Time & Temperature (BTU) Meters White Paper

Energy Metering and
Monitoring Systems

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Meter Description:

The time and temperature (TT) meter is used to measure heating and cooling system delivery into spaces that utilize fan coil, air handler units or baseboard heat that are fed by a central heating and/or cooling hydronic system.

This is accomplished by measuring the water delivery temperature and the time that the delivery device is active (fan coil or baseboard zone valve "open" or fan "on"). This measurement is then converted to an interval pulse output.

One pulse equals "X" amount of energy delivered dependent on the rating of the delivery device. The meter is configured to pulse once every 36 seconds at a measured temperature of 200°F; as the temperature decreases the interval increases.

As an example, if the water temperature reduces to 180°F, the meter will pulse about every 50 seconds. With this in mind, a meter pulse then equals a fixed amount of energy delivered (more time required to deliver the same amount of energy at a lower water temperature).

This pulse is then converted to relative BTUs transferred.

The "relative" term is used since the only accurate method to measure heating BTUs is to measure air temperature differential across the delivery coil plus CFM of delivered air.

Cooling BTU measurements are more complicated, since latent heat transfer is involved. Baseboard heat is even more ambiguous since heat delivered is directly related to the water flow rate through the assembly and the condition of the fin assembly (missing fins, airflow obstructions, dirty fins, etc.)

Water flow can vary substantially depending on how many other zones valves are open, condition of the circulating pumps, if piping is partially obstructed, construction methods, system design, etc. Since conditions will change as it relates to coil condition and air delivery (dirty coil, dirty air filter, partially clogged water side of coil, etc.), the meter measurement is not 100% accurate at all times and under all conditions.

This meter is more accurate than a time only meter, however, since water temperatures in a centralized hydronic system can vary by several degrees. What is relevant is that all delivery units are consistently measured with the same meter and in the same fashion.

The measurement "window" of the meter is between 90°F and 200°F in heating mode, and 38°F and 58°F in cooling mode. Temperatures outside of these ranges are ignored, and the meter produces no output.

The measurement changeover is automatic, i.e. the meter assumes heating measurement when the temperature input is between 90°F and 200°F, and assumes cooling measurement when the temperature input is between 38°F and 58°F.

The meter requires two (2) inputs:

1. The first is **24VAC** that is present only when the conditioned area is calling for heating or cooling (typically via a thermostat). This voltage is typically available at the hydronic zone valve or the fan control relay (fan coil or air handler units).

2. The second input is from the included negative coefficient **thermistor**, which is physically attached to the input water line of the fan coil, air handler or baseboard unit that is utilized to monitor the input temperature to the monitored device.

   The thermistor is a small thermoplastic cylinder that is attached to the water line with a tie-wrap. Thermal compound must be applied to the thermistor's concave mating surface to improve thermal conductivity. The thermistor must be insulated from the surrounding ambient air for an accurate read.

   The meter measures one device or one hydronic circuit (air handler, fan coil or baseboard heating assembly connected to one zone valve).

If the measured unit is a fan coil or air handler, the fan must be set to deliver **a fixed amount of airflow** at all times. Multi-speed fans must have their fan speed selector removed and then "hard-wired" for constant speed delivery. Any speed may be selected as long as the delivered BTU is known for the particular speed selected.

As was mentioned above, BTU transferred from a forced air device is directly related to CFM delivered.

BTU Calculation Method for Baseboard Heat:

We will cover baseboard heating first, since it is the basis for the fan coil calculation.

First we must know the **BTU rating per foot of the installed baseboard assembly**. Most baseboards are rated at one (1) and (4) gallons per minute of water flow.

As an example, a new "clean" baseboard unit will transfer 680 BTUs of heat per hour at a room temperature of 68°F with a water temperature of 200°F at 1 GPM of water flow.

Transfer = 680 BTU/Hour
Room Temperature = 68°F
Water Temperature = 200°F
Water Flow = 1 Gal/Min

Since most of the installs will involve existing systems with some amount of age, missing or bent fins, partially closed convection dampers and/or dirt accumulation, and the room temperature will probably be higher than 68°F, we will **assume a transfer rate of 550 BTUs per hour, per foot**.

Transfer Rate = 550 BTU / Hour / Foot

We then measure the **actual length of the baseboard** and take this result multiplied by the BTUs per foot. The result will be the total BTUs transferred at 200°F. A ten-foot (10) length of baseboard would then transfer 5500 BTUs per hour.

Baseboard length = 10 Ft.
Transfer Rate = 550 BTU / Hr / Ft
Time = 1 Hr
Heat transferred = 5500 BTU

The meter breaks down the data to one pulse every 36 seconds for a measured temperature of 200°F. The 36-second increment is derived from 100th of an hour (60 seconds X 60 minutes = 3600 seconds = 1 hour).

So, if we take the above baseboard example and apply it to this equation, then one (1) meter pulse equals 5.5 (550/100) BTUs per foot of baseboard or 55 BTUs for a ten-foot section.

As the water temperature decreases, the pulse interval increases at a linear rate; however, the pulse will still equal 5.5 BTUs of heat energy transferred (it takes a longer period of time to transfer the same amount of heat energy at a lower delivery temperature).

At 180°F inlet temperature, the meter pulse will occur about every 50 seconds. At 90°F, the meter will pulse once every 360 seconds or 10 pulses per hour. As can be seen by this method, any known, rated baseboard of “X” length can be metered by this system as long as a zone valve is installed to provide “on-off” control of water flow. The transferred BTUs per measured unit can be changed to match the output of the system to the output of the total baseboard, as needed. Once this number is established, it should not be changed.

BTU Calculation Method for Air Handler or Fan Coil Units:

The method is almost identical to the baseboard calculation, except we are dealing with forced airflow instead of convection/radiation heat delivery. We can also meter cooling BTUs with these units.

If we know the **rating of the unit in heat mode at a specific airflow** at 200°F input water temperature, we simply divide this rating by 100 to give us the BTUs per 36-second interval. So, if we have a 60,000 BTU rated unit, we then would deliver 600 BTUs per 36-second interval. The rest is the same as above.

In cooling mode, the meter operates in similar fashion. At 38°F inlet water temperature, the meter is configured to pulse once every 120 seconds or 30 pulses per hour. At 58°F inlet water temperature, the meter is configured to pulse once every 240 seconds or 15 pulses per hour. The pulse interval lengthens as the inlet water temperature warms and shortens as the water temperature cools (inverse of heating mode). Since the scaling is linear, 25 pulses in one hour will be generated for a water temperature of approximately 45°F. In cooling mode, the 120-second interval is .0333 of an hour. Let’s assume that the above coil is rated at 1.5 tons (18,000 BTUs) of cooling at 45°F water temperature, then one pulse would equal 720 BTUs (18,000/25) of total cooling (sensible + latent). As in heating mode, the pulse always equals a set amount of heat transfer regardless of water temperature; in this case 720 BTUs.

BTU Output Calculation Method for Unknown Fan Coil or Air Handler:

HVAC equipment is rated based on the equipments heating and cooling inputs and outputs. The standard ratings are established under standard rating conditions. All standard ratings are verified by tests conducted in Independent Laboratories in accordance with the established standards. If the unit does not have a rating plate the ratings may be estimated utilizing a parallel FCU rating based on motor size, and coil size or it can be calculated from the unit's output.

If the unit does not have a rating plate or if no information is available as far as unit rating is concerned, then we can calculate the unit's output rating. We would also need to calculate the output, if the fan has been changed from the original. Since the calculation is more accurate in heating mode due to latent heat gain issues in cooling mode (humidity), we will utilize the heating formula. The formula for heating output is expressed as: BTU = CFM X 1.08 X (T2 - T1).

Where: CFM = Cubic Feet per Minute of Airflow
T2 = Leaving Air in Degrees Fahrenheit – Dry Bulb
T1 = Entering Air in Degrees Fahrenheit – Dry Bulb

To calculate CFM, we would do the following:

1. Measure the free air space of the return air grille and solve for equivalent square inches (typically L X W of grille in inches X 50%).
2. We then divide the result by 144 (square inches per square foot) to get the equivalent in square feet.
3. We then measure the average air velocity at the return air grille with an aerometer measuring in feet per minute. Our free air space in square feet times air velocity in feet per minute = CFM.

If there is an open plenum ceiling type of air return where a return air measurement is not possible, measure each supply register utilizing the same method as above, then total all results for the total CFM delivered.

Next, we measure the return air and supply air temperatures and the coil entering water temperature. With the total CFM and the measured inlet/outlet dry bulb temperatures, we then can solve for BTUs delivered at the measured water temperature (per the above formula). We must then convert this result to the rating at 200°F coil inlet water temperature.

Let's assume that the measured inlet water temperature is 140°F. The range of the meter is 90°F to 200°F, so the span is 110°F. The measured inlet water temperature is 140°F, which is 50°F span from the bottom of the meter range. Let us also assume that the BTU output at our measured temperature equals 20,000 BTUs. To solve for BTUs at 200°F:

Measured BTUs times Meter Span divided by Measured Span = BTUs at 200°F

or

20,000 X 110 / 50 = 44,000

Therefore, our coil is rated at 44,000 BTUs per hour output at 200°F.

Cooling mode output with the same coil (2-pipe system) is typically, approximately 38% of the heating output (latent + sensible or total cooling).