From fireplace to thermostats in less than seventy years!

Methods for warming people have come a long way in a relatively short time. The historical progress from open fires in caves, through fireplaces and wood stoves to gravity warm air systems was dramatic. It was the advent of steam and gravity hot water heating boilers in the 1890 s that made central heating systems possible. Then came the modern hot water boiler with copper fin baseboard (circa 1947) which made for convenience beyond people s wildest dreams. Just think about it — from fireplace to thermostats in less than seventy years! It was a fantastic period in our industry s history. But pay attention, gang. There is more innovation to be had beyond the technology of 1947. We can learn about what lies ahead by exploring some of the basic principles of comfort and heating.

THE TWELVE COMMANDMENTS OF COMFORT

Every major industry continues to innovate: the computer industry, the automobile, the kitchen appliance. (Can you imagine Ben Franklin working with a Cuisinart? He d wish he had never discovered electricity!) To help you keep your share of the market that is looking for comfort and innovation, here are some basic and very general rules for your review.

Principle One: Heat always goes to cold.

Under normal conditions, the human body maintains an internal temperature around 98 degrees with 70 degree skin temperature. If we lose heat too quickly to a colder space, the blood vessels constrict, thus reducing blood flow to our hands, feet and heads, and we shiver. If it s too warm and our bodies can t shed heat fast enough, we start to sweat. Thus, we should not be trying to lightly toast the human body. What we should be doing is controlling how much of our body heat goes to cold.

In other words, we are not trying to heat or cool the human body; it can do that it s self. We are controlling the external factors that would pull the heat from us or put too much in us. There are six factors that determine human comfort: air temperature, air velocity, relative humidity, radiant environment activity level and insulating value of clothing. Most people tend to think only about air temperature. In fact, it seems as though some people don t know if they are comfortable unless they look at the thermostat. That doesn t tell the whole story. If air were blowing across our body in winter, we might want our environment to be 74 degrees to be comfortable. In a radiant environment, we might feel extremely comfortable at 68 degrees. In the low relative humidity of winter, an even higher air temperature might be required for comfort in both of these cases. There certainly is more to this than setting the thermostat at 70 degrees!

Principle Two: Heat Loss changes all winter.

When the outside air temperature drops below 68 degrees, Principle One kicks in with heat trying to get from hot (inside) to cold (outside). This amount of heat loss, changes from day to day and even hour to hour all season long according to the difference between inside and outside temperature. Engineers call this difference Delta T (Δ T).

The traditional approach for sizing heating equipment has been to determine the coldest weather you would ever expect (design conditions), add a safety factor, some pixie dust and one more boiler section. The end result is a boiler that is probably oversized by a lot the rest of the season. Ideally, we should have a boiler that changes size with the weather. Think about this: if you design for optimum system efficiency, the boiler would never shut off on the coldest day of the year.

Principle Three: Design conditions rarely occur.

Have you ever thought how little of the heating season is at design conditions? Table 1 from ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) reminds us how many hours each certain temperature occur. First, the basic math: 24 hours per day x 365 days = 8.760 hours per year. In New England, the outdoor temperature is above 72 degrees (cooling mode) approximately 700 hours. Simple subtraction tells us that we need heat in our homes for nearly 8,000 hours.

If design conditions are usually no more than 100 hours, then for *99.9 percent of the heating season*, the building can be heated with boiler or less water temperature.

Principle Four: Designing around the minor load is backwards.

There is no question that Americans demand air conditioning. Their automobiles and offices are cooled and they want their homes to be places of refuge during the hottest summer days. But to design a heat delivery system around the cooling load is to let the tail wag the dog . So what are the options?

HOURS OF TEMPERATURE OCCURANCE

Location	°	°	TEMPERATURE RANGE			°	°
	Unit	72 or More	72 — 57	57 - 37	37 - 22	22 - 7	7 or less
Boston	Hours	848	3080	3199	1359	260	14
°	%	9	35	37	16	3	0.2
Burlington	Hours	601	2640	2611	1804	824	280
°	%	9	30	30	21	9	3.2
Hartford	Hours	912	2875	2714	1747	463	49
°	%	10	33	31	20	5	0.6
Portland	Hours	540	2622	3069	1827	592	110
°	%	6	30	35	21	7	1.3
°	Hours	724	2804	2899	1684	535	113
Average	%	8	32	33	19	6	1.3

Heating = 8035 hours

Cooling = 725 hours

Table 1

A stand alone cooling system is best, where the cooling ducts are near the ceiling and the heating registers or radiation are near the floor where they belong. Other products that should be offered to the consumer looking for the best comfort system are split type air conditioners and high velocity air conditioners. These should be part of any comfort contractor s arsenal of choices.

The problem is, if the homeowner calls a duct work guy, they get a dry ducted solution. If they call a plumber, they get a wet piped solution. The key player is the company that can integrate both wet and dry; ducted heating and cooling in the upstairs sleep zones powered by a fan coil off a hydronic heating boiler, radiant floor heating in the great rooms and vaulted spaces, and finally, multiple zone baseboard or radiators (convective or radiant) elsewhere. One indirect fired domestic hot water tank completes the system. Why have multiple burners and flues when one highly efficient, properly maintained power plant can do it all? It is the beat way, makes sense, and is cost effective. Remember, the heating equipment is the only thing that will pay for itself over time by investing in better efficiency or quality.

Principle Five: Temperature modulation is more Efficient.

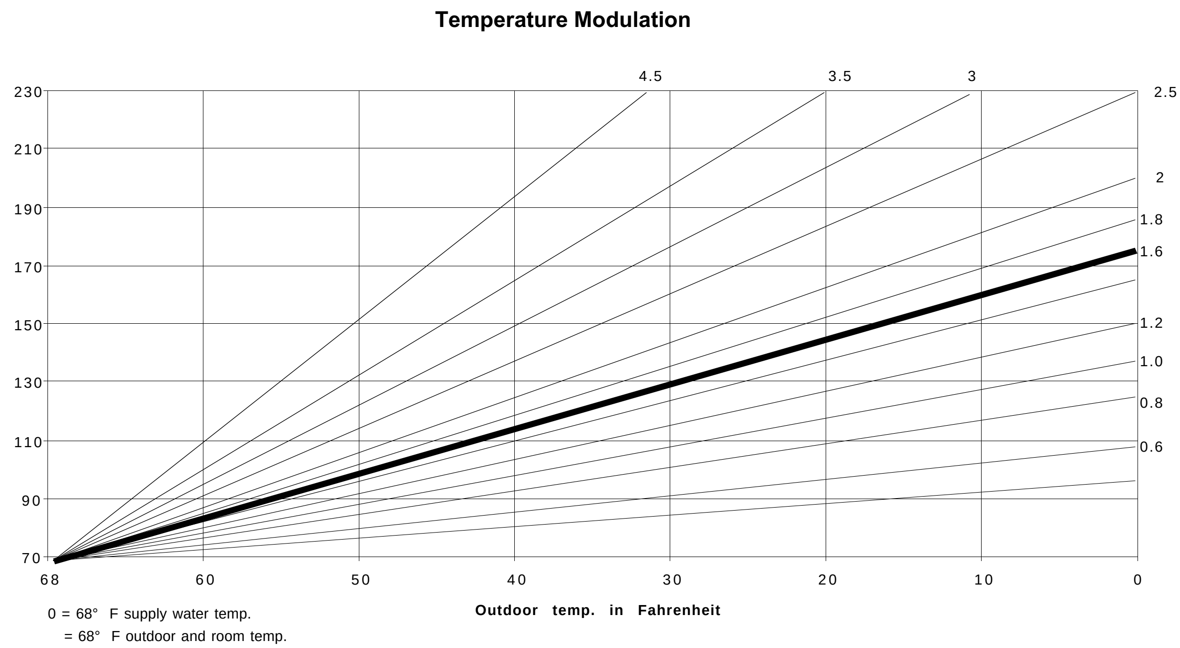
It has been consistently proven world wide that for every three degrees a building s heating supply water temperature is reduced (and still heat the building comfortably), fuel consumption is reduced by about one percent. It is simple physics. For example, a packaged boiler that bounces off 210 degrees versus a system with modulated water temperature at an average of 150 degrees, would save approximately twenty percent on the fuel bill (210 degrees — 150 degrees = 60 ÷ 3 = 20)

With our standard way of controlling hot water systems (intermittent circulation), every time a thermostat calls for heat, the burner will fire until either the high limit is reached or the thermostat is satisfied. Since the thermostat doesn t know how cold it is outside, it will step on the gas until it is satisfied. The thermostat will then be asked to step on the brakes against this freight train of hot water to keep from over-riding the setting on the thermostat.

Heat anticipators were added to thermostats to combat this symptom of our design, not to fix the problem of over-cycling with water that is almost always way too hot. And remember Principle One: heat always goes to cold; so all this super hot water piping will fight like crazy to cool off.

Take a look at the heating curve in table 2 (below). The curve at 1.6 shows a typical water temperature curve that would be needed to heat the typical home that has copper fin baseboard. As you can see, at zero degrees outdoors temperature, the system should still get its 180 degree design water temperature, but at every other point of weather, the outdoor controller will lower the water temperature. Conversely, the zigzag curve shows a traditional cycling pattern on most boilers.

It is easy to understand that the first example would be more efficient. Changing water temperature according to outside conditions should be done even if the system stays with the on/off circulation. Let the thermostat control the pumps and/or zone valves, but let an outdoor sensing control fire the burner.



Principle Six:
Continuous circulation makes sense.

When the boiler s temperature changes with the weather, its role can also change. Instead of being a way-too-hot beast that has to keep boosting up the temperature in the room faster than it falls, the boiler can become a BTO injection device, replacing only the amount of heat last on the lass pass of water through the building. It *keeps up* with heat loss rather than trying to *catch up*. All the technical chin-ups we ve done with heat anticipators would also be unnecessary. They were added to thermostats as a band-aid.

Principle Seven:
Larger mass is best in heating equipment.

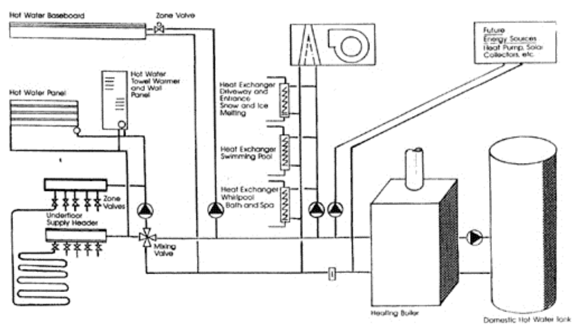
The popular trend is this country has been to smaller and smaller heating plants. From the technical side, this has more to do with reducing boiler cost than anything else. To meet the need for marketing advantage, small baby boilers were heralded as the hot technology.

One thing that was never mentioned was the issue of component cycling. Tests show that the average on-cycle for small boilers is only about two to three minutes and that the burner fires every time a zone calls. If you do the math, that burner could and will fire the burner more than 15,000 times each year. That is a tremendous wear on the ignition and control components.

The combustion process, particularly with oil, takes several minutes to reach its optimum combustion efficiency. This is because upon ignition the combustion chamber is cold and the chimney has poor draft. With a small water content boiler quickly reaching high limit, the boiler cycles quickly and never gets to its best combustion.

Another issue is material stress. The higher the BTU input of the boiler divided by the area of the boiler s heat exchanger, the greater the amount of heat stressing. One boiler manufacturer recently ran an experiment where they fired the rating of a four-section boiler into a three-section one. This is just the opposite of what should have been done. The resulting stresses will shorten the product s life. The American automobile industry, when confronted with the energy crunch in the 1970 s, went to a little four cylinder 2.0 and 2.2 liter engine. The engine couldn t take the material stresses over time and failure resulted. Today, you see greater fuel economy than ever thought possible, but with beefier four and six cylinder engines.

TOTAL SYSTEM SCHEMATIC



System Schematic Only - Not to be Used as Installation Drawing
Not all Controls and System Components Shown

Principle Eight:
AFUE ratings don t tell the whole story.

Did you know that a boiler would get a better rating if its insulation and jacket were removed during the test? The test rewards small poorly insulated pressure vessels by measuring the difference between the boiler room temperature and the flue gas temperature. The smaller the difference, the better the AFUE rating. Seems odd doesn t it? The test also assumes that the boiler is on for nine minutes, then off for thirty.

The AFUE rating is definitely a factor in selecting equipment but it is only one of many criterions. There have been many instances where older boilers were replaced by equipment with high AFUE numbers without any fuel savings. Unless the controls of these systems are also considered , consumers will be disappointed and short changed on efficiency.

Principle Nine:
Larger radiator surface areas mean lower water temperature.

There is a real lesson to be learned from the German hydronic industry. Before 1973, a typical system was designed for 197 degrees supply water and 170 degree return water temperatures. When the energy crunch came, the German government stepped in and changed the way that systems were designed. The new design criteria used a maximum supply water temperature of 167 degrees and a return water temperature of 140 degrees. This meant that the designers had to install more surface area of radiation and large flat panel steel radiators became the norm. Then people found design temperatures could be lowered even lower as non-government innovation led to the advent and development of radiant floor, wall and ceiling heating. The end result of this fundamental change in design is that Germany s per capita fuel consumption is approximately half of ours.

Do not misunderstand. I do not advocate flat panel radiators everywhere. I do think it is important for homeowners and heating professionals to understand that if more radiation or surface area is installed originally, the system will be more efficient and operating costs lower over the life of the building.

Principle Ten:
Radiant heated rooms or buildings have a lower hear loss.

Remember the term design temperature difference ? Well, heat loss goes up and down with it. With any type of heating system, except radiant floor heating, the temperature at the ceiling of the room is warmer than at the floor. This temperature stratification contributes substantially to heat loss. Radiant floor heating does not heat the air in the room directly, but instead heats objects and people. The air will always be cooler at the ceiling. Because of this cooler ceiling temperature, the building has a lower heat loss. I know it is heresy to even think about anything except a super safe heat loss, but it s true and proven. A traditional I=B=R heat loss should be derated by at least fifteen percent with radiant heating equipment.

Principle Eleven:
Circulator pumps should always pump away from the expansion tank.

The circulator pumps will develop an increased pressure on the discharge and a decreased pressure on the suction side. As you go around the distribution loop, these pressures taper off and meet at the point of no pressure change which is located at the expansion tank.

A typical package boiler with the pump on the return will have a positive pressure only through the boiler and up to the air scoop and expansion tank. The rest of the system will be at reduced pressure on the suction side of the pump. Since water can hold less air at a lower temperature and pressure, air will try to come out of solution and collect at the high point of the system.

The pump on a packaged boiler is only mounted on the return for packaging convenience. Every commercial system has the pumps on the supply side with the expansion tank at the boiler. Every system in Europe has them on the supply and after the expansion tank. Don t think about it just do it. Your air purging life will change dramatically.

Principle Twelve:
Diaphragm expansion tanks are a must.

I ve always been amused by the term air control . If you have a closed hydronic system, there should be no new source of oxygen except the air/water interface within a plain steel expansion tank. A diaphragm type tank eliminates this source of air in any hydronic system. Amtrol should be commended and supported for inventing and perfecting this breakthrough in hydronics. In this day and age, it has been proven over and over as the way to go.

About the author:

Richard Trethewey has long been an advocate for better and more comfortable heating and cooling systems. He is president of RST, Inc., Dedham, MA, a consulting company and manufacturer s representative for a variety of contemporary heating products. Trethewey is the mechanical systems expert on the widely acclaimed PBS program, This Old House , and author of two books, This Old House Heating, Ventilating and Air Conditioning, A Practical Guide to Affordable Comfort published by Little Brown and The Homeowners Manual co-authored with Tom Silva and published by Time Warner books. He is a regular columnist for This Old House Magazine and has written for trade journals such as Plumbing and Mechanical and Journal of Light Construction. For many years, he was the radio host of The House Doctors , a weekly radio talk show on WHDH. Trethewey is a fourth generation master plumber and longtime member of the Mass PHCC.