

# Why the Circulation Heater Design You Specify Matters

*Attention to detail during the design stage can pay big dividends once the circulation heater is in your process.*

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**E**lectric circulation heaters offer an efficient, economical means of heating water, oil, air or other liquids and gases. Careful planning and attention to heating requirements are essential to ensure that the heater you select will provide optimal performance for your application and offer years of trouble-free operation.

Selecting the proper watt density, or rate of heat output per unit surface area of heating element, is critical to both the life of the heater and the integrity of the fluid being heated. If the watt density is too high, for example, the fluid may carbonize or break down chemically, or the heater elements may burn out prematurely. Either situation results in unnecessary expense.

Standard heaters — those that are designed to meet the needs of generalized applications — have their place in certain situations. However, the

unique nature of most circulation heater applications — which can range from heating chocolate to high temperature gases to cryogenic fluids — requires users to do more than simply search for an acceptable heater watt density from tables of values for generalized applications.

Custom heater design and specification take into consideration your application's unique combination of parameters that are critical in determining a cost-effective and safe heater design. The design and specification process can be further

enhanced through the use of powerful computer-aided design programs, which allow individual applications to be quickly and accurately assessed using multiple scenarios.

## Application Analysis

The specification process begins with a well-defined picture of the heater's intended use. Consider using a summary sheet that will outline the typical criteria required to evaluate your application (figure 1). Each application has its own unique combination of process parameters that should be used to estimate the operating temperature of the electric heating element sheaths during normal operation. Using the proper element sheath temperature will maximize the life of the heating elements and help prevent possible degradation of the fluid being heated.

Key parameters include process-specific conditions such as minimum and maximum fluid flow rates, operating pressure, and maximum fluid outlet temperature. Other key parameters include thermal fluid properties such as maximum allowable heater element sheath temperature, specific heat, thermal conductivity, viscosity and coefficient of thermal expansion.

## Heater Design

With these specifications, the heater manufacturer is able to consider the physical orientation of the heating vessel as well as the fluid flow direction and fluid flow type during its evaluation. Together, these characteristics dictate the interworking relationship of forced and natural convection — the processes by which heat is transferred via the movement of the heated fluid.

Fluid flow type can be laminar, turbulent or transition. With laminar flow, the fluid travels smoothly



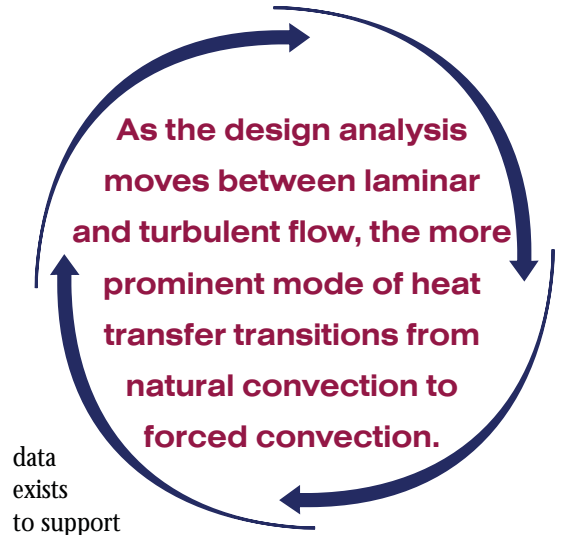
**The design and specification process can be further enhanced through the use of powerful computer-aided design programs.**

or in regular paths, and fluid velocity, pressure and other flow properties remain constant. The preferred or optimal region, turbulent flow, occurs when a fluid undergoes irregular fluctuations or mixing. The fluid's speed at any point is continuously undergoing changes in both magnitude and direction. Transition flow is the largely indeterminate region between the turbulent and laminar flow regimes.

As the design analysis moves between laminar and turbulent flow, the more prominent mode of heat transfer transitions from natural convection to forced convection. Natural convection occurs as a fluid is heated and its mass per unit volume (density) decreases. Thus, the hotter, lighter fluid rises while the colder, heavier fluid sinks. Forced convection is achieved by putting the fluid between a differential pressure; thus, forcing motion to occur according to the laws of fluid mechanics.

These two modes of heat transfer can work either in unison or opposition. Of course, the most effective heat transfer occurs when they work together such as in a vertically oriented vessel with vertical upward flow (figure 2).

Because laminar flow requires considerable length to become fully developed and typical electric heat exchangers are relatively short with element bundle-support spacers that interrupt the flow, pure laminar flow is rare. Extensive empirical



data exists to support fully turbulent and fully developed laminar flow regimes as well as pure natural convection. However, in most real world applications, one mode of heat transfer will dominate or the resultant mode of heat transfer will be a combination of the types.

Properly understanding and applying these heat transfer phenomena can dramatically affect which watt density you select for your circulation heater application. For example, in higher temperature gas applications, the acceptable watt density can be greatly improved by designing the heater's geometry (i.e., shell diameter and baffling types) to ensure that the flow regime within the heater vessel is in the turbulent region.

<b>Heater Specification Summary Sheet</b>	
<b>Application</b>	
Material to be Heated _____	Flow Rate _____
Density or Specific Gravity _____	Specific Heat _____
Operating Temp. (Inlet/Outlet) _____ °F, Design Temp. _____ °F	
Operating Pressure _____ psig	Design Pressure _____ psig
Desired Inlet/Outlet Connection: Size _____ ips, Type (flange, NPT, other _____), Rating _____	
Maximum Allowable Skin Temperature on Heater Element _____ °F	
Location: Indoor or Outdoor / Hazardous Area: Yes / No if Yes, Class ___ Division ___ Groups ___	
ASME Code Stamp: Yes / No	
Describe how heater is to be used _____	
Describe process loop _____	
<b>Heater Design</b>	
Required kW Rating _____	or Heat Duty _____
Available Power _____ volts	_____ phase _____ cycle
Maximum Watt Density on Heater Element _____ W/in <sup>2</sup>	
Vessel Material _____ (carbon steel is standard)	
Element Sheath Material _____	
Special Items _____	
<b>Controls</b>	
Type: On/Off / Multi Stage / Solid-State SCR (modulated)	
Controls Mounted: On heating unit / in remote control panel	
NEMA Type Enclosure: 4 / 4X / 12	
Special Control Items _____	
Visit <a href="http://www.process-heating.com/feature.htm">www.process-heating.com/feature.htm</a> to download this specification sheet as a PDF file.	

Figure 1. Circulation heater specification begins with a clear understanding of the heater's intended use.

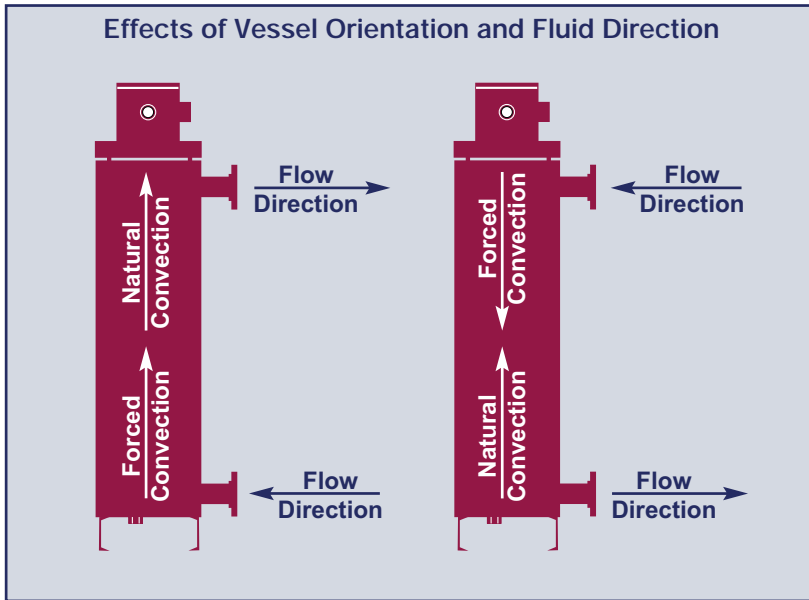


Figure 2. These diagrams compare the effects of vessel orientation and fluid flow direction on convective heat transfer. The heater on the left offers the best heat transfer capability because forced convection and natural convection are working together.

into account the additional heat radiating from the heating elements — which can be extremely dangerous if overlooked — and high-pressure effects on gas properties (heat capacity, thermal conductivity and viscosity). Employing computer-aided design programs to manipulate the heater's physical design and optimize these critical design parameters will provide the best engineered and most economical circulation heater for your specific application. [PH]

### Heater Optimization

With the widely accepted use of computer-aided design tools in today's engineering, the complicated iterations involved in evaluating criteria for circulation heater selection have been greatly facilitated. Individual applications can be quickly and accurately assessed using multiple scenarios to determine the optimal design options based upon your current and future heating needs. A heater manufacturer can, for example, simulate a seamless transition from no-flow to high-flow conditions that accounts for forced convection in laminar, transition and turbulent flow regimes in addition to natural convection.

Geometry plays an important role in heat transfer: Vertical and horizontal installations have different natural convection heat transfer characteristics. Computer-aided design tools can account for vessel orientation and flow direction. Computer-aided design programs also assist in the calculation of pressure drop, which generally acts inversely to heat transfer, for a given geometry.

In gas applications, heater vessel shell temperature calculations take

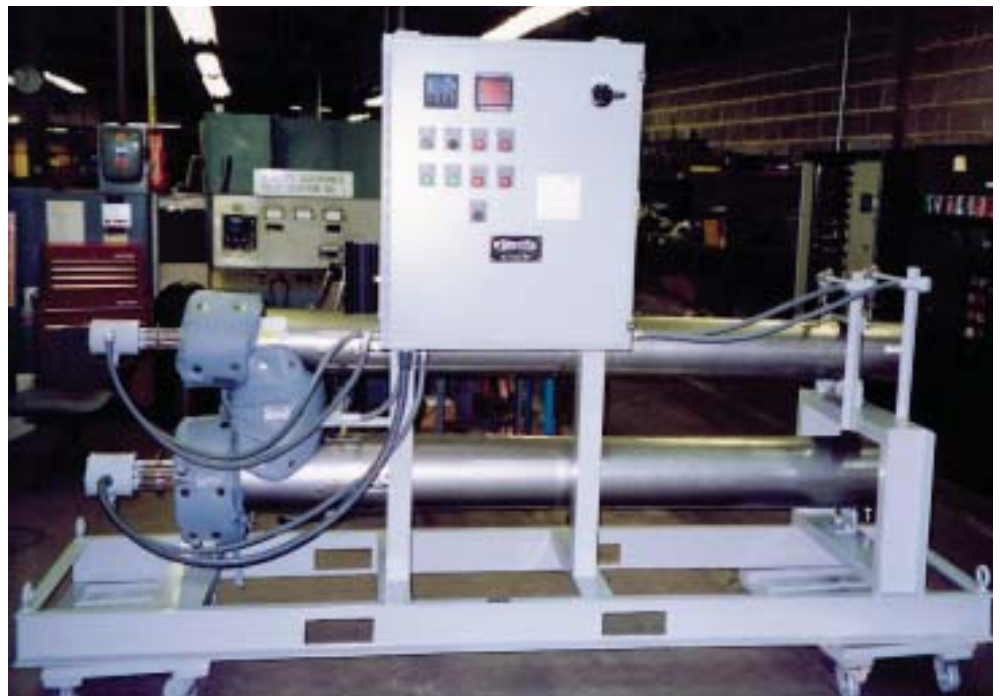
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Custom-designed circulation heaters such as this skid-mounted system with control panel, which was designed for a steam application, take into account the process parameters that are unique to a specific application.

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