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By: Brad Hesse

Wireless Temperature Control

Introduction

Efficiently heating and cooling residential buildings in New York City is a challenge. Decades ago, energy conservation and comfort simply were not the issues that they are today. What may be seen as a hardship today, i.e., lack of air conditioning, wasn't even considered forty and fifty years ago. Today, relatively small temperature fluctuations are considered a problem needing attention. Less technology, fewer creature comfort concerns and lower energy cost then contributed to a variety of building and HVAC design practices which are causing problems for building managers and occupants now. While there have been many advances and improvements in HVAC equipment performance and controls, and good reasons in terms of comfort and energy savings to upgrade to newer technology, dealing with the disruption of implementing equipment retrofits is a major consideration. This consideration often outweighs all other concerns.

Temperature Control — A Common Problem

A variety of HVAC technologies can be found in the NYC residential building stock; several are common. Steam radiators, electric baseboard strip heat, packaged terminal air conditioning (PTAC), packaged terminal heat pump (PTHP), 2-pipe and 4-pipe fan-coils are all common examples. Many buildings lacking cooling design consideration rely solely on window and wall a/c for air conditioning. These common equipment choices typically use integrated line-voltage thermostat controls (bimetallic or refrigerant-tube) mounted within the equipment itself. They are unfortunately synonymous with remarkably poor temperature control. In the case of some fan-coil models, only a fan-speed switch is provided; surprisingly, no thermostat exists of any kind! Equipment efficiency is an important factor, but regardless of efficiency, good temperature control is vital. Without it, energy waste is inevitable regardless of efficiency. After all, if operating unnecessarily, high-efficiency equipment is merely wasting energy, albeit efficiently.

Inadequate temperature control and lack of programmable temperature setback capability is characteristic of residential HVAC equipment in NYC. Poor temperature control leads to overheating and overcooling living spaces and common areas, wasted energy and sacrificed comfort. The truth is, line-voltage thermostats are imprecise as designed, improperly located, difficult to regulate, and generally a nuisance to adjust, often resulting in their being set and left in an unnecessarily high demand state. It is an understandably difficult task to combine the function of an accurate temperature sensor with a power control switch in a single electromechanical device. The line-voltage thermostat is a solution at odds with itself — a device capable of exerting sufficient mechanical force to actuate a line-voltage switch, yet sensitive to small changes in temperature. Such controls can be so flawed that occupants resort to opening windows in the winter to control temperature, rather than fight with impossibly deficient controls. A properly located *precision programmable thermostat* would certainly solve comfort problems; it has been proven to save considerable energy as well. Much of the existing heating and cooling equipment in use today in NYC is perfectly suitable for the job if good thermostatic control is also incorporated. The problem however is *wiring***.** Can a precision, wall-mounted thermostat be properly located and wired to existing equipment without unacceptable disruption to the premises, and at a reasonable cost? The short answer is probably not, unless it is a *wireless thermostat*.

With the help of funding support from the New York State Energy Research and Development Authority (NYSERDA), ENERNET Corporation, a small upstate New York company, was recently awarded a U.S. patent for their wireless thermostat system. Designed specifically to address problems associated with inferior thermostatic controls such as those discussed earlier, the T9000 wireless thermostat is a new and unique tool. A two-part system, it consists of a battery powered thermostat and one or more control devices called Receiver Control Nodes (RCN). The RCN component is connected to the HVAC equipment to be controlled. Battery operated, the thermostat is mounted wherever it is most appropriate, and uses 900MHz radio frequency (RF) communications to remotely actuate its associated RCN(s). It is the only thermostat system that by design provides programmable control of completely unrelated heating and cooling appliances. And, it is the first thermostat designed specifically for retrofitting the often-ignored heating and cooling equipment types discussed in this article.

Energy Conservation and Comfort

A stable, well-regulated space temperature is not only desirable for comfort; it also saves energy and money. It has been well documented that considerable energy savings can be obtained through retrofit to precision, programmable wall mounted thermostats. Studies by the Electric Power Research Institute (EPRI) and others have shown that as much as 30% savings are possible through precision temperature control and temperature setbacks. The primary problem preventing thermostat retrofit is the need to install wiring from the point of best thermostat location to the heating/cooling source. Hardwiring is difficult, expensive and disruptive - strong deterrents to upgrading. For this reason, retrofit to precision thermostat control with its resulting comfort and energy conservation benefits is seldom performed. With the advent of ENERNET Corporation's T9000 wireless thermostat, virtually any poorly controlled heating/cooling load can benefit from precision thermostatic control and programmability, thereby dramatically improving comfort, and economy.

A number of factors contribute to energy waste and diminished comfort with bimetallic line-voltage thermostat technology. EPRI study (RP2034-29) showed low-cost bimetal-strip line-voltage thermostats in electric baseboard heating application perform very poorly. The strips adjust slowly to changes in room temperature, and internal heating of the wires often makes it difficult to maintain a setpoint temperature. Even shortly after installation, these thermostats generally do not maintain stable temperatures, and their performance degrades with time. (September 1992 issue of the EPRI JOURNAL - Developments in line-voltage thermostats)

A line-voltage bimetallic thermostat element consists of a strip of two dissimilar metals (usually copper and steel) with different coefficients of thermal expansion that are bonded together. The expansion difference of these two metals in response to temperature changes causes the strip to bend. The bending motion actuates a switch of sufficient size to handle the current of the load in question. (Refrigerant-tube controls rely on refrigerant pressure and a diaphragm to actuate a line-voltage switch.) As documented in EPRI study RP 3512-05, a typical wall-mounted line-voltage thermostat was tested with the following results:

Accuracy	-	6°F (above set point)
Droop	-	5°F
Deadband	-	8°F

Accuracy: The actual temperature versus that sensed and acted upon by the thermostat.

Droop: A reduction in space temperature that results from internal heating caused by the current passing through the wires inside the thermostat.

Deadband: The temperature range in which the thermostat sends no control (on or off) signal to the heater.

"The test observations of the generic line-voltage thermostat are indeed typical. A deadband as high as 10°F may be experienced." (Heitz, E., “Thermostats: Small but Critical,” Home Energy Update, March/April 1988. Schreiber, R.J., “Assessment of Line Voltage Thermostats,” Final Report Prepared for EPRI under EPRI RP2034-29)

Thermostat controls integrated within the heating or cooling appliance itself, i.e., window a/c, PTAC/PTHP and baseboard electric heat with controls on the baseboard, will exhibit even

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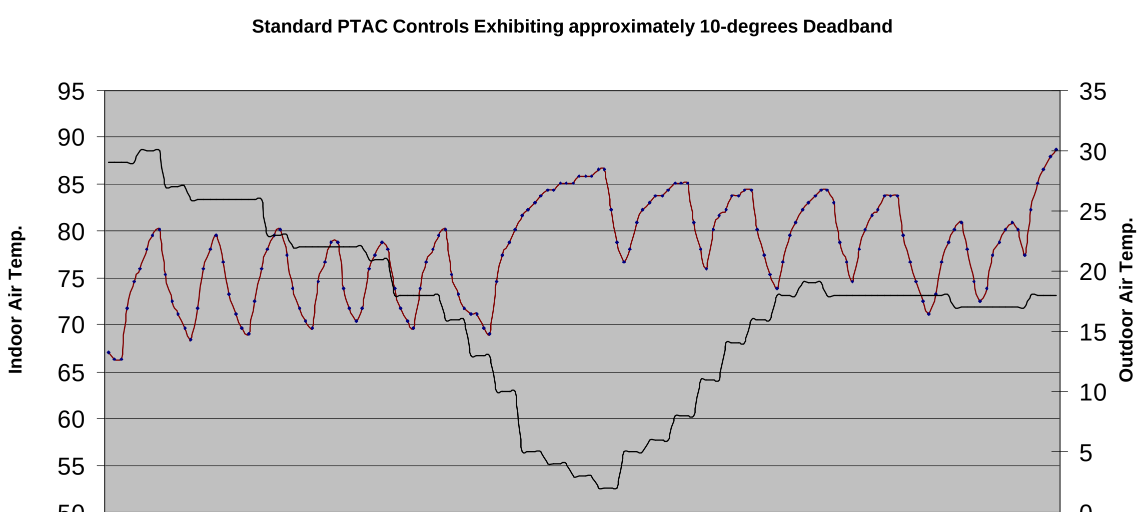
worse performance than that given above due to thermal mass effects, which can only exacerbate droop and deadband. Inappropriate thermostat location (at floor level in the case of electric baseboard with integrated controls, in an outside wall sleeve or window in the case of PTAC/PTHP and window a/c) for the zone being controlled further magnifies control problems. Consequently, test results discussed above can be considered a best case specification.

ROI and Comfort

Occupants select thermostat set points based on maintenance of a minimum acceptable comfort level. Consider an occupant during heating months who desires a minimum space temperature of 72°F: A generic line-voltage thermostat with its previously described accuracy and deadband performance deficiency may need to be set at 80°F and possibly higher to ensure comfort. The <u>*average*</u> space temperature using the bimetal thermostat will be much warmer than needed to make the occupant comfortable. (The opposite logic of course applies to cooling.) Figure 1 is a graphic example showing data that clearly depicts this phenomenon.



	8:45 12/2/02	10:00 12/2/02	11:30 12/2/02	12:45 12/2/02	14:00 12/2/02	15:30 12/2/02	16:45 12/2/02	18:15 12/2/02	19:30 12/2/02	20:45 12/2/02	22:15 12/2/02	23:30 12/2/02	0:45 12/3/02	2:15 12/3/02
Series1	67	76	71.1	78.1	69.7	80.2	69.7	71.8	78.8	69.7	75.3	69.7	80.2	84.4
Series2	29	30	27	26	26	23	22	22	21	18	16	13	10	4

	3:30 12/3/02	4:45 12/3/02	6:15 12/3/02	7:30 12/3/02	8:45 12/3/02	10:15 12/3/02	11:30 12/3/02	13:00 12/3/02	14:15 12/3/02	15:30 12/3/02	17:00 12/3/02	18:15 12/3/02	19:30 12/3/02	21:00 12/3/02
Series1	85.8	78.8	83.7	85.1	81.6	80.2	79.5	84.4	78.1	83.7	71.1	80.9	77.4	82.3
Series2	3	2	6	8	11	16	18	18	18	18	18	17	17	18

12/02/02 08:45 - 12/03/02 22:00

Figure 1

The data set shows indoors versus outdoor temperature at 15-minute intervals. Integrated thermostat controls in this PTAC unit are allowing average temperature fluctuations of 10-degrees. In fact, minimum / maximum temperature peaks in this 37-hour data set are nearly 20°F! Key here is the lowest points in each high/low swing cycle because this is the temperature at which the occupant is in fact comfortable. However, while the acceptable temperature is around 70°F, the average temperature is slightly over 78°F. This excess heat is wasted energy, and it is significant. EPRI research states that if the average indoor temperature is about 4°F higher than necessary, the energy consumption for the bimetallic thermostat will be higher by 28 percent compared to that of a precision electronic thermostat. (EPRI RP 3512-05, Testing and Evaluation of Line-Voltage Thermostats) Clearly, if temperature were better regulated, the occupant would be more comfortable while simultaneously saving energy and money.

ROI and Temperature Setback

Programmable thermostats can save significant amounts of heating and cooling energy, resulting in economic and environmental benefits. “Residential energy use represents 20 percent of all U.S. energy consumption, and nearly one-half of all energy used in the home is for heating and cooling. Consumers spend 6 to 12 percent of their gross income paying for residential fuel and utility costs—an amount equal to $100 billion annually. Programmable thermostats, when used properly, can save consumers 20% -30% on heating and cooling bills." (EPA ENERGY STAR FAQ — http://www.epa.gov/appdstar/hvac/faq.html)

“Adjusting the temperature at night as well as during the daytime (up during the cooling season) can result in an 11% to 15% savings. During the winter, a single temperature setback during the day can result in a 16% to 18% savings. A double setback (at night as well as during the day) can result in up to 30% savings.
(Greenbuilder – Sustainable Building Sourcebook)

Conclusion

Deciding to upgrade heating and cooling equipment to improve efficiency and comfort is a big step. Nonetheless, in many if not most cases, the first order of business should be getting properly located, precision programmable thermostatic control over what is there. Precision temperature control not only dramatically improves comfort; it's a good investment as well. While any means to affect this change is worth considering, the wireless RF thermostat approach can make for a quick, low-impact retrofit.

For more information contact ENERNET Corporation at 315-449-0839 or visit http://www.enernetcorp.com.

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GLOSSARY:

Packaged Terminal Air Conditioner (PTAC)

PTAC is the acronym for packaged terminal air conditioner. PTACs typically include self-contained heating and cooling components such as a compressor and electrical resistance heating intended for mounting through-the-wall to serve a room or single zone area.

Packaged Terminal Heat Pump (PTHP)

A PTAC capable of using the air conditioner refrigeration system in a reverse cycle or heat pump mode to provide heat.

Steam Radiator

Radiator - heater consisting of a series of pipes for circulating steam or hot water to heat rooms or buildings.

Electric Baseboard Heat

A type of heating system that generates heat by passing current through a conductor, causing it to heat up. These systems are packaged as a baseboard heater, typically mounted on the floor along the baseboard of a room and often have a line-voltage thermostat dial control on the unit.

Fan Coil

A fan coil unit is comprised of a finned-tube coil, an insulated drain pan under the coil to collect condensate, a fan to move air through the coil, filters, and a cabinet to house these components. Typically fan coils are located above ceilings and ducted to ceiling diffusers, or under windows in a console style unit. Console units are sometimes ducted through the wall for outside ventilation air.

Two-Pipe Fan Coil System

A two-pipe fan coil system consists of a fan coil unit(s) with single coils, which are connected to two pipes (one supply pipe and one return pipe) that either provide hot water or chilled water to the fan coil. A building with a two -pipe system is either entirely in a heating mode or entirely in a cooling mode. It is not possible to cool some rooms while heating others.

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Four-Pipe Fan Coil System

A four pipe system consists of a fan coil unit(s) with separate heating and cooling coils, as well as separate pairs of heating and cooling pipes. Hot water or chilled water is always available. The system is able to instantly switch from the heating mode to the cooling mode, or vice versa, and can provide heating to some rooms while simultaneously providing cooling to other rooms.

Line-voltage Thermostat

The typical line-voltage thermostat contains a bimetallic strip that bends as the temperature changes to close and open a switch. Refrigerant-tube or bulb thermostats use the change in refrigerant pressure as temperature changes to actuate a switch closure. Unlike low-voltage thermostats that carry very little current, line-voltage thermostats must carry the full current drawn by the heating or cooling system. This can generate considerable heat in the bimetallic element causing it to respond inaccurately.

Ideal Thermostat Location

For best performance results, the thermostat should be located approximately five feet above the floor on an inside wall in an area with good air circulation. A thermostat should not be located where air is stagnating such as behind doors, in corners or under cabinets. Hot or cold drafts from air ducts and windows should be avoided. Avoid heat from the sun, lighting fixtures, appliances, fireplaces, etc.