Case Study : Comparing Method of Heater Control

This case study compares On-Off heater control with modulating (Simmer) control in flat decks. The data is taken from sample flat decks on two different farms with Dicam control and monitor networks. The ages of pigs and general design is similar.

Both farms use dull emitter type electric heaters, but on one farm, the controller is set up for simmer control and on-off in the other.

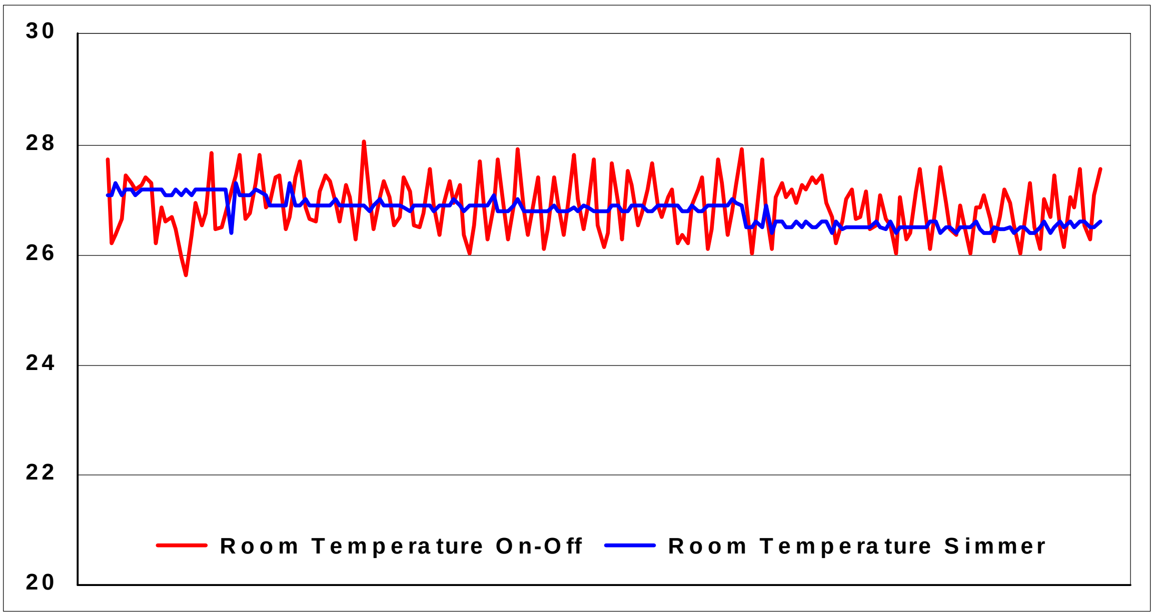
On-Off Control

On the farm with On-Off heater control, the control set up has an Offset and Band set to 0.5ºC and 0.5ºC respectively.
Heating is switched off when temperature rises to within 0.5ºC of Set Temperature (the Offset). Heating is switched on when room temperature falls 0.5ºC below this value (the Band).
Apart from the Offset (intended so that ventilation control and heat control do not overlap), this works in exactly the same way as mechanical thermostats. A temperature change is required to switch the heater on or off (hysteresis).
If not temperature change were needed to cause a thermostat to switch on-off - that is, the temperature change were infinitely small - a thermostat would "flutter".
In Dicam control, offset and band are both adjustable (in 0.1º steps), so the temperature response is exactly predictable. With mechanical thermostats, only the temperature is adjustable. In practice the on-off differential gets bigger with age in thermostats (hysteresis increases).

Simmer Control

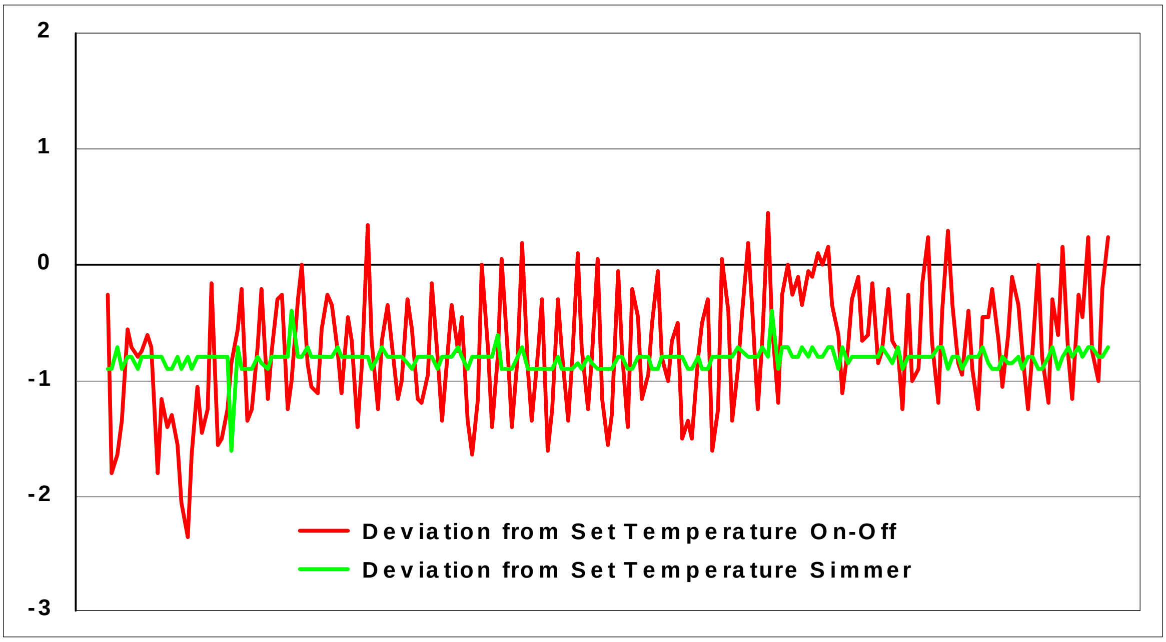
Simmer control also has an Offset and Band, just like On-Off control, the difference being that when room temperature is within the band, heating level is proportional. (In this case, the Offset and Band are both 0.5ºC, as for the On-Off control).
That is, between 0.5ºC below Set Temperature and 0.5ºC below that (1.0ºC below Set temp), Heating level is set to between 0% and 100%. For example, at 0.7º below Set temp, heating level is 40%.
Simmer control achieves this proportional control by time cycling the heater. For example, to achieve 10% heat, it switches the heater on for 10% of the time - say, 6 seconds in every minute.
Dicam simmer control has a fully adjustable time cycle, with an additional "Feed Forward" feature. Feed forward means that when temperature is falling (required heat level is increasing), the "On" part of the time cycle is made first, but when temperature is rising (required heat level is falling), the "Off" part of the time cycle is made first, and changes can be made without a full tie cycle being completed.
For example, if heating level needed is 10%, it switches it on for 6 seconds and off for 54 seconds. Or on for 12 seconds and off for 108 seconds (whatever the time cycle is set to). However, if the controller decides more heat is needed during the off part of the cycle, it can start the cycle again, with the on part first.

Temperature Control



This chart shows temperatures in the respective rooms. (Note actual set temperatures differ marginally, but here have been scaled/adjusted to the same value for clearer comparison). The period covered is about 2 days, and in both cases, set temperature it dropped slightly, twice, according to a set temperature curve.

It can seen immediately that the Simmer controlled room stays relatively constant, whilst On-Off control swings either side.

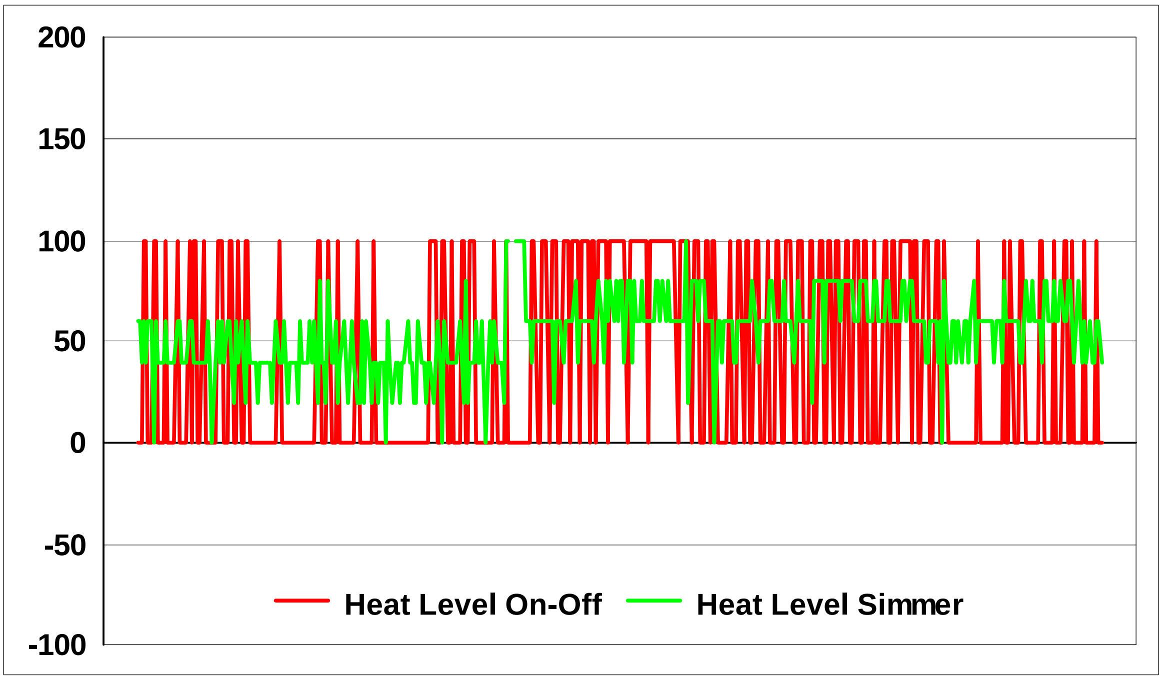


This charts shows temperature as deviation from Set. The Simmer controlled room stays always within the operating band (0.5 to 1.0º below set), whilst the On-Off room swings much more widely.

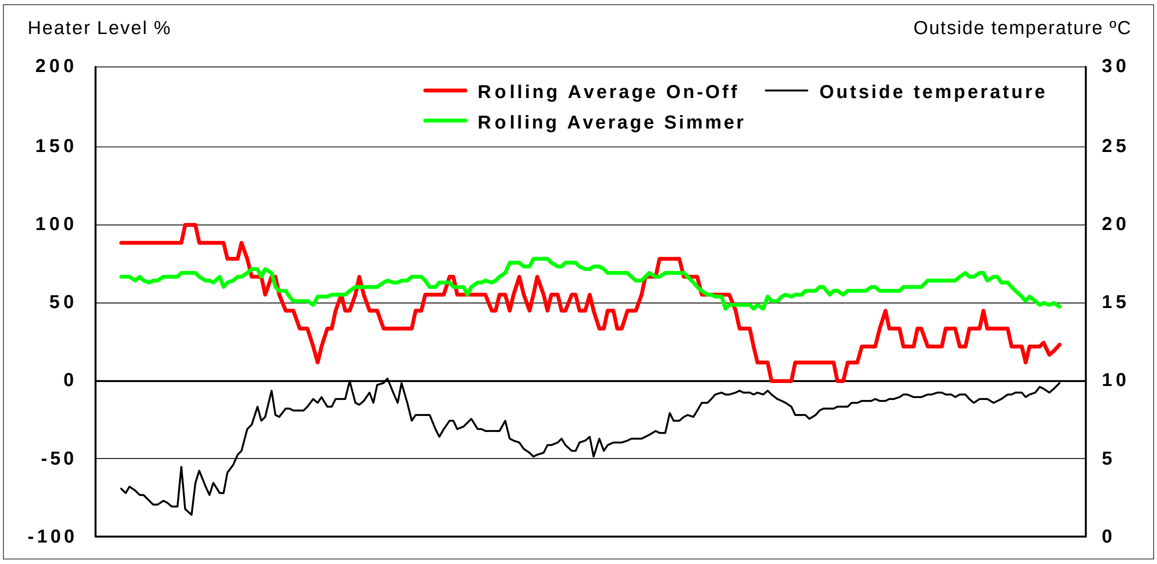
The mean temperature and mean deviation from Set temperature is the same in both cases. Of particular note is that the On-Off control deviates sometimes above Set temperature (i.e. above 0).

Heater Level

This shows heater level (over the same period). Simmer control has levels between 0 and 100% (and rarely goes to either 0 or 100%). With On-Off control, it can only be either 0 or 100%. However, you can see that the lines (when it switches 0 - 100% or vice versa) are more or less densely packed. Sometimes it is more on than off, and sometimes it is more off than on.

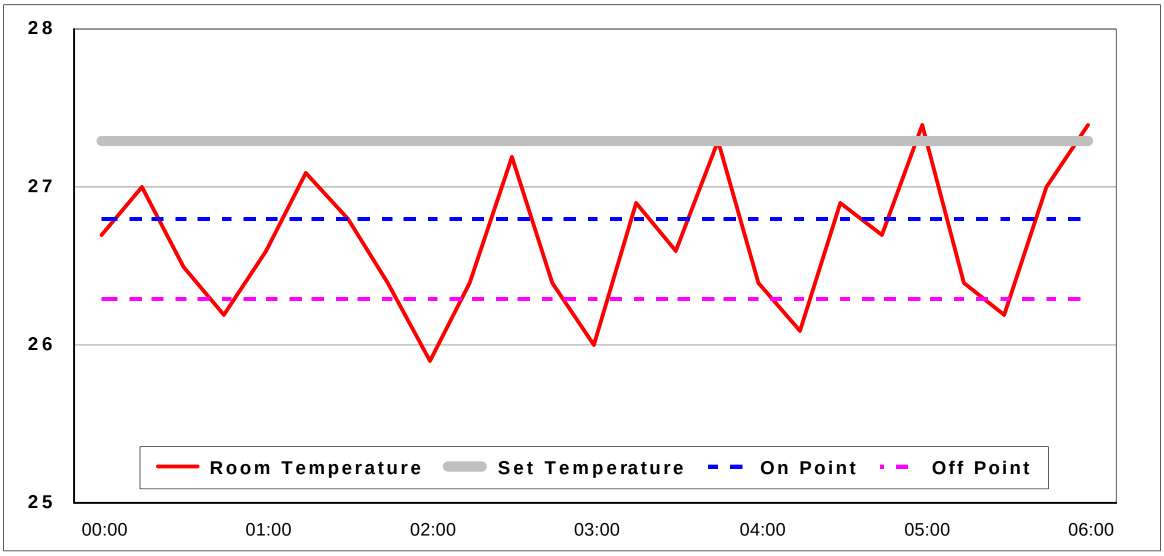


In this chart, the heating levels have been averaged over two hours, showing how the mean heating level varies for On-Off, just as for Simmer. Heating level is actually responding to a combination of outside temperature changes and animal heat output.



Overshoot, Undershoot and Thermal Mass

The reason for temperature swings with On-Off control is because of the thermal mass of heaters and associated building components.
If, say, temperature is slightly above the heater offset, the heater is switched off. Heat loss from the building continues, and room temperature gradually falls. At the chosen point (Offset plus Band), the heater is switched on, but it takes some while for the heater to warm up because of its mass. During this time, heat is still being lost by the room, and room temperature continues to fall. Eventually, the heater becomes sufficiently warmer than the room that heat is emitted, and so the room starts to warm up, eventually reaching the switch off point for the heater. However, the heater is now much hotter than the room, and continues to emit heat, so room temperature continues to rise. After a while, the heat in the heater is dissipated, it falls to room temperature, room temperature falls, and the cycle starts all over again.
This results in so called "temperature overshoot and undershoot" - exhibited quite clearly in the On-Off control, but by no means evident in the Simmer controlled room.



In the On-Off room, this cycle appears to be around 2 hours. (It may be shorter. Logging is at 15 minute intervals, so it's possible there are intermediate swings not shown in the logging. However, it appears to be sufficiently regular as to suggest this is the actual period.)

This is much longer than one would expect from the mass of the heater, and may be due to other factors such as warming up other parts of the building structure such as the walls, floor and ceiling.

Impact and Significance

Average room temperatures appear to relatively similar, and so - if the temperature swings have no particular impact on the process being ultimately controlled (i.e. the growth of the animals) then they may be of interest, but of no importance.

In this case, the only factor would be the occasions when temperature overshoots set temperature, and ventilation might be increased, thereby increasing heat loss and increasing the heating costs.

With radiant heaters (even dull emitter types), there is a secondary effect, not shown in the air temperature logging, but which can be deduced.

The total amount of heat produced by the heater depends only on the power level. That is, a heater using 1000W provides twice as much heat as one using 500W. It doesn't matter whether this is a 500W heater or a 1000W heater at half power.

However, radiant energy depends on the temperature of the heater. The higher the temperature, the greater the proportion of total heat emitted as radiation (the balance being emitted as convection).

In the case of the On-Off heater which - presumably - at some times reaches maximum temperature, there will be times when radiant energy is high, but then when it cools down, it will be none at all.

Hence, the perceived range of conditions for animals lying underneath the heaters will be much greater than is shown by air temperature alone.

According to the logging data, animals in the room with Simmer control experience only mildly changing conditions - air temperature is marginally higher or lower by a fraction of a degree, and radiation similarly, changes only marginally. Animals in the room with On-Off control experience some swings of temperature, but larger swings in radiant energy, if lying underneath the heater.

The impact of changing air temperatures on animal performance - as opposed to constant temperatures - is not at all known in quantitative terms. Although, subjectively and anecdotally, it is believed and reported that more "constant" and "even" are "better for the pigs" or "they are more comfortable", there are no quantities attached. There is no particular definition of even or constant - is a 1ºC range constant? All systems do vary in temperature marginally throughout a day, depending on whether it is warm or cool outside, and so on. If it does have an impact on pigs - how much, and in what way?

Varying temperatures can be regarded as an environmental stressor. That is, it is something which acts upon the pig, to which it has to respond. For example, if it is lying under the heater, receiving a certain amount of radiant heat and it is switched off, it must adjust in some way or other to control it's body temperature - changing position, etc. Small changes in the perceived environment need only minor, perhaps unconscious, adjustments such as changing blood flow. More significant changes need greater and more conscious adaptive changes. It is not at all clear where the border, if there is one, may lie.

If there is any impact on animal performance or behaviour, it would be likely to be greater for younger animals, who have less well developed mechanisms for dealing with environmental changes and a lower body mass, which reduces their own thermal time constant. The effective stress, if any, would be likely to be unequally distributed through the population. More dominant animals would be likely to seize the more desirable situations, so that less dominant animals would be subject to greater stresses.

In the case of the On-Off controlled room, it is not a question of a poorly controlled environment - the room achieves the right temperatures on average, and operates within parameters which, generally, are considered acceptable. Rather, it is the evidence there is something which sits outside our general model of pig performance.

In the absence of any specific information, one can take two approaches.

The first approach is to assume that the air temperature and radiant energy swings don't matter. That is, unless there is specific evidence that it does matter, to assume that it doesn't. The general flaw in this approach is that you then have no particular way of knowing whether you are right or wrong. A general problem with pigs is that they will adjust, or try to adjust to whatever conditions they experience. This doesn't mean that particular factors have no effect, but such effects as there are may be masked.

If taking this approach, no action is required. The general temperatures appear adequate, and there is no evidence (from logging at least) that the temperature swings shown are harmful. If it ain't broke don't fix it.

The second approach is to assume that such environmental swings do matter, unless you are sure they do not - guilty unless proved innocent, as it were. Temperature swings have been detected, radiation swings have been deduced, and whilst there is no evidence it is detrimental, there is a reasonable argument that it could have an effect.

If using this approach, the action would be to use all reasonable efforts to try and improve the present situation at the least. To make it as good as can reasonably be achieved, despite the lack of evidence. A more measured approach would be - since the On-Off room is just one of 8 such rooms, to try as hard as possible to "improve" at least some of the rooms, and to measure if possible whether there is a detectable improvement in pig performance outcomes.

Simmer and Dimming Control

Simmer control achieves modulating heat output by time cycling - on or off - over a period of typically one or two minutes. For example, 6 seconds out of one minute, for 10%.
Dimming, by contrast, gives a modulating heat output in much the same way - time cycling - but giving portions of 10 milliseconds (each half cycle of the mains) - for example, 1 millisecond out of 10, for 10%. (Actually, not quite that, as mains voltage is sinusoidal, but the same principle).
The thermal mass of the heater acts as a "buffer" which accumulates the heat so that the heater temperature does not go up and down, although the input power does. Lamps have a very low thermal mass, so they need "dimming" - turning on and off very rapidly. Dull emitters have a large thermal mass (when you switch them on, they take a long time to warm up) and so they don't need to be switched on and off so rapidly.
Apart from the time cycle, dimming and simmer have just the same effect.
Dimming needs triacs - semiconductors which switch rapidly - but simmer can be achieved with contactors or triacs.

Cost of changing from On-Off to Simmer control

Using Dicam controls, dull emitter electric heaters (such as "black bar" or "ceramic") can be configured for On-Off or Simmer or Dimming control. (For dimming control, triac drivers must be used, but for On-Off and Simmer, either triac or contactors modules can be used.)
With dull emitters, there is little point in using Dimming, as the effect is no different from Simmer.

The only potential cost implication for the farm (apart from the couple of minutes taken to change the setting) is that, since time cycling will mean more on-off switching cycles, the contactors may wear out more quickly.
Contactor life depends on a number of factors including the current being switched - for the type of contactors used, the life may be between 10 million switching cycles (no load) down to 100,000 (full rated load). Typical life expectancy would be, say, 500,000 to 1 million operations.

If the units were set to a 2 minute cycle, and always did a cycle every two minutes, this would amount to 262,000 operations a year, and so the contactors would be expected to last just two years. (Meaning extra costs of, say, £2 to £5 per year.)
In practice, in properly controlled circumstances in flat decks, supplementary heat is only needed for around a quarter of the time or less, so contactor life should be around 10 years or so, and the increased rate of wear is relatively marginal.
If triac switching modules were used instead, operating life would be not affected at all, as there is no particular wear mechanism. (When used for dimming, triacs switch around 3 billion times a year, so the odd million switching cycles here or there don't matter at all.)

Triac switching modules are preferable where practical - because of lack of wear (indefinite service life), "cleaner" switching with resistive loads and voltage tolerance. Because switching is virtually instantaneous (if properly set up, at mains zero voltage), there is no "switching surge" when used with resistive loads. Farm electricity supplies are often weak, suffering more from low voltage than domestic or commercial situations. Triacs are unaffected by low voltage as compared to contactors, which may suffer from dropout problems, or higher wear due to inadequate voltage.
Triac modules are, however, marginally more expensive, require more care in rating and installation, and many installers prefer what they regard as "simpler" contactors.

Electric heating offers several control options, but other types of heating have fewer or no options. For example, direct combustion gas heating can only be controlled on-off. Some gas heaters offer two stage heating, though this is more expensive to control as it needs more control circuits.

Review

This case study compares just a sample room on two otherwise comparable sites with flat deck rooms, one with On-Off control, and the other using Simmer.

The logged temperatures indicate that more constant conditions are achieved using Simmer control. On-Off control tends to exhibit temperature swings, due to control switching oscillation, which are likely to result also in changes in the radiant environment for the pigs housed.
The temperature oscillation is not an indication of a fault or problem with the Dicam controller on the site concerned, but is the inherent nature of On-Off control. The temperature swings are not large in an absolute sense, but the logging shows that it can be avoided by changing the set up from On-Off to Simmer.

Data is not included here, but similar patterns - often with a greater range of values - of temperature oscillation are observed in other installations (with other makes or types of heater controls).

The temperature oscillation may or may not have any impact on pig performance but, unless very minor, there is reason to suppose it may have an impact on either some or all of the pigs housed. Therefore, it would appear to make sense to reduce or avoid them if practical.