | Average crossflow velocity ratio | (--) | 0.0966 | 0.0817 | 0.1801 |
| 19 | **Acoustic Vibration Check** | | **Inlet** | **Center** | **U-Bend** |
| 20 | Vortex shedding ratio | (--) | | | |
| 21 | Chen number | (--) | | | |
| 22 | Turbulent buffeting ratio | (--) | | | |
| 23 | **Tube Vibration Check** | | **Inlet** | **Center** | **U-Bend** |
| 24 | Vortex shedding ratio | (--) | 0.077 | 0.207 | 0.184 |
| 25 | Parallel flow amplitude | (mm) | 0.003 | 0.002 | 0.016 |
| 26 | Crossflow amplitude | (mm) | 0.009 | 0.007 | 0.003 |
| 27 | Tube gap | (mm) | 7.940 | 7.940 | 7.940 |
| 28 | Crossflow RHO-V-SQ | (kg/m-s2) | 55.97 | 401.06 | 194.11 |

| | **Bundle Entrance/Exit** (analysis at first tube row) | | | **Entrance** | **Exit** |
|---|---|---|---|---|---|
| 31 | Fluidelastic instability ratio | | (--) | 0.158 | 0.160 |
| 32 | Vortex shedding ratio | | (--) | 0.194 | 0.197 |
| 33 | Crossflow amplitude | | (mm) | 0.06105 | 0.06239 |
| 34 | Crossflow velocity | | (m/s) | 0.38 | 0.38 |
| 35 | Tubesheet to inlet/outlet support | | (mm) | None | None |
| 36 | **Shell Entrance/Exit Parameters** | | | **Entrance** | **Exit** |
| 37 | Impingement plate | | | No | |
| 38 | Flow area | | (m2) | 0.045 | 0.045 |
| 39 | Velocity | | (m/s) | 1.20 | 1.22 |
| 40 | RHO-V-SQ | | (kg/m-s2) | 1530.45 | 1551.53 |

| | | | | |
|---|---|---|---|---|
| 41 | Shell type | AFU | Baffle type | Single-Seg. |
| 42 | Tube type | Plain | Baffle layout | Parallel |
| 43 | Pitch ratio | 1.2501 | Tube diameter, (mm) | 31.750 |
| 44 | Layout angle | 45 | Tube material | Carbon steel |
| 45 | Number U-Bend supports | 1 | Supports/baffle space | |

**Program Messages**

+ Frequency ratios are based upon lowest natural or acoustic frequency

* Items with asterisk exceed a conservative lower limit for vibration-free design. Review your case using the procedure described in Online Help; You may find that a vibration problem is unlikely.

# 3A-E-325A/B (Max Duty Case) - Shell 2

Used Program : HTRI Xist Ver.6.00 SP.3 Vibration Analysis

| VALUE TO BE CHECKED | Inlet | Center | U-Bend | RECOMMEND LIMIT | CONCLUSION |
|---|---|---|---|---|---|
| Unsupported span (mm) | 1690. | 940. | 908. | 2235 (By TEMA) | O.K |
| Length / TEMA maximum span | 0.756 | 0.421 | 0.478 | < 1.0 TEMA | O.K |
| Fluidelastic Instability Check | | | | | |
| Baffle tip cross velocity ratio | 0.1032 | 0.0857 | 0.1937 | < 0.8 | O.K |
| Ave. crossflow velocity ratio | 0.0965 | 0.0802 | 0.1812 | < 0.8 | O.K |
| Acoustic Vibration Check | | | | | |
| Vortex shedding ratio | - | - | - | - | - |
| Tubulent buffeting ratio | - | - | - | - | - |
| Tube Vibration Check | | | | | |
| Vortex shedding ratio | 0.077 | 0.207 | 0.184 | < 0.5 | O.K |
| Tubulent buffeting ratio | - | - | - | - | - |
| Bundle Entance / Exit | | Entrance | Exit | | |
| Fluidelastic Instability ratio | | 0.157 | 0.159 | < 0.8 | O.K |
| Vortex shedding ratio | | 0.191 | 0.195 | < 0.5 | O.K |
| Shell Entrance / Exit | | | | | |
| Velocity (m/sec) | | 1.18 | 1.20 | < If velocity is exceed 2.36 / 2.37 | O.K. |
| ρv2 (kg/m-s2) | | 1502.60 | 1530.45 | < 5953 by TEMA | O.K. |

12/21

# Vibration Analysis

Released to the following HTRI Member Company:

*sewon*

*M.K.Park*

Xist Ver. 6.00 SP3 2013/09/13 10:47 SN: 1500213869 — **MEG Energy Units**

Max.Duty Case : Shell 2

Rating - Horizontal Multipass Flow TEMA AFU Shell With Single-Segmental Baffles

| | | | | | |
|---|---|---|---|---|---|
| 1 | Shellside condition | | Sens. Liquid | (Level 2.3) | |
| 2 | Axial stress loading | (MPa) | 0.000 | Added mass factor | 1.517 |
| 3 | Beta | | 3.745 | | |
| 4 | **Position In The Bundle** | | **Inlet** | **Center** | **U-Bend** |
| 5 | Length for natural frequency | (mm) | 1690. | 940. | 908. |
| 6 | Length/TEMA maximum span | (--) | 0.756 | 0.421 | 0.478 |
| 7 | Number of spans | (--) | 6 | 6 | 2 |
| 8 | Tube natural frequency | (Hz) | 35.5 | 68.5 | 27.8 + |
| 9 | Shell acoustic frequency | (Hz) | | | |
| 10 | **Flow Velocities** | | **Inlet** | **Center** | **U-Bend** |
| 11 | Window parallel velocity | (m/s) | 0.77 | 0.78 | 0.78 |
| 12 | Bundle crossflow velocity | (m/s) | 0.15 | 0.40 | 0.28 |
| 13 | Bundle/shell velocity | (m/s) | 0.13 | 0.35 | 0.24 |
| 14 | **Fluidelastic Instability Check** | | **Inlet** | **Center** | **U-Bend** |
| 15 | Log decrement | HTRI | 0.100 | 0.100 | 0.100 |
| 16 | Critical velocity | (m/s) | 2.36 | 7.66 | 2.37 |
| 17 | Baffle tip cross velocity ratio | (--) | 0.1032 | 0.0857 | 0.1937 |
| 18 | Average crossflow velocity ratio | (--) | 0.0965 | 0.0802 | 0.1812 |
| 19 | **Acoustic Vibration Check** | | **Inlet** | **Center** | **U-Bend** |
| 20 | Vortex shedding ratio | (--) | | | |
| 21 | Chen number | (--) | | | |
| 22 | Turbulent buffeting ratio | (--) | | | |
| 23 | **Tube Vibration Check** | | **Inlet** | **Center** | **U-Bend** |
| 24 | Vortex shedding ratio | (--) | 0.077 | 0.207 | 0.184 |
| 25 | Parallel flow amplitude | (mm) | 0.003 | 0.002 | 0.016 |
| 26 | Crossflow amplitude | (mm) | 0.009 | 0.007 | 0.003 |
| 27 | Tube gap | (mm) | 7.940 | 7.940 | 7.940 |
| 28 | Crossflow RHO-V-SQ | (kg/m-s2) | 56.13 | 403.10 | 197.06 |
| 29 | **Bundle Entrance/Exit** | | | | |
| 30 | **(analysis at first tube row)** | | | **Entrance** | **Exit** |
| 31 | Fluidelastic instability ratio | | (--) | 0.157 | 0.159 |
| 32 | Vortex shedding ratio | | (--) | 0.191 | 0.195 |
| 33 | Crossflow amplitude | | (mm) | 0.05962 | 0.06139 |
| 34 | Crossflow velocity | | (m/s) | 0.37 | 0.38 |
| 35 | Tubesheet to inlet/outlet support | | (mm) | None | None |
| 36 | **Shell Entrance/Exit Parameters** | | | **Entrance** | **Exit** |
| 37 | Impingement plate | | | No | |
| 38 | Flow area | | (m2) | 0.045 | 0.045 |
| 39 | Velocity | | (m/s) | 1.18 | 1.20 |
| 40 | RHO-V-SQ | | (kg/m-s2) | 1502.60 | 1530.45 |

| | | | | | |
|---|---|---|---|---|---|
| 41 | Shell type | AFU | Baffle type | | Single-Seg. |
| 42 | Tube type | Plain | Baffle layout | | Parallel |
| 43 | Pitch ratio | 1.2501 | Tube diameter, (mm) | | 31.750 |
| 44 | Layout angle | 45 | Tube material | | Carbon steel |
| 45 | Number U-Bend supports | 1 | Supports/baffle space | | |

46 **Program Messages**

47 + Frequency ratios are based upon lowest natural or acoustic frequency

48 * Items with asterisk exceed a conservative lower limit for vibration-free design. Review your case

49 using the procedure described in Online Help; You may find that a vibration problem is unlikely.

50

51

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53

2

## Final Results

Released to the following HTRI Member Company:

*sewon*

*M.K.Park*

Xist Ver. 6.00 SP3 2013/09/13 10:47 SN: 1500213869 **MEG Energy Units**

Max.Duty Case : Shell 1

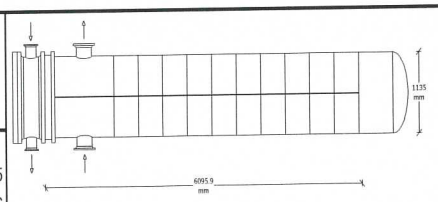
Rating - Horizontal Multipass Flow TEMA AFU Shell With Single-Segmental Baffles

| Process Data | | Cold Shellside | | Hot Tubeside | |
|---|---|---|---|---|---|
| Fluid name | | TEG/Water(60/40 wt%) | | MP Blowdown | |
| Fluid condition | | | Sens. Liquid | | Sens. Liquid |
| Total flow rate | (kg/hr) | | 205102 | | 207611 |
| Weight fraction vapor, In/Out | (--) | 0.000 | 0.000 | 0.000 | 0.000 |
| Temperature, In/Out | (Deg C) | 65.96 | 85.00 | 95.00 | 80.01 |
| Temperature, Average/Skin | (Deg C) | 75.48 | 81.46 | 87.51 | 85.77 |
| Wall temperature, Min/Max | (Deg C) | 74.05 | 91.22 | 74.70 | 91.61 |
| Pressure, In/Average | (kPa) | 939.125 | 913.004 | 1455.02 | 1414.40 |
| Pressure drop, Total/Allowed | (kPa) | 52.244 | 120.000 | 81.236 | 165.000 |
| Velocity, Mid/Max allow | (m/s) | 0.62 | | 1.69 | |
| Mole fraction inert | (--) | | | | |
| Average film coef. | (W/m2-K) | | 2644.88 | | 9440.34 |
| Heat transfer safety factor | (--) | | 1.000 | | 1.000 |
| Fouling resistance | (m2-K/W) | | 0.000088 | | 0.000176 |

**Overall Performance Data**

| | | | | |
|---|---|---|---|---|
| Overall coef., Reqd/Clean/Actual | (W/m2-K) | 1131.40 / | 1854.07 / | 1204.33 |
| Heat duty, Calculated/Specified | (kW) | 3633. / | | |
| Effective overall temperature difference | (Deg C) | 10.7 | | |
| EMTD = (MTD) * (DELTA) * (F/G/H) | (Deg C) | 10.82 * | 0.9849 * | 1.0000 |

**See Runtime Messages Report for warnings.**




**Exchanger Fluid Volumes**

| | | |
|---|---|---|
| Approximate shellside | (L) | 3609.5 |
| Approximate tubeside | (L) | 3718.6 |

**Shell Construction Information**

| | | | | | |
|---|---|---|---|---|---|
| TEMA shell type | AFU | | Shell ID | (mm) | 1135.00 |
| Shells Series | 1 Parallel | 1 | Total area | (m2) | 307.037 |
| Passes Shell | 2 Tube | 8 | Eff. area | (m2/shell) | 301.340 |
| Shell orientation angle (deg) | 0.00 | | | | |
| Impingement present | No | | | | |
| Pairs seal strips | 0 | | Passlane seal rods (mm) | 31.750 | No. 0 |
| Shell expansion joint | No | | Full support at U-Bend | No | |
| Weight estimation Wet/Dry/Bundle | 21427.3 / | 14104.2 / | 6159.16 (kg/shell) | | |

**Baffle Information**

| | | | | | | |
|---|---|---|---|---|---|---|
| Type | Parallel | Single-Seg. | Baffle cut (% dia) | 26.00 | | |
| Crosspasses/shellpass | | 12 | No. | (Pct Area) | (mm) to C.L | |
| Central spacing | (mm) | 470.000 | 1 | 21.38 | 272.400 | |
| Inlet/Outlet Spacing | (mm) | 1220.00 | 2 | 0.00 | 0.000 | |
| Turn Spacing | (mm) | 657.335 | | | | |
| Baffle thickness | (mm) | 12.700 | Long. baffle length | (mm) | 5920. | |
| Insulated long baffle | | Yes | | | | |

**Tube Information**

| | | | | | |
|---|---|---|---|---|---|
| Tube type | | Plain | Tubecount per shell | | 476 |
| Length to tangent | (mm) | 6096. | Pct tubes removed (both) | | 1.26 |
| Effective length | (mm) | 6347. | Outside diameter | (mm) | 31.750 |
| Total tubesheet | (mm) | 120.000 | Wall thickness | (mm) | 2.110 |
| Area ratio | (out/in) | 1.1533 | Pitch (mm) | 39.6900 Ratio | 1.2501 |
| Tube metal | Carbon steel | | Tube pattern (deg) | | 45 |

**Shellside Performance**

Nom vel, X-flow/window 0.74 / 0.80

Flow fractions for heat transfer 0.759

A=0.0183 B=0.7290 C=0.0455 E=0.1424 F=0.0648

**Shellside Heat Transfer Corrections**

| Total | Beta | Gamma | End | Fin |
|---|---|---|---|---|
| 0.986 | 0.920 | 1.072 | 0.921 | 1.000 |

**Pressure Drops (Percent of Total)**

| Cross | Window | Ends | Nozzle | Shell | Tube |
|---|---|---|---|---|---|
| 60.87 | 26.06 | 9.24 | Inlet | 1.93 | 2.70 |
| MOMENTUM | | 0.00 | Outlet | 1.90 | 1.70 |

**Two-Phase Parameters**

| Method | Inlet | Center | Outlet | Mix F |
|---|---|---|---|---|

**H. T. Parameters**

| | | Shell | Tube |
|---|---|---|---|
| Overall wall correction | | 1.016 | 0.997 |
| Midpoint | Prandtl no. | 21.09 | 1.99 |
| Midpoint | Reynolds no. | 8671 | 140382 |
| Bundle inlet | Reynolds no. | 3846 | 152135 |
| Bundle outlet | Reynolds no. | 7245 | 127172 |
| Fouling layer | (mm) | | |

**Thermal Resistance**

| Shell | Tube | Fouling | Metal | Over Des |
|---|---|---|---|---|
| 45.53 | 14.71 | 35.04 | 4.71 | 6.45 |

Total fouling resistance 2.908e-4

Differential resistance 5.352e-5

**Shell Nozzles**

| | | Inlet | Outlet | Liquid Outlet |
|---|---|---|---|---|
| Inlet at channel end-Yes | | | | |
| Number at each position | | 1 | 1 | 0 |
| Diameter | (mm) | 295.301 | 295.301 | |
| Velocity | (m/s) | 0.79 | 0.80 | |
| Pressure drop | (kPa) | 1.010 | 0.992 | |
| Height under nozzle | (mm) | 37.149 | 37.149 | |
| Nozzle R-V-SQ | (kg/m-s2) | 653.80 | 662.81 | |
| Shell ent. | (kg/m-s2) | 1530.45 | 1551.53 | |

| Tube Nozzle | | Inlet | Outlet | Liquid Outlet |
|---|---|---|---|---|
| | | RADIAL | RADIAL | |
| Diameter | (mm) | 193.675 | 193.675 | |
| Velocity | (m/s) | 2.03 | 2.02 | |
| Pressure drop | (kPa) | 2.191 | 1.381 | |
| Nozzle R-V-SQ | (kg/m-s2) | 3983.26 | 3946.36 | |

| Annular Distributor | | Inlet | Outlet |
|---|---|---|---|
| Length | (mm) | | |
| Height | (mm) | | |
| Slot area | (mm2) | | |

**Diametral Clearances (mm)**

| Baffle-to-shell | Bundle-to-shell | Tube-to-baffle |
|---|---|---|
| 6.3500 | 17.8000 | 0.3969 |

## Final Results

Released to the following HTRI Member Company:

*sewon*

*M.K.Park*

Xist Ver. 6.00 SP3 2013/09/13 10:47 SN: 1500213869 **MEG Energy Units**

Max.Duty Case : Shell 2

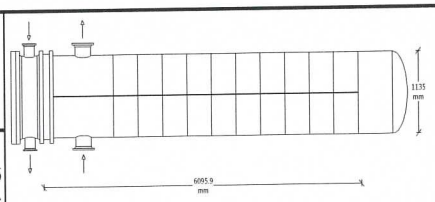
Rating - Horizontal Multipass Flow TEMA AFU Shell With Single-Segmental Baffles

| Process Data | | Cold Shellside | | Hot Tubeside | |
|---|---|---|---|---|---|
| Fluid name | | TEG/Water(60/40 wt%) | | MP Blowdown | |
| Fluid condition | | | Sens. Liquid | | Sens. Liquid |
| Total flow rate | (kg/hr) | | 205102 | | 207611 |
| Weight fraction vapor, In/Out | (--) | 0.000 | 0.000 | 0.000 | 0.000 |
| Temperature, In/Out | (Deg C) | 40.00 | 65.97 | 80.01 | 60.00 |
| Temperature, Average/Skin | (Deg C) | 52.98 | 61.77 | 70.01 | 67.49 |
| Wall temperature, Min/Max | (Deg C) | 51.95 | 74.91 | 52.78 | 75.42 |
| Pressure, In/Average | (kPa) | 994.015 | 966.570 | 1373.81 | 1332.67 |
| Pressure drop, Total/Allowed | (kPa) | 54.890 | 120.000 | 82.272 | 165.000 |
| Velocity, Mid/Max allow | (m/s) | 0.61 | | 1.67 | |
| Mole fraction inert | (--) | | | | |
| Average film coef. | (W/m2-K) | | 2329.27 | | 8557.15 |
| Heat transfer safety factor | (--) | | 1.000 | | 1.000 |
| Fouling resistance | (m2-K/W) | | 0.000088 | | 0.000176 |

**Overall Performance Data**

| | | | | |
|---|---|---|---|---|
| Overall coef., Reqd/Clean/Actual | (W/m2-K) | 1053.54 / | 1658.92 / | 1118.84 |
| Heat duty, Calculated/Specified | (kW) | 4836. / | | |
| Effective overall temperature difference | (Deg C) | 15.2 | | |
| EMTD = (MTD) * (DELTA) * (F/G/H) | (Deg C) | 15.45 * | 0.9856 * | 1.0000 |

**See Runtime Messages Report for warnings.**




**Exchanger Fluid Volumes**

| | | |
|---|---|---|
| Approximate shellside | (L) | 3609.5 |
| Approximate tubeside | (L) | 3718.6 |

**Shell Construction Information**

| | | | | | |
|---|---|---|---|---|---|
| TEMA shell type | AFU | | Shell ID | (mm) | 1135.00 |
| Shells Series | 1 Parallel | 1 | Total area | (m2) | 307.037 |
| Passes Shell | 2 Tube | 8 | Eff. area | (m2/shell) | 301.340 |
| Shell orientation angle (deg) | 0.00 | | | | |
| Impingement present | No | | | | |
| Pairs seal strips | 0 | | Passlane seal rods (mm) | 31.750 | No. 0 |
| Shell expansion joint | No | | Full support at U-Bend | No | |
| Weight estimation Wet/Dry/Bundle | 21430.8 / | 14107.7 / | 6162.61 (kg/shell) | | |

**Baffle Information**

| | | | | | |
|---|---|---|---|---|---|
| Type | Parallel | Single-Seg. | Baffle cut (% dia) | 26.00 | |
| Crosspasses/shellpass | | 12 | No. | (Pct Area) | (mm) to C.L |
| Central spacing | (mm) | 470.000 | 1 | 21.38 | 272.400 |
| Inlet/Outlet Spacing | (mm) | 1220.00 | 2 | 0.00 | 0.000 |
| Turn Spacing | (mm) | 654.046 | | | |
| Baffle thickness | (mm) | 12.700 | Long. baffle length | (mm) | 5920. |
| Insulated long baffle | | Yes | | | |

**Tube Information**

| | | | | | |
|---|---|---|---|---|---|
| Tube type | | Plain | Tubecount per shell | | 476 |
| Length to tangent | (mm) | 6096. | Pct tubes removed (both) | | 1.26 |
| Effective length | (mm) | 6347. | Outside diameter | (mm) | 31.750 |
| Total tubesheet | (mm) | 120.000 | Wall thickness | (mm) | 2.110 |
| Area ratio | (out/in) | 1.1533 | Pitch (mm) | 39.6900 Ratio | 1.2501 |
| Tube metal | Carbon steel | | Tube pattern (deg) | | 45 |

**Shellside Performance**

Nom vel, X-flow/window 0.73 / 0.79

Flow fractions for heat transfer 0.764

A=0.0127 B=0.7368 C=0.0438 E=0.1456 F=0.0612

**Shellside Heat Transfer Corrections**

| Total | Beta | Gamma | End | Fin |
|---|---|---|---|---|
| 0.986 | 0.920 | 1.072 | 0.922 | 1.000 |

**Pressure Drops (Percent of Total)**

| Cross | Window | Ends | Nozzle | Shell | Tube |
|---|---|---|---|---|---|
| 61.54 | 25.50 | 9.20 | Inlet | 1.92 | 2.64 |
| MOMENTUM | | 0.00 | Outlet | 1.84 | 1.66 |

**Two-Phase Parameters**

| Method | Inlet | Center | Outlet | Mix F |
|---|---|---|---|---|

**H. T. Parameters**

| | | Shell | Tube |
|---|---|---|---|
| Overall wall correction | | 1.027 | 0.994 |
| Midpoint | Prandtl no. | 33.48 | 2.53 |
| Midpoint | Reynolds no. | 5452 | 112397 |
| Bundle inlet | Reynolds no. | 2447 | 126531 |
| Bundle outlet | Reynolds no. | 4592 | 97121 |
| Fouling layer | (mm) | | |

**Thermal Resistance**

| Shell | Tube | Fouling | Metal | Over Des |
|---|---|---|---|---|
| 48.03 | 15.08 | 32.56 | 4.33 | 6.20 |
| Total fouling resistance | | | | 2.908e-4 |
| Differential resistance | | | | 5.54e-5 |

**Shell Nozzles**

| | | Inlet | Outlet | Liquid Outlet |
|---|---|---|---|---|
| Inlet at channel end-Yes | | | | |
| Number at each position | | 1 | 1 | 0 |
| Diameter | (mm) | 295.301 | 295.301 | |
| Velocity | (m/s) | 0.77 | 0.79 | |
| Pressure drop | (kPa) | 1.053 | 1.010 | |
| Height under nozzle | (mm) | 37.149 | 37.149 | |
| Nozzle R-V-SQ | (kg/m-s2) | 641.90 | 653.80 | |
| Shell ent. | (kg/m-s2) | 1502.60 | 1530.45 | |

**Tube Nozzle**

| | | Inlet | Outlet | Liquid Outlet |
|---|---|---|---|---|
| | | RADIAL | RADIAL | |
| Diameter | (mm) | 193.675 | 193.675 | |
| Velocity | (m/s) | 2.02 | 1.99 | |
| Pressure drop | (kPa) | 2.171 | 1.365 | |
| Nozzle R-V-SQ | (kg/m-s2) | 3946.37 | 3898.16 | |

**Annular Distributor**

| | | Inlet | Outlet |
|---|---|---|---|
| Length | (mm) | | |
| Height | (mm) | | |
| Slot area | (mm2) | | |

**Diametral Clearances (mm)**

| Baffle-to-shell | Bundle-to-shell | Tube-to-baffle |
|---|---|---|
| 6.3500 | 17.8000 | 0.3969 |

# 3A-E-325A/B (Min Duty Case)

The Thermal/Hydraulic/Vibration calculations are perfomed by using HTRI Xist Ver. 6.00 SP3.

The process condiiton and the physical properties are based on Buyer DATA SHEET (2).

For the design result ( the geometry data), please refer to the Equopment DATA SHEET (2) and Fabrication drawing.

1. Thermal and Hydraulic performance

| | | | | | | |
|---|---|---|---|---|---|---|
| - Thermal performance : | | **27.57** | % Over - Design Case | | ---------- | O.K. |
| - Pressure drop : | | | | | | |
| | Shell-side | **62.465** | < | **100.000 kPa** | ---------- | O.K |
| | tube-side | **93.264** | < | **100.000 kPa** | ---------- | O.K |

2

2. Vibration Analysis

| | | | | | |
|---|---|---|---|---|---|
| - Fluidelastid instability : | characteristic values | << | criteria | ---------- | O.K. |
| - Acoustic vibration : | characteristic values | << | criteria | ---------- | O.K. |
| - Tube vibration check: | characteristic values | << | criteria | ---------- | O.K. |
| - Bundle Entrance/Exit : | characteristic values | << | criteria | ---------- | O.K. |
| - Shell Entrance /Exit: | characteristic values | << | criteria | ---------- | O.K. |

# 3A-E-325A/B (Min Duty Case) - Shell 1

Used Program : HTRI Xist Ver.6.00 SP.3 Vibration Analysis

| VALUE TO BE CHECKED | Inlet | Center | U-Bend | RECOMMEND LIMIT | CONCLUSION |
|---|---|---|---|---|---|
| Unsupported span (mm) | 1690. | 940. | 897. | 2235 (By TEMA) | O.K |
| Length / TEMA maximum span | 0.756 | 0.421 | 0.475 | < 1.0 TEMA | O.K |
| Fluidelastic Instability Check | | | | | |
| Baffle tip cross velocity ratio | 0.0785 | 0.0664 | 0.1481 | < 0.8 | O.K |
| Ave. crossflow velocity ratio | 0.0735 | 0.0621 | 0.1386 | < 0.8 | O.K |
| Acoustic Vibration Check | | | | | |
| Vortex shedding ratio | - | - | - | - | - |
| Tubulent buffeting ratio | - | - | - | - | - |
| Tube Vibration Check | | | | | |
| Vortex shedding ratio | 0.059 | 0.158 | 0.140 | < 0.5 | O.K |
| Tubulent buffeting ratio | - | - | - | - | - |
| Bundle Entance / Exit | | Entrance | Exit | | |
| Fluidelastic Instability ratio | | 0.118 | 0.120 | < 0.8 | O.K |
| Vortex shedding ratio | | 0.145 | 0.147 | < 0.5 | O.K |
| Shell Entrance / Exit | | | | | |
| Velocity (m/sec) | | 0.90 | 0.91 | < If velocity is exceed 2.38 / 2.39 | O.K. |
| ρv2 (kg/m-s2) | | 851.35 | 863.11 | < 5953 by TEMA | O.K. |

# Vibration Analysis

Released to the following HTRI Member Company:

*sewon*
*M.K.Park*

Xist Ver. 6.00 SP3 2013/09/13 10:48 SN: 1500213869 — **MEG Energy Units**

Min.Duty Case : Shell 1
Rating - Horizontal Multipass Flow TEMA AFU Shell With Single-Segmental Baffles

| | | | | | |
|---|---|---|---|---|---|
| 1 | Shellside condition | | Sens. Liquid | (Level 2.3) | |
| 2 | Axial stress loading | (MPa) | 0.000 | Added mass factor | 1.517 |
| 3 | Beta | | 3.745 | | |
| 4 | **Position In The Bundle** | | **Inlet** | **Center** | **U-Bend** |
| 5 | Length for natural frequency | (mm) | 1690. | 940. | 897. |
| 6 | Length/TEMA maximum span | (--) | 0.756 | 0.421 | 0.475 |
| 7 | Number of spans | (--) | 6 | 6 | 2 |
| 8 | Tube natural frequency | (Hz) | 35.6 | 68.6 | 28.2 + |
| 9 | Shell acoustic frequency | (Hz) | | | |
| 10 | **Flow Velocities** | | **Inlet** | **Center** | **U-Bend** |
| 11 | Window parallel velocity | (m/s) | 0.61 | 0.61 | 0.61 |
| 12 | Bundle crossflow velocity | (m/s) | 0.11 | 0.31 | 0.22 |
| 13 | Bundle/shell velocity | (m/s) | 9.731e-2 | 0.26 | 0.18 |
| 14 | **Fluidelastic Instability Check** | | **Inlet** | **Center** | **U-Bend** |
| 15 | Log decrement | HTRI | 0.100 | 0.096 | 0.100 |
| 16 | Critical velocity | (m/s) | 2.38 | 7.56 | 2.39 |
| 17 | Baffle tip cross velocity ratio | (--) | 0.0785 | 0.0664 | 0.1481 |
| 18 | Average crossflow velocity ratio | (--) | 0.0735 | 0.0621 | 0.1386 |
| 19 | **Acoustic Vibration Check** | | **Inlet** | **Center** | **U-Bend** |
| 20 | Vortex shedding ratio | (--) | | | |
| 21 | Chen number | (--) | | | |
| 22 | Turbulent buffeting ratio | (--) | | | |
| 23 | **Tube Vibration Check** | | **Inlet** | **Center** | **U-Bend** |
| 24 | Vortex shedding ratio | (--) | 0.059 | 0.158 | 0.140 |
| 25 | Parallel flow amplitude | (mm) | 0.002 | 0.001 | 0.009 |
| 26 | Crossflow amplitude | (mm) | 0.005 | 0.004 | 0.002 |
| 27 | Tube gap | (mm) | 7.940 | 7.940 | 7.940 |
| 28 | Crossflow RHO-V-SQ | (kg/m-s2) | 32.38 | 232.01 | 114.90 |
| 29 | **Bundle Entrance/Exit** | | | | |
| 30 | **(analysis at first tube row)** | | | **Entrance** | **Exit** |
| 31 | Fluidelastic instability ratio | | (--) | 0.118 | 0.120 |
| 32 | Vortex shedding ratio | | (--) | 0.145 | 0.147 |
| 33 | Crossflow amplitude | | (mm) | 0.03359 | 0.03431 |
| 34 | Crossflow velocity | | (m/s) | 0.28 | 0.29 |
| 35 | Tubesheet to inlet/outlet support | | (mm) | None | None |
| 36 | **Shell Entrance/Exit Parameters** | | | **Entrance** | **Exit** |
| 37 | Impingement plate | | | No | |
| 38 | Flow area | | (m2) | 0.045 | 0.045 |
| 39 | Velocity | | (m/s) | 0.90 | 0.91 |
| 40 | RHO-V-SQ | | (kg/m-s2) | 851.35 | 863.11 |

| | | | | |
|---|---|---|---|---|
| 41 | Shell type | AFU | Baffle type | Single-Seg. |
| 42 | Tube type | Plain | Baffle layout | Parallel |
| 43 | Pitch ratio | 1.2501 | Tube diameter, (mm) | 31.750 |
| 44 | Layout angle | 45 | Tube material | Carbon steel |
| 45 | Number U-Bend supports | 1 | Supports/baffle space | |

46 **Program Messages**

47 + Frequency ratios are based upon lowest natural or acoustic frequency
48 * Items with asterisk exceed a conservative lower limit for vibration-free design. Review your case
49 using the procedure described in Online Help; You may find that a vibration problem is unlikely.
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# 3A-E-325A/B (Min Duty Case) - Shell 2

Used Program : HTRI Xist Ver.6.00 SP.3 Vibration Analysis

| VALUE TO BE CHECKED | Inlet | Center | U-Bend | RECOMMEND LIMIT | CONCLUSION |
|---|---|---|---|---|---|
| Unsupported span (mm) | 1690. | 940. | 897. | 2235 (By TEMA) | O.K |
| Length / TEMA maximum span | 0.756 | 0.421 | 0.475 | < 1.0 TEMA | O.K |
| Fluidelastic Instability Check | | | | | |
| Baffle tip cross velocity ratio | 0.0781 | 0.0648 | 0.1482 | < 0.8 | O.K |
| Ave. crossflow velocity ratio | 0.0730 | 0.0607 | 0.1387 | < 0.8 | O.K |
| Acoustic Vibration Check | | | | | |
| Vortex shedding ratio | - | - | - | - | - |
| Tubulent buffeting ratio | - | - | - | - | - |
| Tube Vibration Check | | | | | |
| Vortex shedding ratio | 0.058 | 0.156 | 0.139 | < 0.5 | O.K |
| Tubulent buffeting ratio | - | - | - | - | - |
| Bundle Entance / Exit | | Entrance | Exit | | |
| Fluidelastic Instability ratio | | 0.117 | 0.119 | < 0.8 | O.K |
| Vortex shedding ratio | | 0.143 | 0.146 | < 0.5 | O.K |
| Shell Entrance / Exit | | | | | |
| Velocity (m/sec) | | 0.88 | 0.90 | < If velocity is exceed 2.36 / 2.37 | O.K. |
| ρv2 (kg/m-s2) | | 835.88 | 851.35 | < 5953 by TEMA | O.K. |

# Vibration Analysis

Released to the following HTRI Member Company:

*sewon*
*M.K.Park*

Xist Ver. 6.00 SP3 2013/09/13 10:48 SN: 1500213869

MEG Energy Units

Min.Duty Case : Shell 2
Rating - Horizontal Multipass Flow TEMA AFU Shell With Single-Segmental Baffles

| | | | | | |
|---|---|---|---|---|---|
| 1 | Shellside condition | | Sens. Liquid | (Level 2.3) | |
| 2 | Axial stress loading | (MPa) | 0.000 | Added mass factor | 1.517 |
| 3 | Beta | | 3.745 | | |
| 4 | **Position In The Bundle** | | **Inlet** | **Center** | **U-Bend** |
| 5 | Length for natural frequency | (mm) | 1690. | 940. | 897. |
| 6 | Length/TEMA maximum span | (--) | 0.756 | 0.421 | 0.475 |
| 7 | Number of spans | (--) | 6 | 6 | 2 |
| 8 | Tube natural frequency | (Hz) | 35.5 | 68.5 | 28.2 + |
| 9 | Shell acoustic frequency | (Hz) | | | |
| 10 | **Flow Velocities** | | **Inlet** | **Center** | **U-Bend** |
| 11 | Window parallel velocity | (m/s) | 0.60 | 0.60 | 0.60 |
| 12 | Bundle crossflow velocity | (m/s) | 0.11 | 0.30 | 0.21 |
| 13 | Bundle/shell velocity | (m/s) | 9.999e-2 | 0.27 | 0.19 |
| 14 | **Fluidelastic Instability Check** | | **Inlet** | **Center** | **U-Bend** |
| 15 | Log decrement | HTRI | 0.100 | 0.100 | 0.100 |
| 16 | Critical velocity | (m/s) | 2.36 | 7.66 | 2.37 |
| 17 | Baffle tip cross velocity ratio | (--) | 0.0781 | 0.0648 | 0.1482 |
| 18 | Average crossflow velocity ratio | (--) | 0.0730 | 0.0607 | 0.1387 |
| 19 | **Acoustic Vibration Check** | | **Inlet** | **Center** | **U-Bend** |
| 20 | Vortex shedding ratio | (--) | | | |
| 21 | Chen number | (--) | | | |
| 22 | Turbulent buffeting ratio | (--) | | | |
| 23 | **Tube Vibration Check** | | **Inlet** | **Center** | **U-Bend** |
| 24 | Vortex shedding ratio | (--) | 0.058 | 0.156 | 0.139 |
| 25 | Parallel flow amplitude | (mm) | 0.002 | 0.001 | 0.009 |
| 26 | Crossflow amplitude | (mm) | 0.005 | 0.004 | 0.002 |
| 27 | Tube gap | (mm) | 7.940 | 7.940 | 7.940 |
| 28 | Crossflow RHO-V-SQ | (kg/m-s2) | 32.14 | 230.81 | 115.47 |
| 29 | **Bundle Entrance/Exit** | | | | |
| 30 | **(analysis at first tube row)** | | | **Entrance** | **Exit** |
| 31 | Fluidelastic instability ratio | | (--) | 0.117 | 0.119 |
| 32 | Vortex shedding ratio | | (--) | 0.143 | 0.146 |
| 33 | Crossflow amplitude | | (mm) | 0.03282 | 0.03377 |
| 34 | Crossflow velocity | | (m/s) | 0.28 | 0.28 |
| 35 | Tubesheet to inlet/outlet support | | (mm) | None | None |
| 36 | **Shell Entrance/Exit Parameters** | | | **Entrance** | **Exit** |
| 37 | Impingement plate | | | No | |
| 38 | Flow area | | (m2) | 0.045 | 0.045 |
| 39 | Velocity | | (m/s) | 0.88 | 0.90 |
| 40 | RHO-V-SQ | | (kg/m-s2) | 835.88 | 851.35 |

| | | | | |
|---|---|---|---|---|
| 41 | Shell type | AFU | Baffle type | Single-Seg. |
| 42 | Tube type | Plain | Baffle layout | Parallel |
| 43 | Pitch ratio | 1.2501 | Tube diameter, (mm) | 31.750 |
| 44 | Layout angle | 45 | Tube material | Carbon steel |
| 45 | Number U-Bend supports | 1 | Supports/baffle space | |

46 **Program Messages**

47 + Frequency ratios are based upon lowest natural or acoustic frequency
48 * Items with asterisk exceed a conservative lower limit for vibration-free design. Review your case
49 using the procedure described in Online Help; You may find that a vibration problem is unlikely.
50
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## Final Results

Released to the following HTRI Member Company:

*sewon*

*M.K.Park*

Xist Ver. 6.00 SP3 2013/09/13 10:48 SN: 1500213869

**MEG Energy Units**

Min.Duty Case : Shell 1

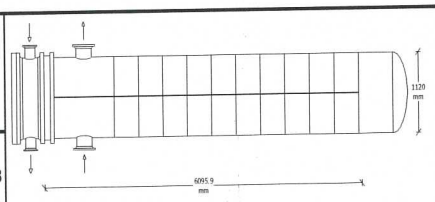
Rating - Horizontal Multipass Flow TEMA AFU Shell With Single-Segmental Baffles

| Process Data | | Cold Shellside | | Hot Tubeside | |
|---|---|---|---|---|---|
| Fluid name | | TEG/Water(60/40 wt%) | | MP Blowdown | |
| Fluid condition | | | Sens. Liquid | | Sens. Liquid |
| Total flow rate | (kg/hr) | | 152546 | | 154412 |
| Weight fraction vapor, In/Out | (--) | 0.000 | 0.000 | 0.000 | 0.000 |
| Temperature, In/Out | (Deg C) | 65.93 | 85.00 | 95.00 | 79.98 |
| Temperature, Average/Skin | (Deg C) | 75.46 | 81.67 | 87.49 | 85.54 |
| Wall temperature, Min/Max | (Deg C) | 74.14 | 91.36 | 74.72 | 91.71 |
| Pressure, In/Average | (kPa) | 962.140 | 946.846 | 1455.02 | 1431.88 |
| Pressure drop, Total/Allowed | (kPa) | 30.590 | 100.000 | 46.281 | 100.000 |
| Velocity, Mid/Max allow | (m/s) | 0.47 | | 1.25 | |
| Mole fraction inert | (--) | | | | |
| Average film coef. | (W/m2-K) | | 2258.20 | | 7467.84 |
| Heat transfer safety factor | (--) | | 1.000 | | 1.000 |
| Fouling resistance | (m2-K/W) | | 0.000088 | | 0.000176 |

**Overall Performance Data**

| | | | | |
|---|---|---|---|---|
| Overall coef., Reqd/Clean/Actual | (W/m2-K) | 843.17 / | 1571.43 / | 1078.34 |
| Heat duty, Calculated/Specified | (kW) | 2708. / | | |
| Effective overall temperature difference | (Deg C) | 10.7 | | |
| EMTD = (MTD) * (DELTA) * (F/G/H) | (Deg C) | 10.83 * | 0.9849 * | 1.0000 |

**See Runtime Messages Report for warnings.**




**Exchanger Fluid Volumes**

| | | |
|---|---|---|
| Approximate shellside | (L) | 3456.3 |
| Approximate tubeside | (L) | 3655.1 |

**Shell Construction Information**

| | | | | | |
|---|---|---|---|---|---|
| TEMA shell type | AFU | | Shell ID | (mm) | 1120.00 |
| Shells Series | 1 Parallel | 1 | Total area | (m2) | 306.801 |
| Passes Shell | 2 Tube | 8 | Eff. area | (m2/shell) | 301.103 |
| Shell orientation angle (deg) | 0.00 | | | | |
| Impingement present | No | | | | |
| Pairs seal strips | 0 | | Passlane seal rods (mm) | 31.750 | No. 0 |
| Shell expansion joint | No | | Full support at U-Bend | | No |
| Weight estimation Wet/Dry/Bundle | 20971.0 / | 13864.3 / | 6097.24 (kg/shell) | | |

**Baffle Information**

| | | | | | | |
|---|---|---|---|---|---|---|
| Type | Parallel | Single-Seg. | Baffle cut (% dia) | 26.00 | | |
| Crosspasses/shellpass | | 12 | No. | (Pct Area) | (mm) to C.L | |
| Central spacing | (mm) | 470.000 | 1 | 21.42 | 268.800 | |
| Inlet/Outlet Spacing | (mm) | 1220.00 | 2 | 0.00 | 0.000 | |
| Turn Spacing | (mm) | 649.835 | | | | |
| Baffle thickness | (mm) | 12.700 | Long. baffle length | (mm) | 5920. | |
| Insulated long baffle | | Yes | | | | |

**Tube Information**

| | | | | | |
|---|---|---|---|---|---|
| Tube type | | Plain | Tubecount per shell | | 476 |
| Length to tangent | (mm) | 6096. | Pct tubes removed (both) | | 1.26 |
| Effective length | (mm) | 6342. | Outside diameter | (mm) | 31.750 |
| Total tubesheet | (mm) | 120.000 | Wall thickness | (mm) | 2.110 |
| Area ratio | (out/in) | 1.1533 | Pitch (mm) | 39.6900 Ratio | 1.2501 |
| Tube metal | Carbon steel | | Tube pattern (deg) | | 45 |

**Shellside Performance**

Nom vel, X-flow/window 0.56 / 0.62

Flow fractions for heat transfer 0.763

A=0.0146 B=0.7347 C=0.0436 E=0.1429 F=0.0644

**Shellside Heat Transfer Corrections**

| Total | Beta | Gamma | End | Fin |
|---|---|---|---|---|
| 0.986 | 0.920 | 1.072 | 0.921 | 1.000 |

**Pressure Drops (Percent of Total)**

| Cross | Window | Ends | Nozzle | Shell | Tube |
|---|---|---|---|---|---|
| 59.42 | 27.28 | 9.56 | Inlet | 1.89 | 2.62 |
| MOMENTUM | | 0.00 | Outlet | 1.85 | 1.65 |

**Two-Phase Parameters**

| Method | Inlet | Center | Outlet | Mix F |
|---|---|---|---|---|

**H. T. Parameters**

| | | Shell | Tube |
|---|---|---|---|
| Overall wall correction | | 1.017 | 0.996 |
| Midpoint | Prandtl no. | 21.10 | 2.00 |
| Midpoint | Reynolds no. | 6689 | 104379 |
| Bundle inlet | Reynolds no. | 2919 | 113151 |
| Bundle outlet | Reynolds no. | 5562 | 94545 |
| Fouling layer | (mm) | | |

**Thermal Resistance**

| Shell | Tube | Fouling | Metal | Over Des |
|---|---|---|---|---|
| 47.75 | 16.65 | 31.38 | 4.22 | 27.89 |
| Total fouling resistance | | | | 2.908e-4 |
| Differential resistance | | | | 2.586e-4 |

**Shell Nozzles**

| | | Inlet | Outlet | Liquid Outlet |
|---|---|---|---|---|
| Inlet at channel end-Yes | | | | |
| Number at each position | | 1 | 1 | 0 |
| Diameter | (mm) | 295.301 | 295.301 | |
| Velocity | (m/s) | 0.58 | 0.59 | |
| Pressure drop | (kPa) | 0.577 | 0.564 | |
| Height under nozzle | (mm) | 37.149 | 37.149 | |
| Nozzle R-V-SQ | (kg/m-s2) | 361.65 | 366.65 | |
| Shell ent. | (kg/m-s2) | 851.35 | 863.11 | |

**Tube Nozzle**

| | | Inlet | Outlet | Liquid Outlet |
|---|---|---|---|---|
| | | RADIAL | RADIAL | |
| Diameter | (mm) | 193.675 | 193.675 | |
| Velocity | (m/s) | 1.51 | 1.50 | |
| Pressure drop | (kPa) | 1.212 | 0.764 | |
| Nozzle R-V-SQ | (kg/m-s2) | 2203.42 | 2182.98 | |

**Annular Distributor**

| | | Inlet | Outlet |
|---|---|---|---|
| Length | (mm) | | |
| Height | (mm) | | |
| Slot area | (mm2) | | |

**Diametral Clearances (mm)**

| Baffle-to-shell | Bundle-to-shell | Tube-to-baffle |
|---|---|---|
| 6.3500 | 17.8000 | 0.3969 |

## Final Results

Released to the following HTRI Member Company:

*sewon*

*M.K.Park*

Xist Ver. 6.00 SP3 2013/09/13 10:48 SN: 1500213869 **MEG Energy Units**

Min.Duty Case : Shell 2

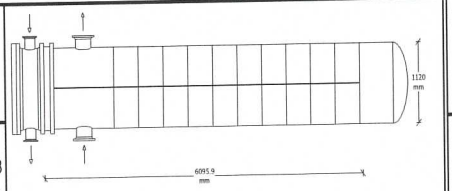
Rating - Horizontal Multipass Flow TEMA AFU Shell With Single-Segmental Baffles

| Process Data | | Cold Shellside | | Hot Tubeside | |
|---|---|---|---|---|---|
| Fluid name | | TEG/Water(60/40 wt%) | | MP Blowdown | |
| Fluid condition | | | Sens. Liquid | | Sens. Liquid |
| Total flow rate | (kg/hr) | | 152546 | | 154412 |
| Weight fraction vapor, In/Out | (--) | 0.000 | 0.000 | 0.000 | 0.000 |
| Temperature, In/Out | (Deg C) | 40.00 | 65.93 | 79.98 | 60.00 |
| Temperature, Average/Skin | (Deg C) | 52.96 | 62.08 | 69.99 | 67.18 |
| Wall temperature, Min/Max | (Deg C) | 52.10 | 75.07 | 52.85 | 75.53 |
| Pressure, In/Average | (kPa) | 994.015 | 978.077 | 1408.76 | 1385.27 |
| Pressure drop, Total/Allowed | (kPa) | 31.875 | 100.000 | 46.982 | 100.000 |
| Velocity, Mid/Max allow | (m/s) | 0.47 | | 1.24 | |
| Mole fraction inert | (--) | | | | |
| Average film coef. | (W/m2-K) | | 1984.80 | | 6767.50 |
| Heat transfer safety factor | (--) | | 1.000 | | 1.000 |
| Fouling resistance | (m2-K/W) | | 0.000088 | | 0.000176 |

**Overall Performance Data**

| | | | | | | |
|---|---|---|---|---|---|---|
| Overall coef., Reqd/Clean/Actual | (W/m2-K) | 782.90 | / | 1402.62 | / | 996.08 |
| Heat duty, Calculated/Specified | (kW) | 3591. | / | | | |
| Effective overall temperature difference | (Deg C) | 15.2 | | | | |
| EMTD = (MTD) * (DELTA) * (F/G/H) | (Deg C) | 15.46 | * | 0.9856 | * | 1.0000 |

**See Runtime Messages Report for warnings.**




**Exchanger Fluid Volumes**

| | | |
|---|---|---|
| Approximate shellside | (L) | 3456.3 |
| Approximate tubeside | (L) | 3655.1 |

**Shell Construction Information**

| | | | | | |
|---|---|---|---|---|---|
| TEMA shell type | AFU | | Shell ID | (mm) | 1120.00 |
| Shells Series | 1 Parallel | 1 | Total area | (m2) | 306.801 |
| Passes Shell | 2 Tube | 8 | Eff. area | (m2/shell) | 301.103 |
| Shell orientation angle (deg) | 0.00 | | | | |
| Impingement present | No | | | | |
| Pairs seal strips | 0 | | Passlane seal rods (mm) | 31.750 | No. 0 |
| Shell expansion joint | No | | Full support at U-Bend | | No |
| Weight estimation Wet/Dry/Bundle | 20974.4 | / 13867.8 / | 6100.67 | (kg/shell) | |

**Baffle Information**

| | | | | | | |
|---|---|---|---|---|---|---|
| Type | Parallel | Single-Seg. | Baffle cut (% dia) | 26.00 | | |
| Crosspasses/shellpass | | 12 | No. | (Pct Area) | (mm) to C.L | |
| Central spacing | (mm) | 470.000 | 1 | 21.42 | 268.800 | |
| Inlet/Outlet Spacing | (mm) | 1220.00 | 2 | 0.00 | 0.000 | |
| Turn Spacing | (mm) | 646.539 | | | | |
| Baffle thickness | (mm) | 12.700 | Long. baffle length | | (mm) | 5920. |
| Insulated long baffle | | Yes | | | | |

**Tube Information**

| | | | | | |
|---|---|---|---|---|---|
| Tube type | | Plain | Tubecount per shell | | 476 |
| Length to tangent | (mm) | 6096. | Pct tubes removed (both) | | 1.26 |
| Effective length | (mm) | 6342. | Outside diameter | (mm) | 31.750 |
| Total tubesheet | (mm) | 120.000 | Wall thickness | (mm) | 2.110 |
| Area ratio | (out/in) | 1.1533 | Pitch (mm) | 39.6900 Ratio | 1.2501 |
| Tube metal | Carbon steel | | Tube pattern (deg) | | 45 |

**Shellside Performance**

Nom vel, X-flow/window 0.55 / 0.61

Flow fractions for heat transfer 0.765

A=0.0099 B=0.7387 C=0.0456 E=0.1459 F=0.0599

**Shellside Heat Transfer Corrections**

| Total | Beta | Gamma | End | Fin |
|---|---|---|---|---|
| 0.986 | 0.920 | 1.072 | 0.922 | 1.000 |

**Pressure Drops (Percent of Total)**

| Cross | Window | Ends | Nozzle | Shell | Tube |
|---|---|---|---|---|---|
| 59.98 | 26.79 | 9.52 | Inlet | 1.90 | 2.56 |
| MOMENTUM | | 0.00 | Outlet | 1.81 | 1.61 |

**Two-Phase Parameters**

| Method | Inlet | Center | Outlet | Mix F |
|---|---|---|---|---|

**H. T. Parameters**

| | | Shell | Tube |
|---|---|---|---|
| Overall wall correction | | 1.028 | 0.994 |
| Midpoint | Prandtl no. | 33.50 | 2.53 |
| Midpoint | Reynolds no. | 4183 | 83563 |
| Bundle inlet | Reynolds no. | 1849 | 94072 |
| Bundle outlet | Reynolds no. | 3509 | 72231 |
| Fouling layer | (mm) | | |

**Thermal Resistance**

| Shell | Tube | Fouling | Metal | Over Des |
|---|---|---|---|---|
| 50.19 | 16.97 | 28.98 | 3.86 | 27.23 |

Total fouling resistance 2.908e-4

Differential resistance 2.734e-4

| Shell Nozzles | | Inlet | Outlet | Liquid Outlet |
|---|---|---|---|---|
| Inlet at channel end-Yes | | | | |
| Number at each position | | 1 | 1 | 0 |
| Diameter | (mm) | 295.301 | 295.301 | |
| Velocity | (m/s) | 0.57 | 0.58 | |
| Pressure drop | (kPa) | 0.605 | 0.577 | |
| Height under nozzle | (mm) | 37.149 | 37.149 | |
| Nozzle R-V-SQ | (kg/m-s2) | 355.08 | 361.65 | |
| Shell ent. | (kg/m-s2) | 835.88 | 851.35 | |

| Tube Nozzle | | Inlet | Outlet | Liquid Outlet |
|---|---|---|---|---|
| | | RADIAL | RADIAL | |
| Diameter | (mm) | 193.675 | 193.675 | |
| Velocity | (m/s) | 1.50 | 1.48 | |
| Pressure drop | (kPa) | 1.201 | 0.755 | |
| Nozzle R-V-SQ | (kg/m-s2) | 2182.98 | 2156.35 | |

| Annular Distributor | | Inlet | Outlet |
|---|---|---|---|
| Length | (mm) | | |
| Height | (mm) | | |
| Slot area | (mm2) | | |

**Diametral Clearances (mm)**

| Baffle-to-shell | Bundle-to-shell | Tube-to-baffle |
|---|---|---|
| 6.3500 | 17.8000 | 0.3969 |