Case Study : Assessment of Supplementary Heat

This document examines methods of assessing heater use using Barn Report data.

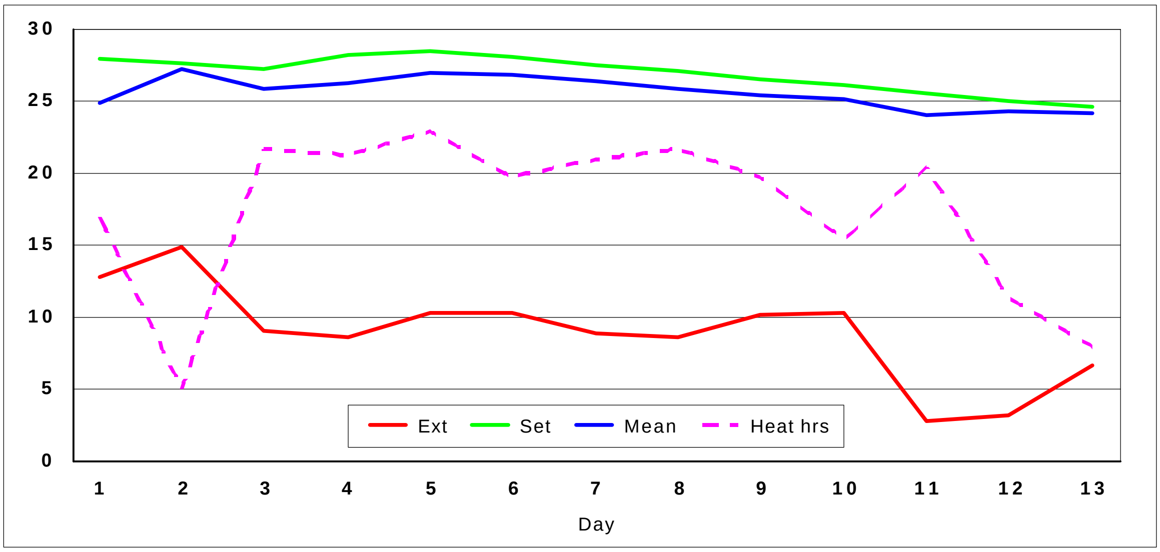
Background

Flat deck of 150 pigs with 2kW supplementary heating. Data from the beginning of a batch. Heating is controlled on-off, and so there is a sampled nature to heater usage.

Date	Ext	Set	Mean	Heat hrs	Fan%
2001-10-29	12.81	28	24.94	17	16.2%
2001-10-30	14.98	27.69	27.29	5	16.4%
2001-10-31	9.05	27.3	25.86	21.75	16.7%
2001-11-01	8.73	28.2	26.35	21.25	17.1%
2001-11-02	10.38	28.5	27	23	16.3%
2001-11-03	10.31	28.1	26.81	19.75	16.0%
2001-11-04	8.97	27.63	26.46	21	16.7%
2001-11-05	8.74	27.13	25.84	21.75	17.0%
2001-11-06	10.22	26.63	25.46	19.75	17.7%
2001-11-07	10.3	26.13	25.22	15.5	18.7%
2001-11-08	2.88	25.63	24.1	20.5	15.6%
2001-11-09	3.31	25.13	24.35	11.5	14.9%
2001-11-10	6.8	24.7	24.27	8	16.1%
2001-11-11	10.45	24.3	24.39	0.5	19.5%

Data is taken from the batch function in Barn Report.
Ext = Mean daily ambient temperature
Set = Mean Target temperature
Mean = Mean daily room temperature
Heat = Daily heating hours
Fan = Mean fan speed (as controlled)

Temperature and heater use summary



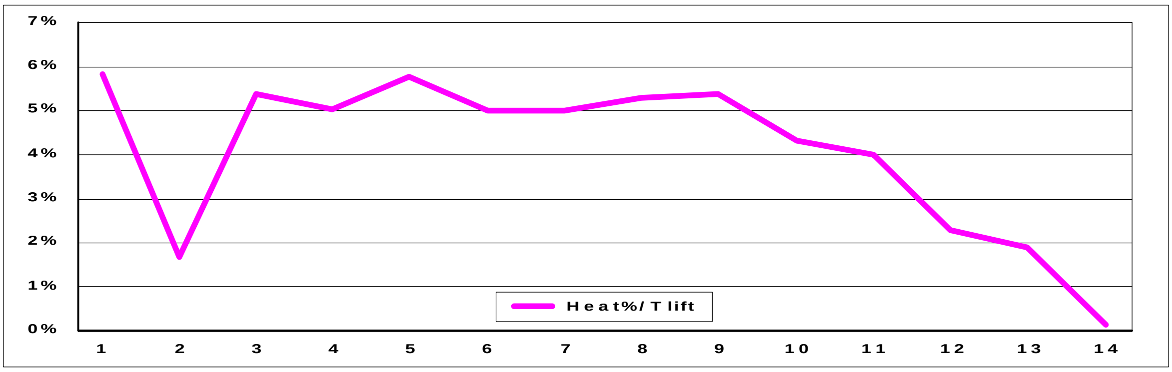
This graphical presentation of the summary data shows us that room temperature runs, on average, a little below set temperature - mostly due to heater control offset - and that it maintains temperature reasonably well.

Note that the heater use is substantially down on Day 2 - presumably due to higher ambient temperature, and that heater usage falls away towards the end of the chart.

Whilst this shows us that the situation is generally satisfactory during the period examined, it gives limited insight into the underlying factors, not least because several things are changing at once - target temperatures, ambient temperature, age of pig and so on.

The following pages illustrate ways to examine these issues.

H K and DT



In principle, the situation is :

Temperature rise above ambient is proportional to heat produced or added in the room or :
$\Delta T \propto H$
or
$\Delta T = H.k$

Where k is a constant or expression for rate of heat loss.
If other factors were constant then :
$k = H / \Delta T$

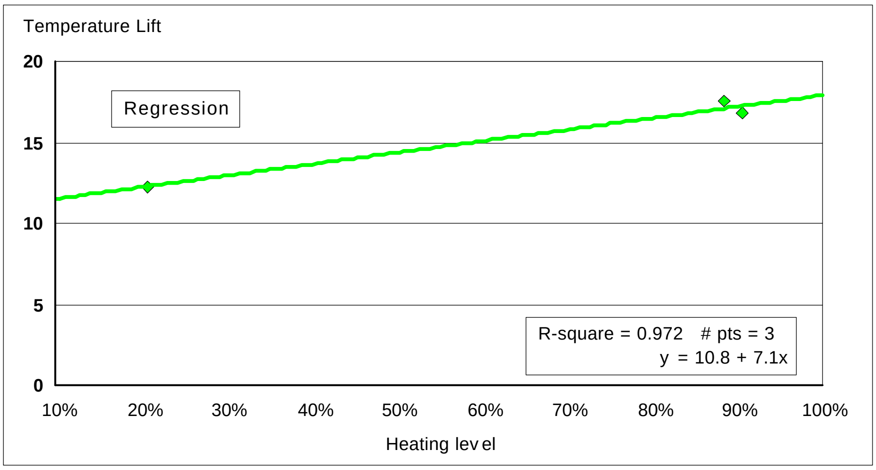
The above chart shows this calculation applied to the data. (Heating hours as a percentage Heating Hours/ 24).

As we can see, it is approximately constant from Day 3 to Day 9, but falls away thereafter, and Day 2 is much lower.

The reason is that H is not just supplementary heat, but includes animal heat as well.
I.e.
$k = (H_A + H_S) / \Delta T$

where
H_A = Animal heat output
H_S = Supplementary heat

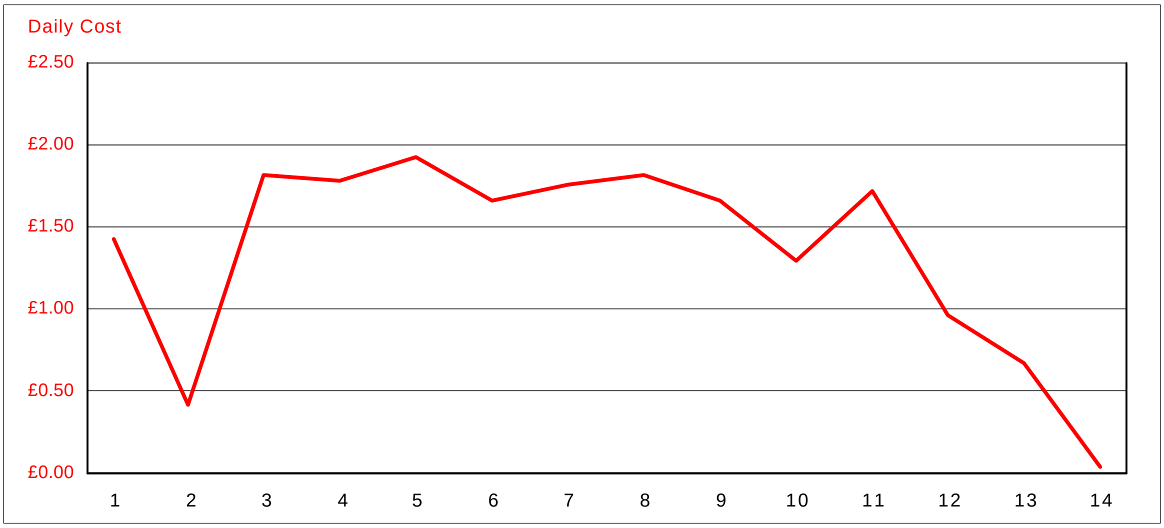
The dip in heat requirement on Day 2 gives us a way of estimating animal heat output, by estimating the temperature lift without any supplementary heat input. This chart shows regression over the period Day 2 to 4 (when we judge animal heat output has not changed much).



This indicates that temperature lift without supplementary heat would be 10.8ºC, and that full supplementary heat would add a further 7.1ºC. (That is, a total temperature lift of 17.9ºC.)

We can therefore estimate animal heat output :
The rooms hold approximately 150 pigs and heating capacity is 2000 W.

From the above regression, animal heat output is approximately
2000 W x (10.8 / 7.1) = 3042 W
= 20.3 W per pig



Over this period, the total heating cost is estimated at **£19.01** (@ £0.042 per unit) - about 12 pence per pig, or 3.02 kWh.

According to our calculation, 2000 W would give a temperature lift (on it's own) of 7.1ºC.
k = 2000 / 7.1 = 281 W per ºC

That is, the characteristic rate of heat loss from this room (with the ventilation rate as presently used) is 281 W per ºC.

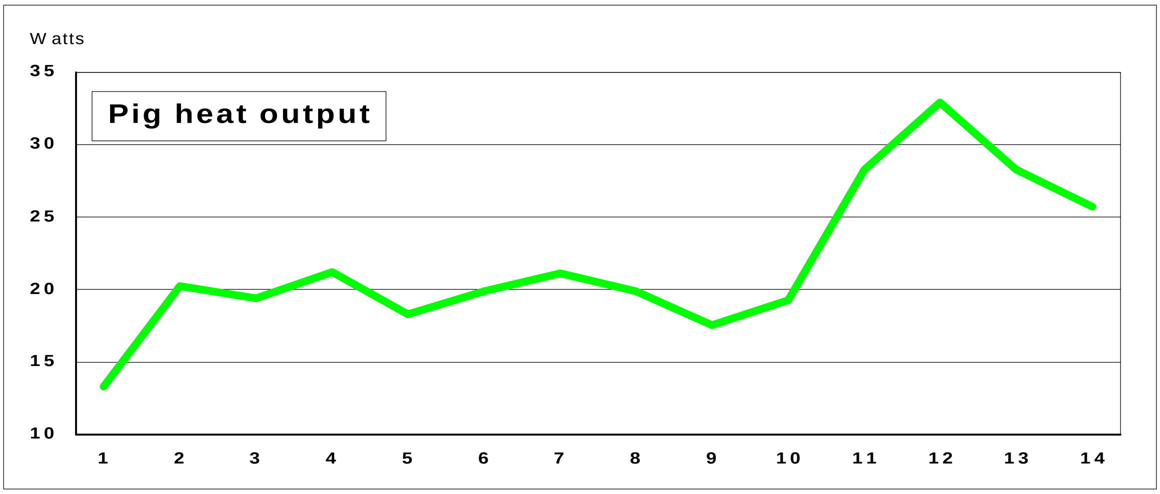
Changing the set temperature marginal over this period would increase or decrease supplementary heating requirement (since animal heat output can be regarded as fixed).

Increasing or decreasing set temperature by 1ºC (assuming sufficient heat capacity is present and properly controlled) would increase or decrease supplementary heating requirement by about **£3.97** per batch, or **2.67pence/pig/ºC**.

Ventilation rate
Using a rough estimate of 200 m2 surface area with a U value of 0.5, an overall heat loss of 100W /ºC would be expected.
The ventilation heat loss, correspondingly is estimated at 180 W /ºC.

Ventilation rate, accordingly, is calculated as 540 m^3h^{-1} (cubic metres per hour) or 3.6 m^3h^{-1} per pig.
The room has a 450mm fan with a notional throughput of 5000 m^3h^{-1} so the actual ventilation rate is 10.8% - this is marginally lower than the given fan speed of 16 to 17%, which may be due to an uncalibrated fan, or the nature of the ventilaiton system..

Animal Heat Output



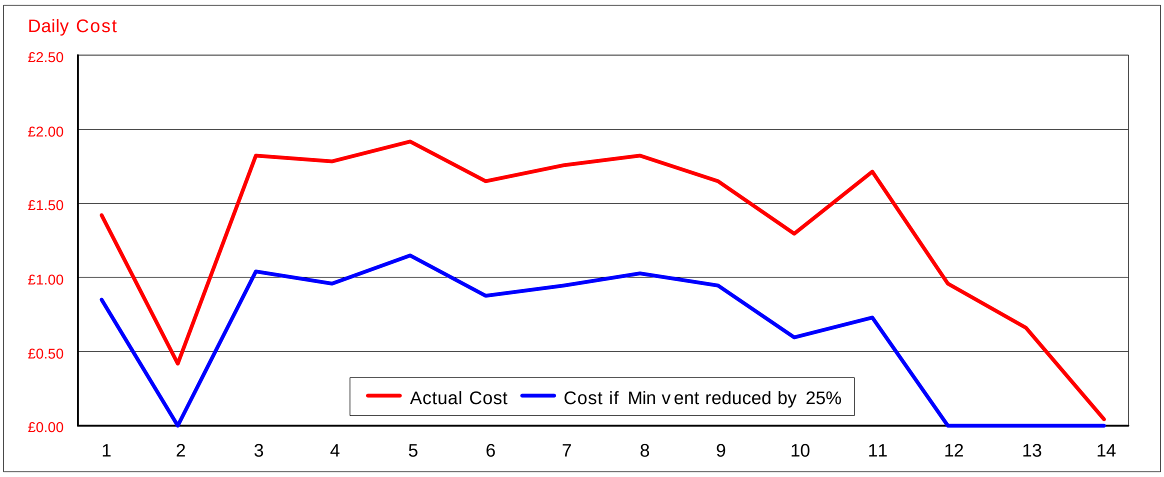
The above chart is derived by subtracting the temperature lift due to supplementary heating from the total temperature lift and calculating the animal heat from the k value of 281 W/ºC.

The basic problem with this calculation is that it assumes the 281W/ºC value remains the same. Referring back to the ventilation levels, it can be seen that these are actually changing marginally, which will therefore change the k value. (Thus, it is probably not actually higher on Day 12 than on Day 14).

Nevertheless, it can be seen that animal heat output appears to rise rapidly after Day 9, although it is approximately constant up to then.

It would be interesting to know whether this change is related to a change a feed ration and, correspondingly, whether an earlier changeover could be achieved.

The minimum ventilation rate is somewhat higher than "book values" indicate are necessary for small pigs - over twice suggested values.



Using the estimated pig heat output, we can calculate the supplementary required if minimum ventilation rate was reduced marginally (as above)

Reducing ventilation rate by 25% (of the present value) to 2.7 m^3h^{-1} per pig would reduce overall heat loss to approximately 235W/ºC, reducing supplementary heating requirement by 52% (to £9.18 for the batch) saving 6.5 pence per pig.

General Discussion

Producers rarely know the characteristics, capabilities and limitations of their buildings and environmental control systems in a quantifiable way.

Capital decisions - such as whether to improve this or that, what insulation values to use - and operational decisions - what set temperatures or ventilation rates - are therefore made on the basis of guesswork, habit, or generalised advice from other sources (which or not be based on hard fact).

A most important point is that one should look at the performance and capabilities of a system as a whole as it is being used. The method should not be regarded as especially accurate, but it nevertheless give some basis for realistic assessment of systems "as is", rather than theoretical estimates of what "should be" since actual operation often deviates significantly from intentions.

In this study, estimates have been made - based on partial data and some educated guesses - on such factors as heat loss rate, animal heat output, structural and ventilation heat loss.

It should be mentioned that a simplified model has been used, and no great accuracy is claimed. Also, some skill may be needed to select appropriate data. Nevertheless, the methods appear to give reasonably usable results in management terms.

Hitherto, the cost and effort in making such measurements and, perhaps, the technical knowledge required to analyse the results, have acted as a significant disincentive to such analytical methods in the general production situation.

Now, with Dicam and Barn Report, data logging is now cost effective and available to all, and the ready distribution of data means that external analysis becomes more practical and lower cost.

In this case, the estimates have been made purely on the basis of "incidental observations". That is, nothing has been changed in order to obtain the raw data, it has been merely analysed "as is". This leads to some question marks over values such as specific heat loss.

Establishing these may be relatively straightforward. For example, running the room with normal minimum ventilation, and heating controlled but with no pigs, means the k value can be calculated more accurately.
Repeating the process with varying values of ventilation - including none at all - means that the structural and ventilation heat loss components can be calculated separately.

Characterising the system (in terms of heat loss and varying ventilation rates) means that the room is, effectively, a calorimeter. This may have lasting benefit to the producer as changes in both room and pig characteristics can be tracked in the longer term.

It should be pointed out that this particular building appears to perform well by general standards, with good control of ventilation, and relatively low heat use.
However, it is clear that the heating capacity is somewhat undersized, given it only appears to have a temperature lift of about 7ºC. Even though ambient temperatures were not especially low during this period, the room was obviously struggling to hold temperature. In colder weather, the room may significantly fail to achieve desired temperatures with younger pigs.

The fact of a room "usually" maintaining temperature (for example by looking at max and min temperatures) gives no guide as to whether it will do it even in lower ambient temperatures. Measuring heating use (by logging), gives a much more accurate guide.

The fact that heater use has - in this case - been estimated with sampling (96 times a day) or on or off status, gives useful data, but with a relatively high level of uncertainty (possible sampling errors).

Greater accuracy (lower uncertainty) would be given were the heating controlled proportionately (variable level such as Dicam "Simmer" control) or using mains detectors (MD2 modules) for direct measurement of on-time.
There remains some uncertainty due to variations in mains voltage and/or uncertainty over heater ratings - pulse interface electricity meters, connected to Dicam units would give higher accuracy since they account for such variations. However, the output estimation methods are cheaper and simplerand probably accurate enough for comparative assessment.

With the method given above, animal heat output can only be assessed by reference to heater use. That is, some heating must be used in order to calculate its effect, and by correlation, the animal heat output.

If the ventilation system were "characterised" for heat loss at different levels as suggested above, animal heat output could be measured right across the production range.

To assess actual heating requirements more accurately, the annual profile of ambient temperatures must also be considered.

Summary

This case study illustrates quantitative methods of assessing heating use and capacity, as well as the underlying factors which affect it in a practical situation.

The characteristic rate of heat loss at minimum ventilation for this room is about 281 W /ºC, and the effects of marginal changes have been calculated.

In the case studied, heating capacity is barely adequate for the circumstances and substandard temperatures are liable to occur in colder weather with young pigs unless minimum ventilation rates are changed.

Heater use has also been used to estimate animal heat output, which is a crucial factor in the equation. Since animal heat output is directly affected by feed intake, it should be possible to cross-correlate heat use/production and growth rates.

In this case, animal heat output seems not to increase until after Day 9, which is probably related to feed ration.

With a little more work to characterise the system, animal heat output estimates could be carried out over a wider age range.