Evaporators

Purpose:
Liquid Refrigerant is “Boiled” from a Low Pressure Liquid to a Low Pressure Gas by Absorbing Heat from the Medium that is being Cooled

Types:

- Direct Expansion
- Flooded
- Recirculated Over Feed
Direct Expansion Evaporators

- Liquid Refrigerant Enters the Evaporator, Absorbs Heat from the fluid to be cooled, Evaporates and Exits the Evaporator as 100% Gas
- The Liquid Refrigerant Entering the Evaporator is Regulated by a Thermo Expansion Valve (TXV) which Meters out only enough Refrigerant to Ensure Dry Gas out of the Evaporator; the Amount is based on Demand or Load Imposed on the Evaporator
- It has a Smaller Refrigerant Charge, but does not use the heat exchanger as efficiently as other types of feed.
Direct Expansion Evaporators

Shell and Tube Evaporator

- Referred to in the Industry as a "Chiller"
- Liquid Refrigerant is Passed into the Lower Tubes while Traveling Back and Forth through a Number of Passes
- Liquid Refrigerant Absorbs the Heat from the Brine and Evaporates (Gas)
- The Refrigerant Gas is Drawn Back to the Suction of the Compressor
Flooded Evaporators

- Evaporator is Kept Nearly Filled (or Flooded) with Liquid Refrigerant through its Entire Surface
- Refrigerant Enters Evaporator as 100% Liquid and Exits with Some Carry-Over of Liquid (e.g., 80% Gas; 20% Liquid)
- In most applications, Flooded Evaporators are Connected to a Surge Drum
Flooded Evaporators

- Surge Drums either Provide a Constant Source of Liquid Refrigerant or Ensure an Adequate Separation Space between the Liquid Refrigerant and the Suction Gas Back to the Compressor, or Do Both

- It has the Advantage of being the Most Efficient type of Evaporator, but has a Larger Refrigeration Charge
Flooding Evaporators

Shell and Tube

- The Liquid Refrigerant is Contained within the Shell of the Evaporator
- The Tubes Carrying the Brine or Glycol to be Cooled are Immersed in the Liquid Refrigerant
- The Refrigerant Vapor that is Produced by the Heat of the Brine flowing through the Tubes is Taken Back off the Top of the Surge Drum
Flooded Evaporators

Plate and Frame

- Ammonia is Contained between Two Welded Plates

- The Brine is in Contact with Both Sides of the Gasketed Plate

- The Plates have a “Herringbone” Design = Greater Surface Area
Flooded Evaporators

Plate and Frame

- Advantages: Less Refrigerant Charge, No Corrosion; 304/316 Stainless Steel or Titanium, Higher Operating Suction Temperature, and Smaller Footprint
Chiller/Transfer

NORMAL OPERATION
Chiller/Transfer

LIQUID CARRYOVER
Chiller/Transfer

TRANSFER FILLING
Chiller/Transfer

TRANSFER STARTS
Chiller/Transfer

TRANSFER COMPLETE
Finned-Tube Evaporators

- A finned-tube evaporator includes rows of tubes passing through sheets of formed fins.
- Liquid refrigerant flows through the tubes, cools the tube and fin surfaces.
- When air passes through the coil and comes into contact with the cold fin surfaces, heat is transferred from the air to the refrigerant.
- Causes the refrigerant to boil and leave the evaporator as vapor as heat is transferred.
- The fins of the coil are formed to produce turbulence as the air passes through them. This turbulence enhances heat transfer, preventing stratification within the coil-leaving air stream.
- Producing cooled air comparing with shell-and-tube type which is for chilled water.
Liquid Overfeed

- Liquid is pumped from an Accumulator to the Air Units.
- A portion of the liquid boils off while a greater amount by weight returns to the accumulator as a liquid.
- The liquid enters at nearly the same temperature as the suction temperature reducing flash load.
- Efficiencies similar to flooded evaporators except for the pump power.
- MUCH less complicated piping and controls at the evaporator/air unit.
Plate Heat Exchanger Types and Maintenance

Presented by:
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October 18, 2007
Discussion Outline

• Basic Heat Transfer

• Compact solutions for Liquid/Liquid applications
  • Gasketed plate
  • Semi-Welded plate heat exchanger
  • Welded plate heat exchanger
  • Compabloc
  • Spiral heat exchanger

• Compact solutions for Two-Phase applications (evaporation and condensing)

• Maintenance of compact heat exchangers

• Questions
Data needed to design any heat exchanger

• Flows and temperatures for both sides

• Fluid properties including: density, specific heat, thermal conductivity, and viscosity for at least two points.

• For condensers and evaporators, data such as a condensing curve, boiling point elevation, and/or other parameters may be required.

• Process conditions and limitations such as system pressure, potential for fouling or plugging, pressure drop limitations etc.

• The supplier may be able to use their experience to assist in determining proper values from above.
Types of Heat Exchangers

- Shell and Tube (Most common in industry)
- Gasketed plate and frame
- Welded plate and frame
- Spiral heat exchanger
- Plate coils
- Tubular heat exchanger
- Scraped surface heat exchanger
The Plate Heat Exchanger
**Heat Transfer Formula #1**

\[ Q = mC_p(T_{H_i} - T_{H_o}) \]

- Where

\[ Q = \text{heat transferred (BTU/hr)} \]
\[ m = \text{mass flow rate (hot fluid) (lb/hr)} \]
\[ C_p = \text{specific heat (hot fluid) (Btu/lb,F)} \]
\[ T_{H_i} = \text{hot fluid entering temperature (F)} \]
\[ T_{H_o} = \text{hot fluid leaving temperature (F)} \]
Heat Transfer Formula #2

\[ Q = U A \ (LMTD) \]

- Where

\[ Q = \text{heat transferred} \]
\[ U = \text{overall heat transfer coefficient} \]
\[ A = \text{heat transfer surface area} \]
\[ LMTD = \text{log mean temperature difference} \]
Determining Heat Transfer Area

\[ mC_p(T_{H_i} - T_{H_o}) = U \cdot A \ (LMTD) \]

Therefore

\[ A = \frac{m \cdot C_p \cdot (T_{H_i} - T_{H_o})}{U \ (LMTD)} \]

Determining Proper “U” value is the key!!
Items That Effect “U” value and Fouling Tendency

- Channel Geometry (turbulence)
- Fluid velocity and wall shear
- Fluid Properties (particularly viscosity)

*Viscosity also has a major impact on the pressure drop that will be seen in the heat exchanger
Shear stress versus fouling rate

- Rule of thumb: Try to keep the shear stress >50 Pa
Why Use a Compact Heat Transfer Solution?

• Lower Capital Cost
• Better heat recovery = Energy Savings!
• Can be expanded (PHE) for future upgrades
• Less weight and smaller footprint
• Low hold up volume means quicker system response time.
• Can be easily chemically or mechanically cleaned
## PHE Advantages

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<td>Number of units</td>
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Countercurrent Flow

Temperature

Length of Channel

$T_{H_i}$

$T_{C_0}$

$T_{H_0}$

$T_{C_1}$
Cocurrent Flow

Temperature vs. Length of Channel

- $T_{H_i}$
- $T_{H_o}$
- $T_{C_i}$
- $T_{C_o}$
True “Countercurrent” Flow Means a Very Close Temperature Approach Possible!

Very close temperature approach (Within 3-5°F)
PHE uses in the World Today

- Central cooling engineering
- Food and dairy industries
- Heating, ventilation and air conditioning
- Oil and gas production and refining
- Petroleum and chemical process industries
- Pulp and paper industries
- Hydrocarbon processing industries
- Refrigeration and air conditioning
- Steel and metal works
- Sugar, distillery and fermentation
- Light industries
- Metal recovery industries
Single Pass, Parallel Flow

Pass/Channel: Hot Side  \(1 \times 5\)
Cold Side  \(1 \times 4\)
Multi-Pass, Parallel Flow

Pass/Channel: Hot Side  \(2 \times 4\)

Cold Side  \(1 \times 4 + 1 \times 5\)
Wide-Gap Plate Heat Exchanger

Non-Clogging Port Design
Prevents Build-up of Solids in Entrance Area

Free Flow Channels for Fibrous or Particle Laden Fluids Such as Mash, Beer or Stillage.
Double Sided Wide Gap Heat Exchanger

Single Side Wide Gap Heat Exchanger
Performance Improvements by type of sealing system

- All-Welded PHE
- Semi-Welded PHE
- Gasketed PHE

Design Pressure (psi) vs Temp (°F)
Semi-Welded Plate Exchanger

- Aggressive Media On One Side
- High Heat Transfer Efficiency
- Flexible For Cleaning And Expansion
Semi-Welded Plate Heat Exchanger

- Welded channel for aggressive fluid
- Gasketed channel for non-aggressive medium
- Peripheral weld
Two-Phase Applications for Compact Heat Exchangers

• 190/200 Proof Condenser
• Distillation Column Reflux and Vent Condensers
• Distillation Column Reboilers
• Evaporator Station Final Condenser
• Regen Condenser
• Ammonia Vaporizer
• Many other applications in various industries
Honeycomb Pattern

• The plate edges of some newly designed plates are corrugated in such a manner that they form a honeycomb pattern. This provides mechanical support and a visual aid that the plates have been correctly hung in the frame.
Honeycomb Pattern

• Improperly hung plates, or those which do not alternate A,B,A,B..... will disrupt the honeycomb pattern.
Gaskets......Purpose

• Gaskets are the sealing strips which are fastened to each plate. They mate up against the back side of the adjacent plate, forming a sealed flow channel.
Operating Parameters Which Directly Affect The Service Life Of A Gasket

• Working Pressure- the higher the working pressure, the shorter the service life.

• Difference In Pressure- the greater the differential pressure, the shorter the service life.

• Fluid Temperature- The higher the gasket temperature, the shorter the service life.

• Aggressive Fluids
Other Factors Affecting Gasket Life

- Exposure to Ultra-Violet Rays
- Ozone - electric motors, welding
Gasket......Material

• Gaskets can be made of rubber, fiber, or plastic. Gasket selection is based on the specific application or duty of the heat exchanger.
• Majority of gasket material is rubber.
Gasket......Temperature Ratings

• Nitrile (NBR)..................230 degrees F
• EPDM..........................320 degrees F
• Viton...........................350 degrees F
Gasket......Types

- Glue-On
- Clip-on
Opening Your Heat Exchanger
Opening Your Heat Exchanger

- Dismantle any piping connected to the pressure plate.
Opening Your Heat Exchanger

• Inspect the sliding surface of the carrying bar, and the pressure plate roller.
Opening Your Heat Exchanger

• Mark the plate assembly on the outside by a diagonal line, or number the plates in sequence. Then measure and note the “A” dimension.
Frame – 6” and larger

- Tightening bolts to allow easy opening

- Four tightening bolts have bearing boxes
  - These are used for opening and closing the unit

- Remaining bolts with wearing washer
  - When closing these are tightened last
  - When opening these are removed first
Opening Your Heat Exchanger

• Pattern for removal of the tightening bolts on a model M10. First remove the two center bolts so that only the four outside corners
Closing Your Heat Exchanger

• Closing your heat exchanger to the proper “A” dimension is critical to leak free operation.
Troubleshooting

• Identifying The Problem(s)
  Leakage
  Heat Transfer Performance
  High Pressure Losses
Leakage

• Internal Leakage:
When internal leakage occurs, 99.9% of the time there is a crack or pin holes in the plate(s).

Fix: Dye Pen Test All Plates, Replace Bad.

Exception To The Rule: Check Plate Alignment. Adjust Hangers. Check Leak Detect Area.
Leak Detection

• Special venting ports are an integral part of the gasket design to prevent cross contamination.
Leakage

- External Leakage:
  Locate the area of leakage. Is the leak constant or periodic?
  Is the unit subjected to extreme temperature shocking?

Fix: Check The “A” Dimension. The “A” Dimension is the length of the plate pack in the heat exchanger that ensures proper gasket compression and contact between plates.

Acceptable range is +/- 1%. Check Plate Alignment. You May Need To Regasket The Unit.
Plugging - Fouling and

FOUL UPS !!!
What Is Plugging?

• Blockage of the flow channels by ...... foreign material large enough in size to lodge in the passages between the heat transfer plates.
Impact Of Plugging On Your Process System

• Increased Pressure Drop Results In:
  a) Increased Pumping Cost.
  b) Decreased Temperature Profile
  c) Decreased Flow
Solution For Maintenance

• Removal Of The Foreign Material By Opening The Unit And Washing.

Note: Depending On The Size, Plugging May Be Confined To The Port Area Only.
What is Fouling?

• Fouling is the build up of a film on the heat transfer surface which forms over a period of time. If this film is not removed, it will eventually reduce the heat exchangers ability to transfer heat. Fouling also reduces the hydraulic volume between plates and can cause increased pressure losses.
Sources Of Fouling

• Algae Growth
• Precipitation Of Fine Suspended Solids
• Burn-On (Proteins In Milk)
• Chill Wall Effect (Nitrates In Wine)
Impact

- Decreased Temperature Profile
- Dependent Upon The Degree Of Fouling, Increased Pressure Drop
Solution For Maintenance

• CIP
• Open And Clean By:
  1) Hand Washing
  2) Chemical Cleaning

Note: Never Use Wire Brushes On Plates
Monitoring Your System

• Pressure And Temperature Gauges On All Inlets And Outlets Will Be Required To Determine If Plugging And/Or Fouling Is Prevalent.
Monitoring Your System

• Normal Pressure Drop With Reduced Temperature Profile=thin film fouling.
• Increased Pressure Drop With Maintained Temperature Profile=Minor Plugging.
• High Pressure Drop, Plus Loss Of Temperature Profile:
  a) Normal Flow Maintained-
     Combination Of Thin Film Fouling & Plugging.
  b) Reduced Flow-Heavy Fouling & Plugging.