

# THERMAL SHOCK

Recent forum chatter has questioned “thermal shock” as it relates to **GARN® WHS** equipment. So, what is the real story regarding thermal shock?

A fairly simple “technical definition” of thermal shock may be found at the following site: [http://en.wikipedia.org/wiki/thermal\\_shock](http://en.wikipedia.org/wiki/thermal_shock). As stated, “thermal shock is the name given to (the) *cracking* (of a material) as the result of rapid temperature change.” Several methods to prevent thermal shock include:

1. Reducing the thermal gradient by changing its temperature more slowly
2. Reducing the thermal gradient by increasing the materials thermal conductivity
3. Reducing a materials coefficient of thermal expansion

**GARN® WHS** hydronic wood fired heating equipment is characterized by its *large integral water storage mass*. Whereas the typical *outdoor* hydronic wood fired unit utilizes *minimal* water storage. What effect does this have on thermal shock?

As an example, assume a heating load of 225,000 BTUH, with a temperature difference of 30F between the hot water supply and the return. This load and temperature difference requires a pumping rate of 15 gpm. How does a **GARN WHS 1350** (the *smallest* GARN unit) compare with a typical outdoor unit containing 50 gallons of water (acknowledging that some outdoor units are larger and some are smaller)?

## Item #1:

At a pumping rate of 15 gpm 3,753 BTU’s are removed from the wood unit every minute; thus the return water is 30 *cooler* than the bulk water temperature within the wood unit. The temperature drop/minute for each unit is:

- **GARN WHS 1350:** .38 deg/minute.
- Conventional low mass outdoor unit: 9 deg/minute (about **23 times** the temperature rise per minute of the GARN unit).

**GARN WHS** units utilize an internal tube to quickly mix the cooler return water with the large integral water mass. Most low volume outdoor hydronic wood fired units do not have a dispersion tube; thus the temperature drop in a small area near the return fitting could be much greater than the 9 degrees/minute stated above.

## Item #2:

This relates to the properties of the material from which the hydronic units are fabricated. **GARN WHS** units and many outdoor units are fabricated from mild steel. Some outdoor units utilize various grades of stainless steel. However, thermal conductivity *alone* may not be the best indicator of a materials resistance to thermal shock.

Instead of thermal conductivity, consider thermal diffusivity. Thermal diffusivity is the ratio of the *thermal conductivity* of a material *divided by its density times its specific heat* (k/pC). The higher the conductivity and the lower the density and specific heat, the quicker heat will move through the material during a thermal transient (shock).

Title: Heat Transfer Handbook					
Table: Table 2.9a Thermophysical Properties of Metallic Alloys at 293 K					
no.	Alloy	Density (kg/m <sup>3</sup> )	Specific Heat (J/(g K))	Thermal Conductivity (W/(m K))	Thermal Diffusivity (10 <sup>-6</sup> cm <sup>2</sup> /s)
1	Iron, Carbon steel, 0.5% C	7833	0.465	54	0.148
2	Nickel-chrome steel, Stainless steel, type 304	7817	0.46	13.8	0.04
Heat Transfer Handbook © 2003 John Wiley & Sons					

The thermal diffusivity of mild steel and stainless steel vary slightly. In any event, mild steel is approximately **3.7 times** (.148/.040) more resistant to shock than 304 stainless steel.

### Item #3:

This also relates to the properties of the material from which the hydronic units are fabricated. **GARN WHS** units and many outdoor units are fabricated from mild steel. Some outdoor units utilize various grades of stainless steel. The coefficients of thermal expansion can be found at [http://en.wikipedia.org/wiki/Coefficient\\_of\\_thermal\\_expansion](http://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) for various materials. Thus:

- Mild steel – 10.8  $\alpha$  in 10<sup>-6</sup>/C at 20 °C
- Stainless steel – 17.3  $\alpha$  in 10<sup>-6</sup>/C at 20 °C

The coefficients of thermal expansion for mild steel and stainless steel vary slightly. However, in general the coefficient of thermal expansion for mild steel is **approximately 38% less** than that of stainless steel (10.8 vs 17.3)

### Conclusion:

Based on the above, low mass equipment and units fabricated from stainless steel are, in general, more prone to thermal shock cracking than high mass units or units fabricated from mild steel. Low mass wood fired units with a stainless steel combustion chamber may, in fact, be the most susceptible to shock fracture (intermittent combustion on the inside side surface of the combustion chamber with water on the outside). European manufactures of gas, oil and wood fired equipment dedicate significant Engineering resources to minimizing the problem of thermal shock cracking in low mass hydronic boilers.

Over the long history (since 1976) of **GARN® WHS** equipment, thermal shock has never been an issue because of its Engineered high mass mild steel construction.