**Technical Reference**

### Related Formulas

**MASS FLOW RATE**  
\[ \text{MASS FLOW RATE} = \text{VOL FLOW RATE} \times \text{DENSITY} \]

**CENTIPOSE**  
\[ \text{CENTIPOSE} = \text{CENTISTOKES} \times \text{SPECIFIC GRAVITY} \]

**SCFM**  
\[ \text{SCFM} = \text{FACE AREA (ft}^2\text{)} \times \text{FACE VELOCITY (sfpm)} \]

**PRESSURE (psi)**  
\[ \text{PRESSURE (psi)} = \frac{\text{FORCE (pounds)}}{\text{AREA (in}^2\text{)}} \]

**VOL FLOW RATE (gpm)**  
\[ \text{VOL FLOW RATE (gpm)} = \frac{\text{VOLUME (gallons)}}{\text{TIME (minutes)}} \]

**INPUT POWER (hp)**  
\[ \text{INPUT POWER (hp)} = \frac{\text{PRESSURE (psig)} \times \text{FLOW (gpm)}}{1714} \]

**VEL THROUGH PIPING (ft/s)**  
\[ \text{VEL THROUGH PIPING (ft/s)} = 0.3208 \times \text{FLOW RATE (gpm)} \times \frac{\text{INTERNAL AREA (in}\,\text{)}}{\text{AVG.}} \]

**SPECIFIC GRAVITY OF A FLUID**  
\[ \text{SPECIFIC GRAVITY OF A FLUID} = \frac{\text{WT OF ONE CUBIC FT OF FLUID}}{\text{WT OF ONE CUBIC FT OF WATER}} \]

**PUMP OUTLET FLOW (gpm)**  
\[ \text{PUMP OUTLET FLOW (gpm)} = \frac{\text{RPM} \times \text{PUMP DISPLACEMENT (in/inrev)}}{231} \]

**PUMP INPUT POWER (hp)**  
\[ \text{PUMP INPUT POWER (hp)} = \frac{\text{FLOW RATE OUTPUT (gpm)} \times \text{PRESSURE (psig)}}{1714 \times \text{OVERALL EFFICIENCY}} \]

**OVERALL PUMP EFFICIENCY (%)**  
\[ \text{OVERALL PUMP EFFICIENCY (%)} = \frac{\text{OUTPUT HORSEPOWER}}{\text{INPUT HORSEPOWER}} \times 100 \]

**VOL PUMP EFFICIENCY (%)**  
\[ \text{VOL PUMP EFFICIENCY (%)} = \frac{\text{ACTUAL FLOW RATE OUTPUT (gpm)} \times 100}{\text{THEORETICAL FLOW RATE OUTPUT (gpm)}} \]

**MECHANICAL PUMP EFFICIENCY (%)**  
\[ \text{MECHANICAL PUMP EFFICIENCY (%)} = \frac{\text{THEORETICAL TORQUE TO DRIVE} \times 100}{\text{ACTUAL TORQUE TO DRIVE}} \]

**PUMP DISPLACEMENT (in³/rev)**  
\[ \text{PUMP DISPLACEMENT (in³/rev)} = \frac{\text{FLOW RATE (gpm)} \times 231}{\text{PUMP RPM}} \]

**PUMP TORQUE (in·lb)**  
\[ \text{PUMP TORQUE (in·lb)} = \frac{\text{HORSEPOWER} \times 63025}{\text{RPM}} \]

**RESERVOIR COOLING CAPACITY (BTU/HR)**  
\[ \text{RESERVOIR COOLING CAPACITY (BTU/HR)} = 2 \times \Delta T \times \text{RESERVOIR AREA (ft²)} \]

**HEAT IN HYDRAULIC SYSTEM DUE TO UNUSED FLOW/PRESSURE (BTU/HR)**  
\[ \text{HEAT IN HYDRAULIC SYSTEM DUE TO UNUSED FLOW/PRESSURE (BTU/HR)} = \text{FLOW RATE(gpm)} \times 1.485 \times \text{PRESSURE DROP (psig)} \]

---

### Heat Transfer in Fluids

#### General

Most fluid power systems require a method of heat transfer (dissipation or absorption).

#### Producing Heat

The energy loss is caused by inefficiencies of the energy process. Some of these losses contribute to the fluid heating. Heat is also produced by passing pressurized fluid through orifices, valves, and piping where a pressure drop occurs. Keeping these pressure drops to a minimum conserves performance and reduces costs. The following table shows the types of systems that will have losses to the fluid and/or the reservoir:

<table>
<thead>
<tr>
<th>System</th>
<th>% Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple circuits with minimal valves</td>
<td>25%</td>
</tr>
<tr>
<td>Simple circuits with cylinders</td>
<td>28%</td>
</tr>
<tr>
<td>Simple circuits with fluid motors</td>
<td>31%</td>
</tr>
<tr>
<td>Hydrostatic transmissions</td>
<td>35-40%</td>
</tr>
<tr>
<td>Servo based systems</td>
<td>55%</td>
</tr>
<tr>
<td>Low pressure fluid transfer systems</td>
<td>15%</td>
</tr>
</tbody>
</table>

These losses are expressed in units of power, e.g., HP, KW and BTU/HR. Heat problems are usually expressed in HP or KW in terms of the work expanded and losses absorbed. Cooling problems are usually expressed in BTU/HR.
Conversion and Formula Summary

There are many conversions and formulas used in selecting oil coolers. This will be a brief summary of those most commonly used.

**Conversions**
- HP = (BTU/HR) / 2545 = (BTU/min) / 42.4 = KW/.746, or BTU/HR = HP x 2545; BTU/min = HP x 42.4; KW = HP x .746
- GPM = (L/min) / 3.78 or L/min = GPM x 3.78
- °F = (1.8 x °C) + 32 or °C = (°F - 32) / 1.8
- Mobil Series: Air Velocity SFPM = SCFM/Face Area in FT², or SCFM = FT² Face Area x Face Velocity SFPM

**Methods to Determine Heat Loads**
- Hydraulic oil cooling: Assume 30% of the input horsepower will be rejected to heat. If the input horsepower is unknown, this formula may be used: BTU/HR = (System PSI) x (GPM Flow) x 1.8 x .3
- Hydrostatic oil cooling: Assume 25% of the input horsepower will be rejected to heat.
- Automatic transmission: Assume 30% of the engine horsepower will be rejected to heat.
- Engine oil cooling: Assume 10% of the engine horsepower will be rejected to heat.

**Heat Loads**
- BTU/HR = (Input Horsepower) x (2545) x (.25 – .5)
- BTU/HR = (System GPM Capacity) x (System Pressure) x (1.8) x (.25 –5)
- BTU/HR = (PSI Pressure Drop) x (GPM Oil Flow) x (1.5) x (% Time)
- BTU/HR = (Horsepower to Gearbox) x (2545 x .05 – .5)
- BTU/HR = (Compressor HP) x (1.1) x (.85) x (2545)
- BTU/HR = (Max Temp. Rise °F/HR) x (Gallons of Oil Changing Temp.) x (3.5)
- BTU/HR = (GPM Oil Flow) x (Oil T) x (210)

**Conversions**
- °F = (1.8 x °C)+32
- BAR = PSI ÷ 14.5
- BTU/hr = WATTS ÷ .2931
- BTU/min = KW ÷ .01757
- ft³ = in³ ÷ 144
- ft² = mm² ÷ 92900
- GPM = L/min ÷ 3.78
- HP = BTU/hr ÷ 2545
- HP = BTU/min ÷ 42.41
- HP = KW ÷ 0.746
- in³ = mm³ ÷ 645.2
- in³ = GAL ÷ .004329
- in³ = LITERS ÷ .01639
- m³ = GAL ÷ 264.2
- m³ = LITERS ÷ 1000
- mm = 25.4 x in
- PSIG = PSIA - 14.7
- 1 ton = 12,000 BTU/HR
- KW = HP x 1.343

**Temperature Changes**
- Oil △T = (BTU/HR) / (GPM Oil Flow x 210)
- Water △T = (BTU/HR) / (GPM Water Flow x 500)
- 50/50 Ethylene Glycol △T = (BTU/HR) / (GPM Flow x 432)
- Air △T = (BTU/HR) / (SCFM Air Flow x 1.08)

**Temperature Changes**

<table>
<thead>
<tr>
<th>Water Cooled</th>
<th>HP curve = HP Heat x 40 x Correction A</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Oil outlet °F - Water inlet °F)</td>
<td></td>
</tr>
<tr>
<td>AO Series: (except AOL)</td>
<td>HP curve = HP Heat x 100</td>
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<tr>
<td>(Oil outlet °F - Ambient air °F)</td>
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<tr>
<td>AOL Series:</td>
<td>HP curve = HP Heat x 100</td>
</tr>
<tr>
<td>(Oil inlet °F - Ambient air °F)</td>
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</tr>
<tr>
<td>Mobile Series:</td>
<td>BTU/HR curve = HP Heat x 2545 x 100</td>
</tr>
<tr>
<td>(Oil inlet °F - Ambient air °F)</td>
<td></td>
</tr>
</tbody>
</table>

**Centistokes to Saybolt Universal Seconds Conversion**
Heresite is a unique baked phenolic coating TTP uses to protect air cooled heat exchangers from external corrosion.

The following information has been supplied to TTP by Heresite-Saekaphen Inc.

Introduction
The first HERESITE coating application to the exterior surfaces of finned tube coils took place over thirty years ago. Since that time, the HERESITE baked phenolic coating has effectively demonstrated its value in protecting heat transfer coils from corrosive attack, thereby increasing equipment service life. The excellent chemical and temperature resistance, coupled with the superior heat transfer properties of the HERESITE coating, lead to outstanding results.

Description
The HERESITE coating of finned tube coils is accomplished by a multiple coat application of dipping and baking, resulting in complete coating coverage of the fins, tubes, headers, casings, etc. Consequently, protection against corrosion is provided for the entire coil. Due to specialized surface preparation techniques, plus the good adhesive properties of the HERESITE coating, it is possible to efficiently HERESITE coat all the usual metals used in fabricating finned tube coils.

The HERESITE coating that is applied to finned tube coils is a Flexible Brown Baked Phenolic Coating. This coating is applied to either aluminum, copper or steel with equal results.

We feel it is important to emphasize that HERESITE baked phenolic coatings are manufactured and sold only by HERESITE-SAEKAPHEN, INC. Further, the application of the HERESITE baked phenolic coating to finned tube coils is performed only at our plant in Manitowoc, Wisconsin.

Practically all types of finned tube coils used for oil, water, air, gas and process cooling (and heating), as well as large condensing coils can HERESITE protected against damaging environments. Currently, the HERESITE coating of air-conditioning and industrial process coils exposed to corrosive fumes and salt atmosphere is on the increase.

HERESITE coating offers a more economical solution than special metals for these applications. For example, we understand that aluminum fin coils coated with HERESITE are more economical than copper fin coils. Special metal casing materials are unnecessary since the HERESITE coating is applied to the casing as well as to the finned tubes. Additionally, HERESITE coated aluminum fins will resist attack from most cleaning agents more successfully than copper fin coils. It is noted that the HERESITE coating is applied to both plate fin coils as well as spiral wound tubing.

Chemical Resistance
The HERESITE baked phenolic coating will withstand exposure to practically all corrosive and chemical fumes with the exception of strong alkalis such as sodium hydroxide, strong oxidizing agents such as aqua regia and concentrations of bromine, chlorine, and fluorine in excess of 100 parts per million. Complete chemical resistance data is shown on the following page.

Temperature Resistance
Maximum temperature resistance of 450°F. However, HERESITE baked phenolic coatings cannot be recommended for all chemical atmospheres at temperatures up to 450°F since corrosive activity and permeation may be greater at higher temperatures depending upon the chemicals involved. Excellent adhesion and flexibility enable HERESITE coating to withstand thermal shock. Also, the HERESITE lining will operate at sub zero temperatures without loss of chemical and mechanical properties.

Thermal Conductivity
The HERESITE baked phenolic coating is a good thermal conductor and its thermal conductivity is expressed as approximately 2000 BTU per hour per square foot per degree Fahrenheit based on an average 3 mil coating thickness. The “K” factor = 6.0.

Coil manufacturers have indicated there is no need to add additional heating or cooling surface due to the presence of the HERESITE coating.

Guide to Chemical Resistance of HERESITE Baked Phenolic Linings:
HERESITE baked phenolic linings will withstand exposure to practically all corrosive atmospheres with the exception of strong alkalis, strong oxidizers and wet bromine, chlorine and fluorine in concentrations greater than 100 PPM. Due to the fact that resistance of HERESITE is dependent upon conditions of service, environment, fabrication details plus other factors, TTP should be consulted for specific recommendation.

HERESITE Advantages
- Elimination of costly metals
- Extended service life
- Smooth surface – reduced cleaning
- Complete coverage by dipping
- Good thermal conductor
- Good abrasion resistance
- Resistant to many corrosive environments
- Good temperature resistance

Note
3 week lead time adder
HERESITE is resistant to Fumes of the Following

- acetates - all
- acetic acid
- acetone
- acetylene
- acrylonitrile
- alcohols - all
- aldehydes - all
- alum
- amines - all
- ammonia
- ammonium hydroxide
- ammonium nitrate
- aniline
- benzoic acid
- benzol
- boric acid
- brine
- butane
- carbolic acid
- carbonates - all
- carbon monoxide
- carbon tetrachloride
- chlorides - all
- chlorinated solvents - all
- chlorine - less than 100 ppm
- chloroform
- chromic acid
- citric acid
- coke oven gas
- esters - all
- ethers - all
- ethylene oxide
- fatty acids
- fluosilicic acid
- formaldehyde
- formic acid
- freon
- fuels - all
- gases - inert
- gases - manufactured
- gases - natural
- glycerin
- glycols - all
- hydrocarbons - all
- hydrochloric acid
- hydrogen
- iodides - all
- ketones - all
- lacquers
- lactic acid
- maleic acid
- malic acid
- methanol
- methylene chloride
- naphthalene
- nitrates - all
- nitric acid (dilute)
- nitrobenzene
- nitrogen fertilizers
- oils, mineral and vegetable - all
- oxalic acid
- oxygen
- perchloric acid (dilute)
- phenol
- phosphoric acid
- picric acid
- propane
- salicylic acid
- silicic acid
- steam vapor
- stearic acid
- sulfate liquors
- sulfonic acid
- sulfur dioxide
- sulfuric acid
- sulfurous acid
- surfactants
- tannic acids
- tetraethyl lead
- toluene
- trisodium phosphate
- urea
- saltwater
- water
- xylene

HERESITE is not resistant to Fumes of the Following

- aluminum fluoride
- ammonium fluoride
- aqua regia
- bleaching compounds
- brass plating solutions
- bromine - over 100 ppm
- bronze plating solutions
- cadmium cyanide
- calcium hypochlorite
- caustic soda
- chlorine - over 100 ppm
- cyanide plating solutions
- fluorine - over 100 ppm
- hydrofluoric acid (conc.)
- hydrogen peroxide
- hypochlorites
- nitric acid (conc.)
- nitrogen oxides
- potassium hydroxide
- sodium fluoride (conc.)
- sodium hydroxide (conc.)
- tetraethyl lead
- toluene
- trisodium phosphate
- urea
- saltwater
- water
- xylene
High Elevation – Air Cooled Oil Coolers

When sizing air cooled heat exchangers for high elevation applications, consideration should be given to the loss in performance because of the lower density of the cooling air. Use one of the following formulas that has an added factor $C_{E1}$ or $C_{E1}$ to offset this loss of performance. The net result of these calculations is a larger cooler.

$C_{E1}$
1. For AO, ACOC, AOVH, Air or Gas Aftercoolers (Air Cooled) coolers, AOC - Industrial and RM

   \[
   \text{Horsepower to be removed} \times 2545 \times Cv \times C_{E1}
   \]

   °F (Oil Leaving - Ambient Air Entering)

$C_{E2}$
2. For AOL, BOL, MA, OCA, ACOC(H), AOC - Mobile, MF, DF, DH, AOHM and AOVHM

\[
\text{Horsepower at Elevation} = \text{Horsepower Heat Load} \times C_{E2}
\]

<table>
<thead>
<tr>
<th>Elevation</th>
<th>$C_{E1}$</th>
<th>$C_{E2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>1000</td>
<td>1.03</td>
<td>1.02</td>
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<td>2000</td>
<td>1.05</td>
<td>1.04</td>
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<tr>
<td>3000</td>
<td>1.08</td>
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<tr>
<td>15000</td>
<td>1.30</td>
<td>1.16</td>
</tr>
</tbody>
</table>
Shell & Tube Recommendations

Installation
The satisfactory use of this heat exchange equipment is dependent upon precautions which must be taken at the time of the installation.

1. Connect and circulate the hot fluid in the shell side (over small tubes) and the cooling water in the tube side (inside small tubes). Note piping diagrams.

2. If an automatic water regulating valve is used, place it on the INLET connection of the cooler. Arrange the water outlet piping so that the exchanger remains flooded with water, but at little or no pressure. The temperature probe is placed in the hydraulic reservoir to sense a system temperature rise. Write the factory for water regulating valve recommendations.

3. There are normally no restrictions as to how this cooler may be mounted. The only limitation regarding the mounting of this equipment is the possibility of having to drain either the water or the oil chambers after the cooler has been installed. Both fluid drain plugs should be located on the bottom of the cooler to accomplish the draining of the fluids. Drains are on most models.

4. It is possible to protect your cooler from high flow and pressure surges of hot fluid by installing a fast-acting relief valve in the inlet line to the cooler.

5. It is recommended that water strainers be installed ahead of this cooler when the source of cooling water is from other than a municipal water supply. Dirt and debris can plug the water passages very quickly, rendering the cooler ineffective. Write the factory for water strainer recommendations.

6. Fixed bundle heat exchangers are generally not recommended for steam service. For steam applications, a floating bundle exchanger is required. Note: When installing floating bundle unit, secure one end firmly and opposite end loosely to allow bundle to expand and contract. Consult factory for selection assistance.

7. Piping must be properly supported to prevent excess strain on the heat exchanger ports. If excessive vibration is present, the use of shock absorbing mounts and flexible connectors is recommended.

Service
Each heat exchanger has been cleaned at the factory and should not require further treatment. It may be well to inspect the unit to be sure that dirt or foreign matter has not entered the unit during shipment. The heat exchanger should be mounted firmly in place with pipe connections tight.

Caution
If sealant tape is used on pipe threads, the degree of resistance between mating parts is less, and there is a greater chance for cracking the heat exchanger castings. Do not overtighten. When storing the unit, be sure to keep the oil and water ports sealed. If storage continues into cold winter months, the water chamber must be drained to prevent damage by freezing.

Performance information should be noted and recorded on newly installed units so that any reduction in effectiveness can be detected. Any loss in efficiency can normally be traced to an accumulation of oil sludge, or water scale.

Recommendations
Replace gaskets when removing end castings. It is recommended that gaskets be soaked in oil to prevent corrosion and ensure a tight seal.

Salt water should not be used in standard models. Use salt water in special models having 90/10 copper-nickel tubes, tube sheets*, bronze bonnets and zinc anodes on the tube side. Brackish water or other corrosive fluids may require special materials of construction.

When zinc anodes are used for a particular application, they should be inspected two weeks after initial startup.

At this time, by visual inspection of the anode, determination of future inspection intervals can be made, based on the actual corrosion rate of the zinc metal.

The zinc anodes must be replaced when 70% of the zinc volume has been consumed.

It may be necessary to drain the water chambers of the exchanger to protect it from damage by freezing temperatures. Drains are provided in most standard models.

The oil chamber of the exchanger may become filled with sludge accumulation and require cleaning. It is recommended that the unit be flooded with a commercial solvent and left to soak for one-half hour. Backflowing with the solvent or regular oil will remove most sludge. Repeated soaking and backflowing may be required, depending on the degree of sludge buildup.

It may be necessary to clean the inside of the cooling tubes to remove any contamination and/or scale buildup. It is recommended that a fifty-fifty percent solution of inhibited muriatic acid and water may be used. For severe problems, the use of a brush through the tubes may be of some help. Be sure to use a soft bristled brush to prevent scouring the tube surface causing accelerated corrosion. Upon completion of cleaning, be certain that all chemicals are removed from the shellside and the tubeside before the heat exchanger is placed into service.

When ordering replacement parts or making an inquiry regarding service, mention model number, serial number, and the original purchase order number.

*Available on HC/SSC/SSCA Series models only.
### Maximum Shell & Tube Flow Rates

**CAUTION**
Incorrect installation can cause this product to fail prematurely, causing the shell side and tube side fluids to intermix. Maximum allowable flow rates are as charted below.

#### B Series Model No. Example: B-702-A4-F

<table>
<thead>
<tr>
<th>Unit Size</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>O</th>
<th>T</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>9.6</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>25</td>
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<td>115</td>
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<td>1600</td>
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<td>149</td>
<td>253</td>
<td>—</td>
<td>363</td>
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<td>2000</td>
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<td>187</td>
<td>347*</td>
<td>—</td>
<td>652</td>
<td>326</td>
<td>163</td>
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</table>

*281 GPM maximum for all B-2005-D **500 GPM maximum for all B-20080-E and 562 GPM maximum for all B-2006-E6 or B-2006-E10

562 GPM maximum for all B-2006-E6 or B-2006-E10

#### A Series Model No. Example: A-1024-2-6-F

<table>
<thead>
<tr>
<th>Unit Size</th>
<th>Baffle Spacing</th>
<th>Shell Side (GPM)</th>
<th>Tube Side (GPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA-400</td>
<td>.75</td>
<td>7</td>
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#### HC / SSC Series Model No. Example: HC-1024-2-6-F

<table>
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<tr>
<th>Unit Size</th>
<th>Baffle Size</th>
<th>Shell Side (GPM)</th>
<th>Tube Side (GPM)</th>
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<tbody>
<tr>
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</table>

#### EC Series Model No. Example: EC-1236-6-F

<table>
<thead>
<tr>
<th>Unit Size</th>
<th>Baffle Size</th>
<th>Shell Side (GPM)</th>
<th>Tube Side (GPM)</th>
</tr>
</thead>
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</tr>
<tr>
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</tr>
<tr>
<td>1700</td>
<td>6</td>
<td>140</td>
<td>220</td>
</tr>
</tbody>
</table>

#### EC Series Model No. Example: EC-1236-6-F

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<tr>
<th>Unit Size</th>
<th>Shell Side (GPM)</th>
<th>Tube Side (GPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>20</td>
<td>33</td>
</tr>
<tr>
<td>1000</td>
<td>100</td>
<td>66</td>
</tr>
<tr>
<td>1700</td>
<td>220</td>
<td>110</td>
</tr>
</tbody>
</table>

#### K / EK Series Model No. Example: EK or K-712-F

<table>
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<tr>
<th>Unit Size</th>
<th>Shell Side (GPM)</th>
<th>Tube Side (GPM)</th>
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<tr>
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</tbody>
</table>

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Piping Hook-up

A Series

B Series

HC / SSC / EC Series

SLE / SL / R Series

EK / EKS / EKM Series

K / KN Series

U / UC / UR Series

1 Hot Fluid In
2 Cooled Fluid Out
3 Cooling Water In
4 Cooling Water Out

*Note: For all two pass and four pass heat exchangers: connections 1 and 2 may be reversed, and connections 3 and 4 may be reversed with no effect on performance.

Note: For all two pass and four pass heat exchangers: connections 1 and 2 may be reversed, and connections 3 and 4 may be reversed with no effect on performance.

Note: EC bonnet rotation is slightly different from what is shown. See Series literature for details.

Note baffle location when inserting bundle into shell assembly after cleaning.

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