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Unsteady State Relief Valve Evaluation

External Pool Fire Scenario

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Description of Problem

The following slides describe a special case encountered while performing a refinery relief valve evaluation project. A pool fire scenario is near a large bank of stacked horizontal heat exchangers used in a chiller unit. The solvent-oil mixture has a large boiling point variation. Also, these heat exchangers have a small liquid volume relative to their overall physical cylindrical volume size.

In this case Process Engineering Associates recognized that the normal API 520 and 521 standards would not accurately represent reality for a fire case relief scenario.

API Recommended Practice 520 & 521

(Design Pressure > 15 psig)

- Total Heat Absorbed (Btu/hr) from the fire
  - $Q = 21{,}000 * F * A^{0.82}$
    - F: environmental factor (insulation, earth covered, below grade storage...)
    - A: wetted surface area (ft^2)

- Fire Relief Requirement (lb/hr) = Q / H
  - H: latent heat of vaporization (Btu/lb)
- ASME Section VIII, Division 1

  Accumulated pressure limited to 121% of MAWP

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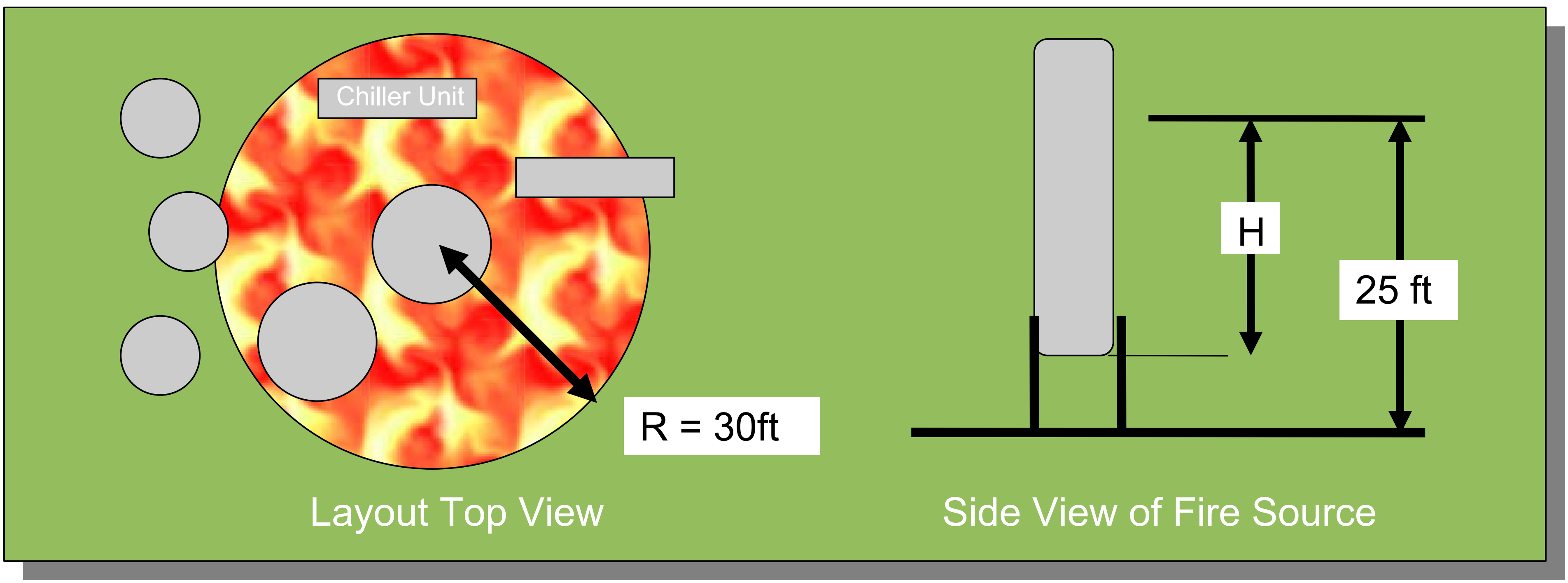
API RP 521: External Pool Fire

- Pool fire area – 2500 ft^2 (30 ft radius)
- Wetted surface area to a height of 25ft above the source of flame

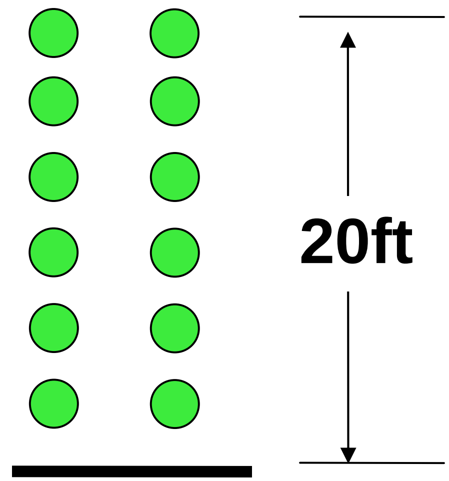


Description of Chiller to be Evaluated

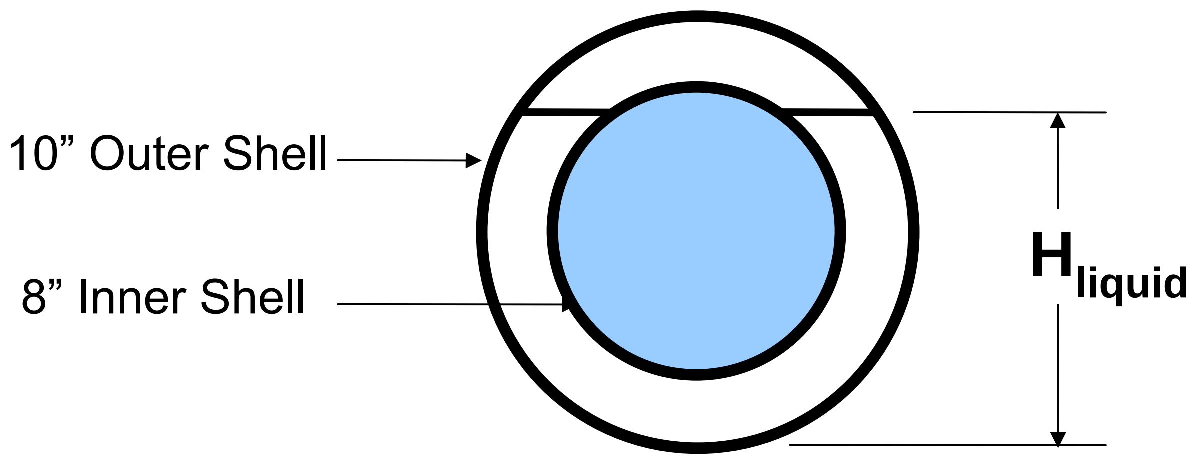
- Chiller – 12 double pipe exchangers
  - 10” outer pipe, 8” inner pipe, 42ft long
  - Arrangement: 2 columns x 6 rows
    - 20” spacing between rows
  - No steel enclosure or insulation jacketing
  - Shell side fluid: Wax Free Oil and Solvent
    - 80 vol% Solvent (MEK & Toluene)
  - Relief valve: 1D2 (0.11 in^2 orifice area) @ 400 psig

Chiller Layout

Chiller HX Stack End View



Cross Section of Individual Exchanger (liquid in annulus)



API Calculation

- Relieving pressure (121% MAWP) = 484 psig
- Total Surface area (12 exchangers) = 1418.4 ft^2
- Environmental credits – none, F =1
- $Q = 21000 * 1 * 1418.4^{0.82}$

  = 8.07 MMBtu/hr
- Latent Heat of Vaporization, H = 67.5 Btu/lb
- Fire Relief Requirement = 119,526 lb/hr (33.2 lb/s)

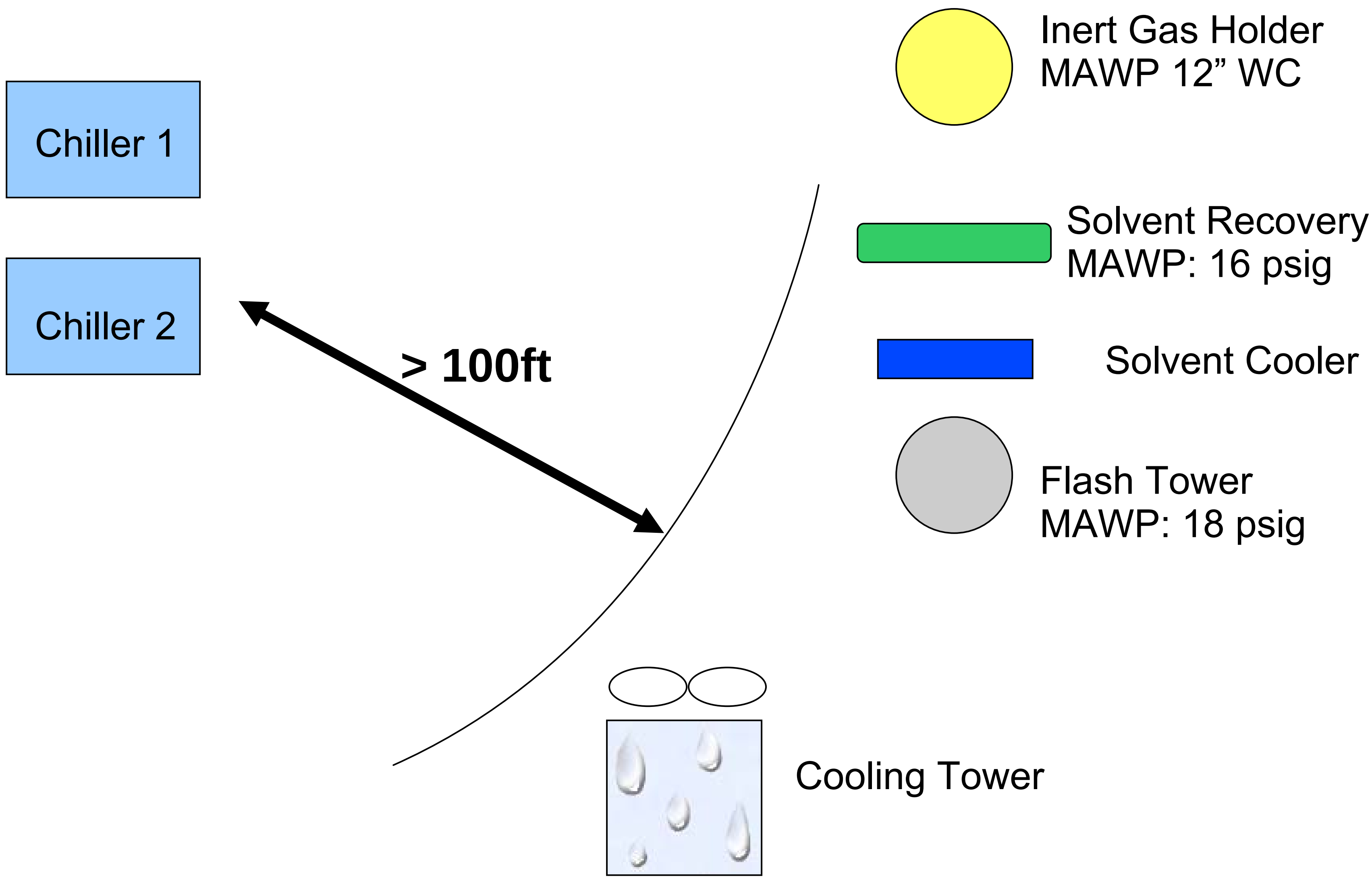
  Current relief valve (1D2) capacity is 6207 lb/hr

  Recommended valve size – 4L6 (2.853 in^2)

Alternative Relief Path

- An alternative relief path was evaluated through the 6" process piping.
- The process line ties into the inert gas header via the Flash Tower, the Solvent Cooler, and the Solvent Recovery Drum.
- The MEK Unit has a dedicated cooling tower.
- The above equipment is located outside the boundary for an external pool fire around the chillers.

MEK Unit Layout

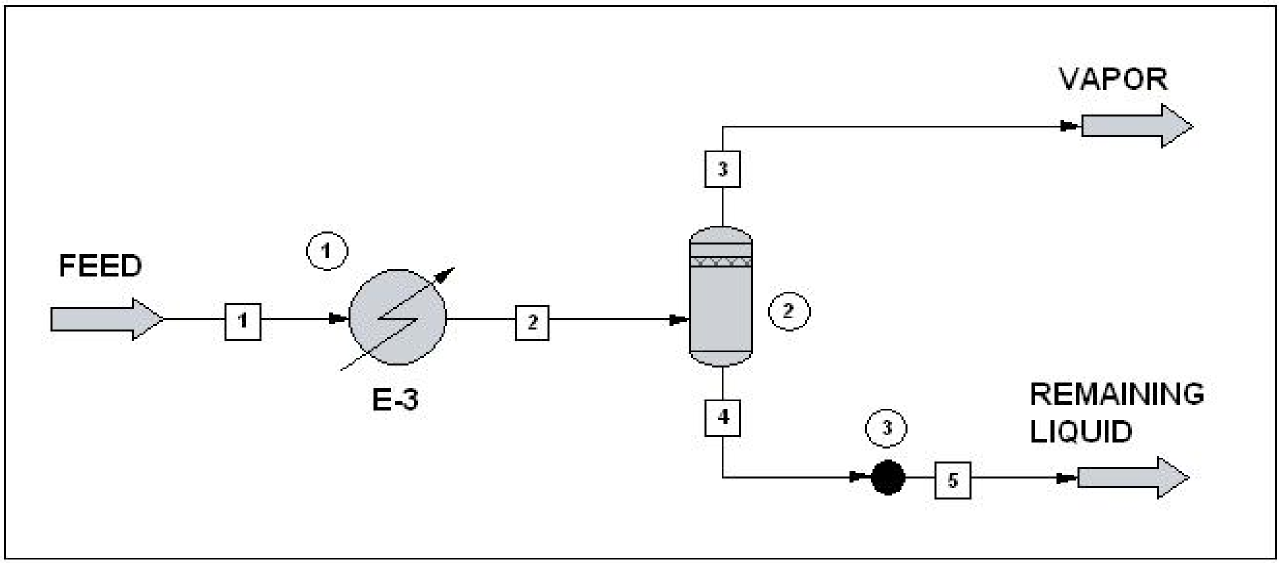


Dynamic Simulation Needed

- Large variation in boiling point between solvent and wax free oil.
- The annulus volume is relatively small compared to shell surface area, therefore the wetted shell height will decrease rapidly as the solvent boils off.
- Using dynamic simulation the change in the rate of vaporization can be calculated as the liquid composition changes and the heat input decreases due to reduce liquid height.

Unsteady State Simulation

ChemCAD Simulation



Sequence for Varying Heat Load (Q)
1) Run Simulation
2) Export Vapor and Remaining Liquid streams to Excel
3) Calculate new liquid height
   Obtain wetted surface area
   Obtain new heat absorbed, Q
4) Import Q to exchanger
5) Repeat steps 1 - 4

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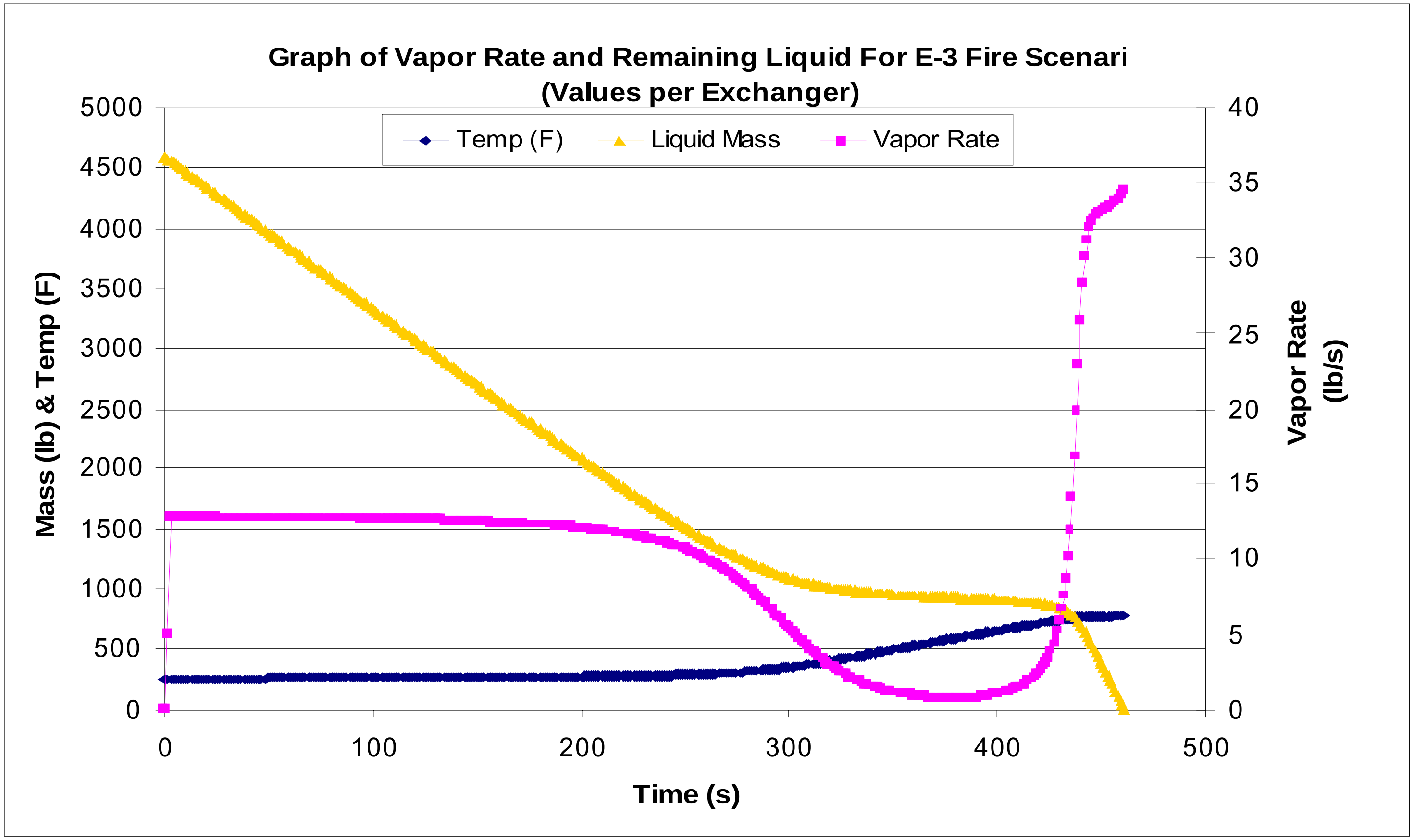
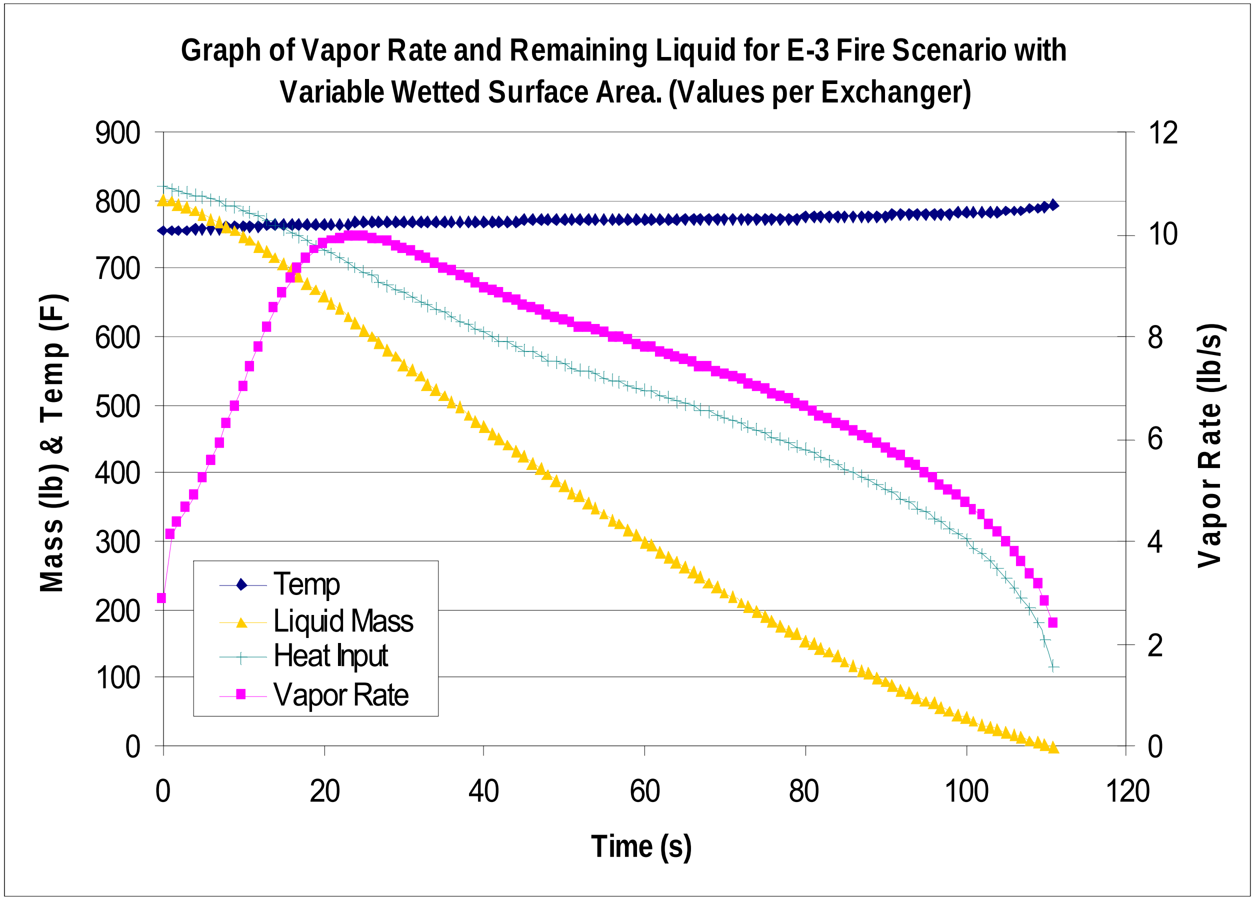
Unsteady State: Constant Heat Load



Peak solvent vapor rate = 12.8 lb/s (46,080 lb/hr)

Unsteady State: Varying Heat Load

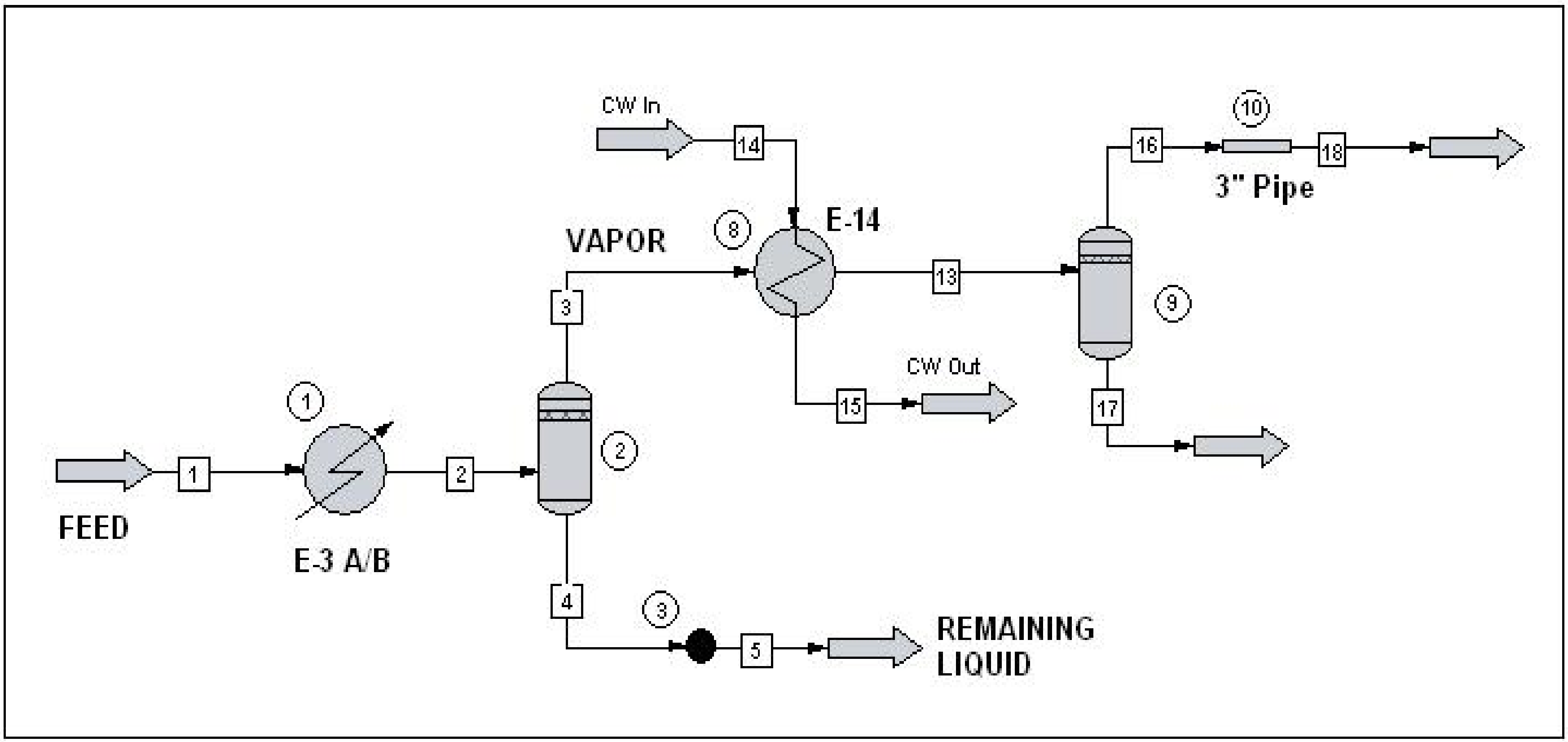


Peak WFO vapor rate: 9.97 lb/s (35,892 lb/hr)

Vapor Recovery Simulation

To verify that the conservation valve on the Inert Gas Holder can handle the fire relief requirement, the vapor stream from the Unsteady State simulation is connected to the Solvent Cooler in the Vapor Recovery Simulation. Any uncondensed vapor then flows through the 3” pipe section that connects the Solvent Recovery Drum to the Inert Gas Holder, and the corresponding back pressure is calculated.

Vapor Recovery Simulation



Results Comparison

API

- Recommended valve size: 4L6 (2.853 in^2)
- Maximum rate: 119,256 lb/hr
- Excessive back pressure process line, above MAWP of down stream equipment.

Unsteady State

- Recommended valve size: 2J3 (1.287 in^2)
- Maximum rate: 46,080 lb/hr
- Acceptable back pressure.
- Condenser can handle peak loads.

Shortfall of API 521 Method

In Summary

- It does not account for large variation in boiling points.
- It provides an unrealistic vapor relief rate when the exchanger volume is much smaller than the surface area.