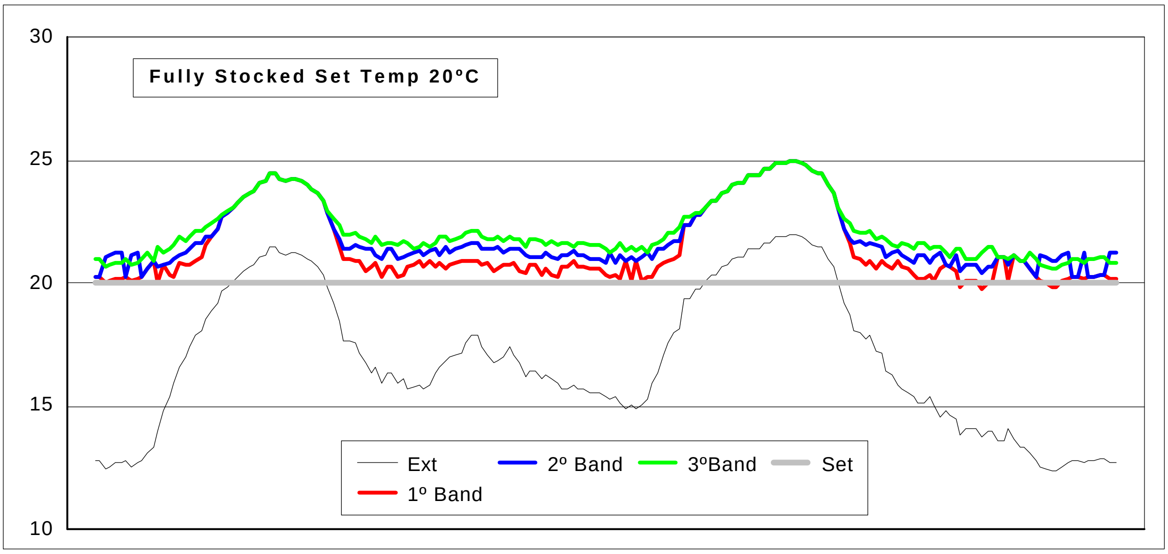
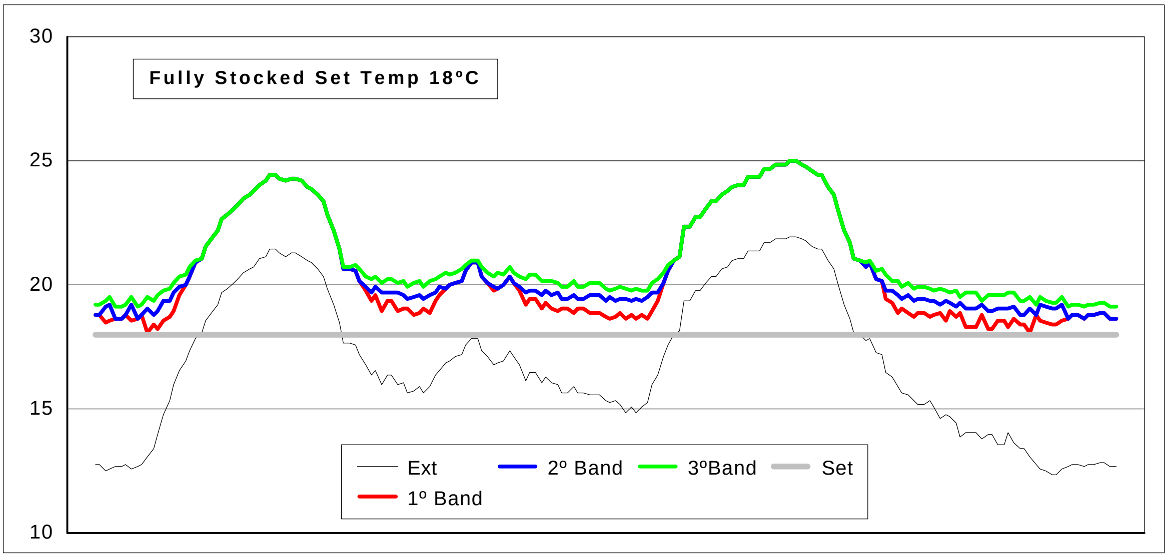
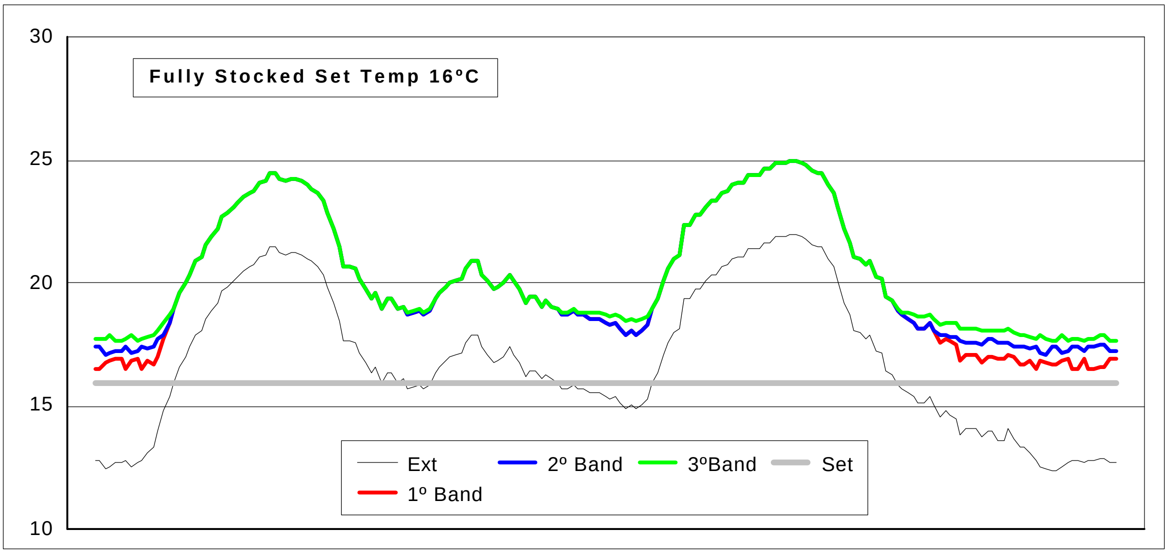
Effect of Set Temperature, Proportional Band and Stocking Level on Actual Temperatures and Fan Power Requirement







The preceding charts show the (calculated) effect of changing set temperature and proportional band in a fully stocked pig building in mild spring autumn weather over a period of two days.
The calculation is based on calculating the closest match of ventilation rate (according to the set temp and prop band "rules" for the system, and then resulting actual temperature by a standard calculation. Calculations are based only on ventilation heat loss.)

In the first chart, for example, you can see that changing the proportional band to 3ºC (that is, full ventilation is not reached until room temperature is 3ºC above set temperature) as compared to 1º or 2º. The control system achieves a "balance" whereby the temperature deviation (above set) is just enough to balance with proportional band ventilation rate
Note that this higher proportional means that it runs slightly warmer at intermediate ambient (Ext) temperatures than with a lower band.
Temperature lift at maximum ventilation rate is 3ºC. So when it reaches 20ºC outside, it makes no difference which proportional band is used. Ventilation is at maximum, and thereafter inside temperature tracks outside temperature, but 3ºC above.
Whilst temperature deviations from set are greater with a wider prop band, temperatures are more stable as it can achieve a closer match to requirements.
Note also that the temperature transition from "controlled" (variable speed) to "uncontrolled" (full speed) is much smoother with a wider band.

Subsequent charts show the effect of reducing temperature on actual temperatures. The results are summarised in the following tables.

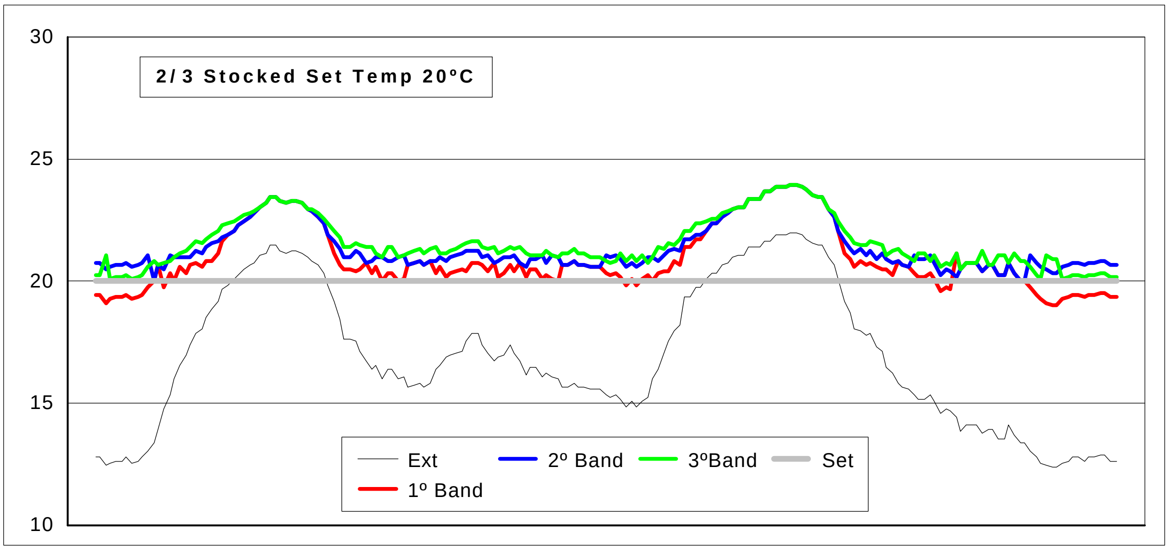
Set Temp	***20ºC***			***Fully Stocked***		
Ext	Temperature			Fan power		
16.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	21.50	21.90	22.18	74%	69%	65%
Compared to 3º band	**- 0.69**	**- 0.28**		**+ 13.8%**	**+ 5.6%**	

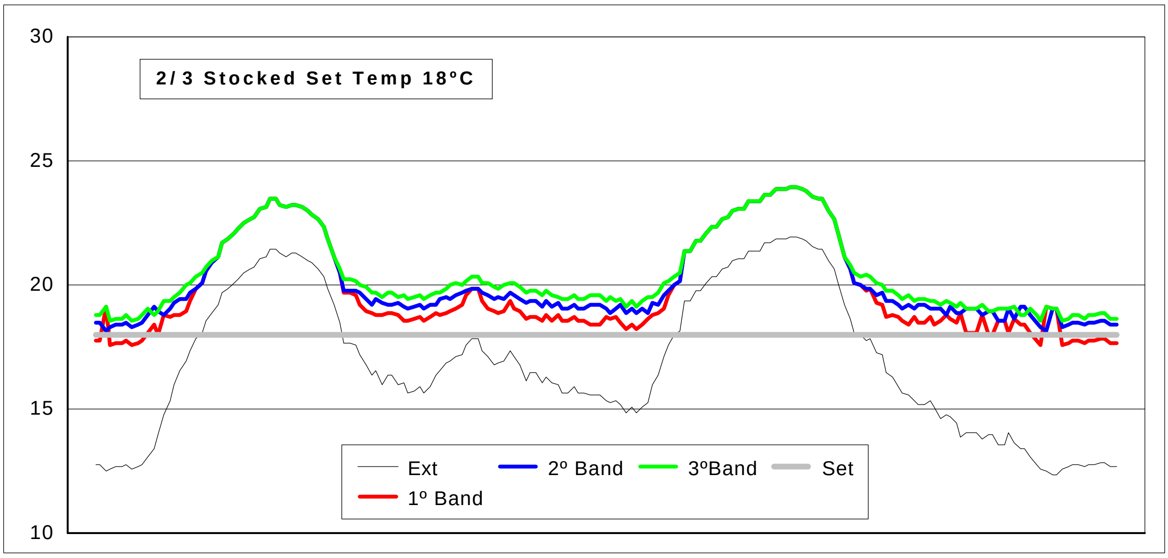
Set Temp	***18ºC***			***Fully Stocked***		
Ext	Temperature			Fan power		
16.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	20.58	20.83	21.13	88%	83%	78%
Compared to3º band	- 0.55	- 0.29		+ 13%	+ 6%	
Compared to 20º/3º	**- 1.60**	**- 1.35**	**- 1.06**	**+ 35%**	**+ 27%**	**+ 20%**

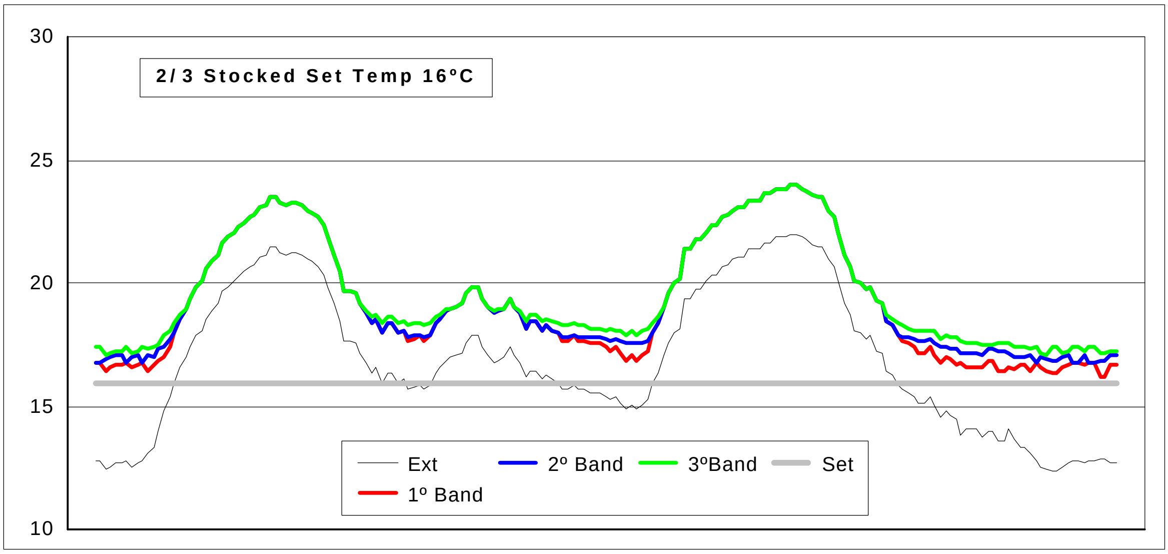
Set Temp	***16ºC***			***Fully Stocked***		
Ext	Temp			Fan power		
16.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	20.09	20.23	20.39	96%	93%	90%
Compared to 3º band	- 0.30	- 0.16		7%	4%	
Compared to 20º/3º	**- 2.09**	**- 1.95**	**- 1.79**	**48%**	**44%**	**39%**

The lowest temperatures are, of course, achieved with the lowest set temperature, and the narrowest proportional band. But by no mean as great as might be thought by many users. In fact, in this situation, the system is more or less permanently at full speed, and merely tracks outside temperature, but about 3ºC above.

Note that a smaller proportional band gives marginally lower temperatures - though somewhat less than users might imagine - but with greater fan operating costs.
The following pages show corresponding results for less than fully stocked - e.g. when the animals are $2/3^{rd}$ size (and with correspondingly lower heater output).


2/3 Stocked Set Temp 20°C
30
25
20
15
10
Ext
2º Band
3ºBand
Set
1º Band

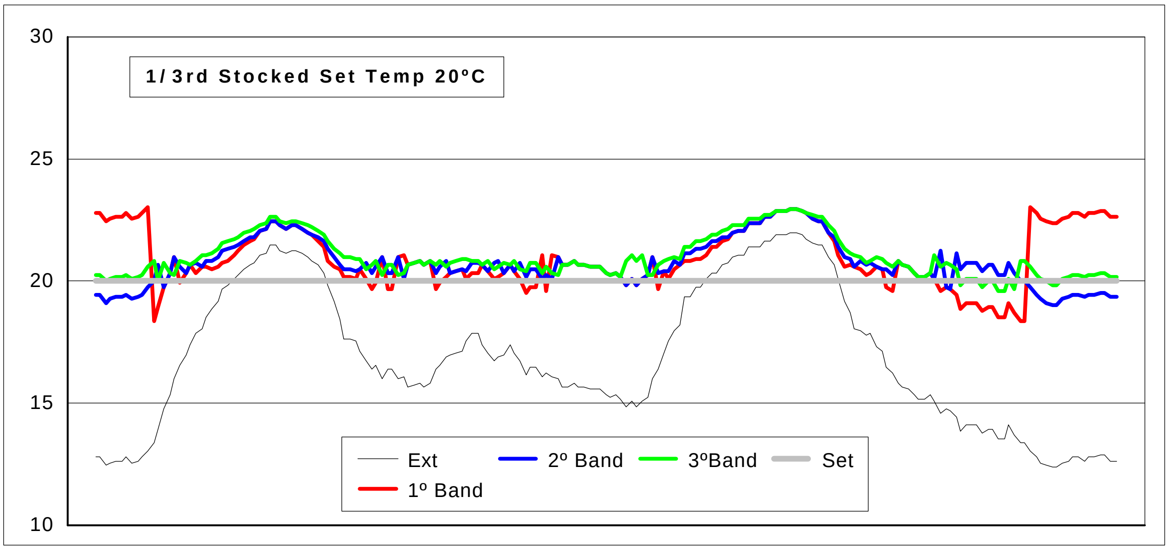

2/3 Stocked Set Temp 18°C
30
25
20
15
10
Ext
2º Band
3ºBand
Set
1º Band

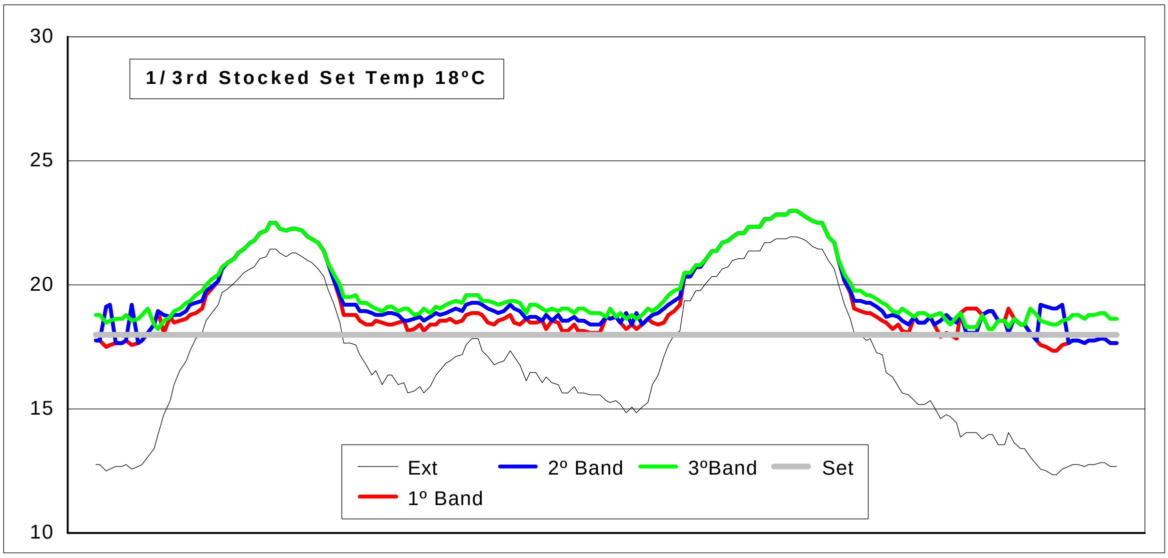

2/3 Stocked Set Temp 16°C
30
25
20
15
10
Ext
2º Band
3ºBand
Set
1º Band

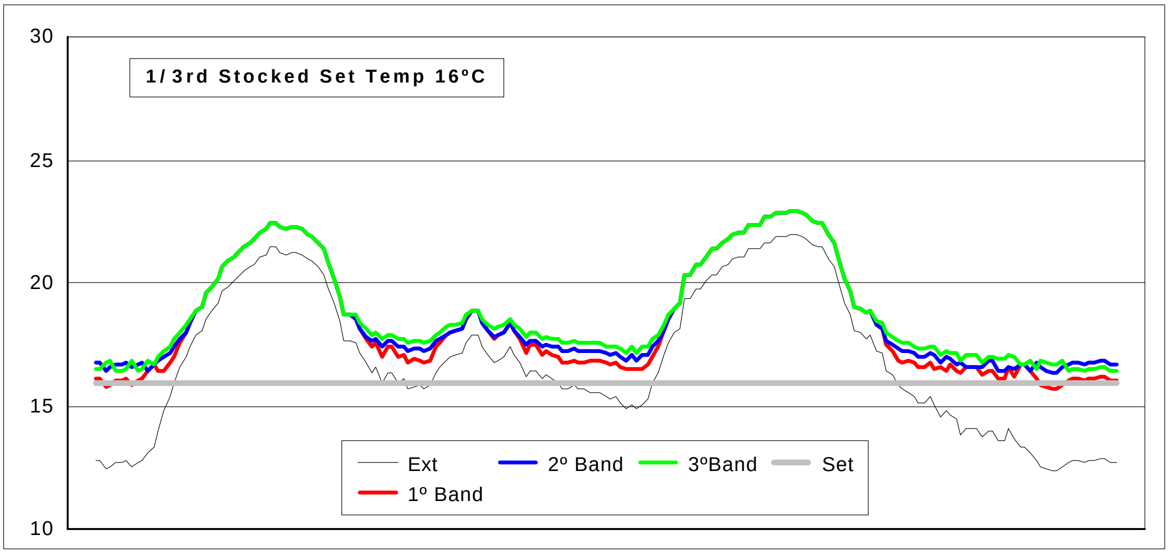
Set	***20ºC***			***2/3rd Stocked***		
Ext	Temperature			Fan power		
16.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	20.98	**21.42**	**21.60**	**61%**	**56%**	**53%**
Compared to 3º band	**- 0.62**	**- 0.17**		**+ 14.5%**	**+ 5.9%**	

Set	***18ºC***			***2/3rd Stocked***		
Ext	Temperature			Fan power		
16.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	19.89	**20.22**	**20.46**	**78%**	**71%**	**66%**
Compared to 3º band	- 0.58	- 0.25		+ 17%	+ 7%	
Compared to 20º/3º	- 1.09	- 0.76	-0.51	+ 27%	+ 17%	+9%

Set	***16ºC***			***2/3rd Stocked***		
Ext	Temperature			Fan power		
16.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	19.28	**19.43**	**19.63**	**90%**	**87%**	**82%**
Compared to 3º band	- 0.34	- 0.20		+ 11%	+ 6%	
Compared to 20º/3º	**- 1.69**	**- 1.55**	**- 1.35**	**+ 48%**	**+ 42%**	**+ 34%**







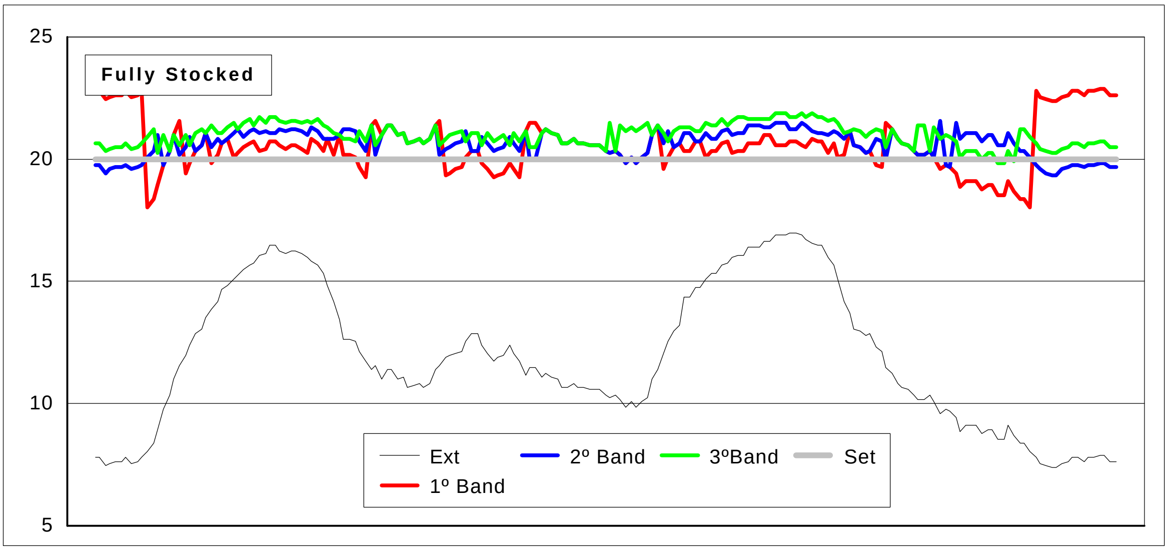
Note : Please note "anomaly" in the simulation in the upper chart. The calculation aims to find the closest match of permissible fan speeds to temperature. In this case, a low fanspeed (closest fit) results in a higher temperature than with other band settings. In practice, such a controller would be liable to switch between levels, giving a smaller error.

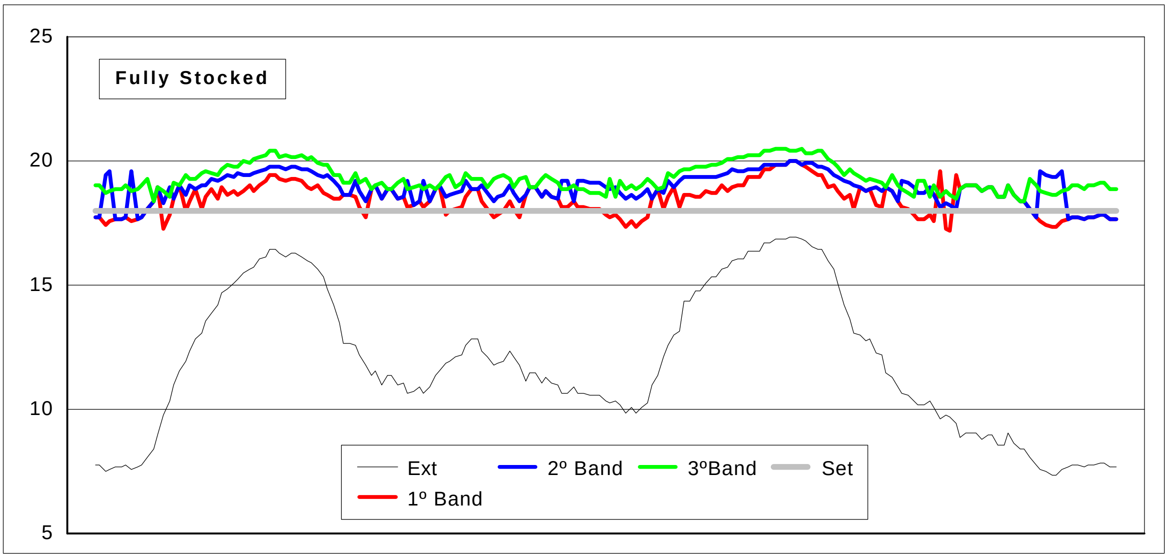
Set	20ºC			1/3rd stocked		
Ext	Temperature			Fan power		
16.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	21.01	20.79	21.03	44%	41%	36%
Compared to 3º band	- 0.02	- 0.24		+ 20.7%	+ 12.9%	

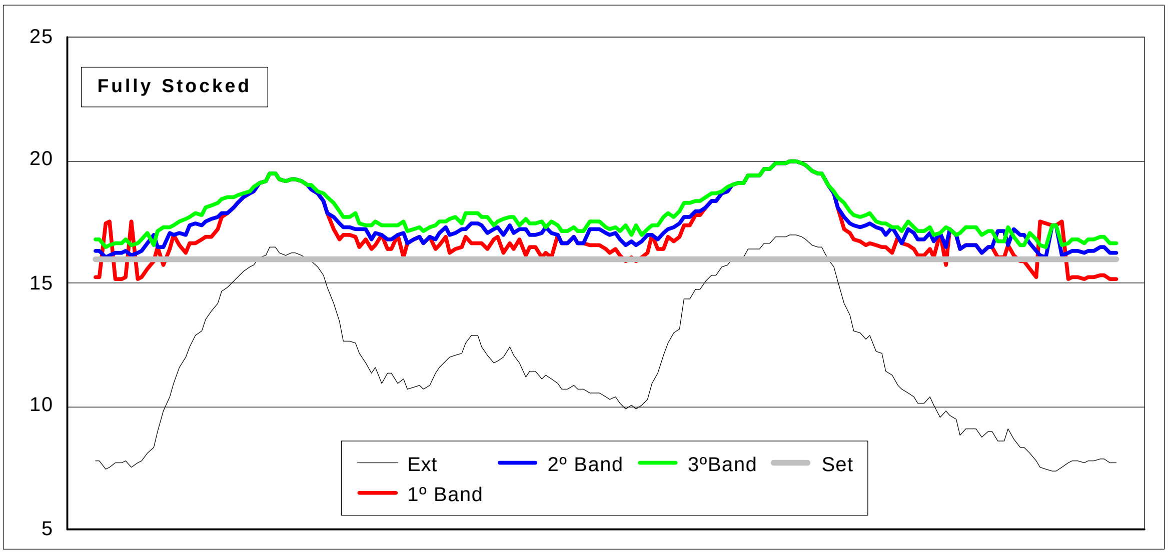
Set	18ºC			1/3rd stocked		
Ext	Temperature			Fan power		
16.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	19.39	19.60	19.82	60%	55%	51%
Compared to 3º band	- 0.43	- 0.22		+ 17%	+ 7%	
Compared to 20º/3º	- 1.62	- 1.41	- 1.19	+ 36%	+ 25%	+ 16%

Set	16ºC			1/3rd stocked		
Ext	Temp			Fan power		
16.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	18.47	18.69	18.82	81%	74%	68%
Compared to 3º band	- 0.35	- 0.13		+ 19%	+ 9%	
Compared to 20º/3º	- 2.54	- 2.32	- 2.19	+ 83%	+ 67%	+ 54%

The following charts show effect of lower outside temperature.







Set	***20ºC***			***Fully stocked***		
Ext	Temperature			Fan power		
11.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	20.63	**20.68**	**21.04**	**40%**	**38%**	**36%**
Compared to 3º band	**- 0.40**	**- 0.36**		**+ 12.0%**	**+ 5.4%**	

Set	***18ºC***			***Fully stocked***		
Ext	Temperature			Fan power		
11.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	18.51	18.98	19.35	55%	50%	46%
Compared to 3º band	- 0.85	- 0.38		19%	8%	
Compared to 20º/3º	**- 2.12**	**- 1.66**	**- 1.28**	**+ 35%**	**+ 23%**	**+ 14%**

Set	***16ºC***			***Fully stocked***		
Ext	Temp			Fan power		
11.93	1º Band	2º Band	3ºBand	1º Band	2º Band	3ºBand
	17.10	17.46	17.79	67%	63%	59%
Compared to 3º band	- 0.69	-0.33		+ 13%	+ 6%	
Compared to 20º/3º	**- 3.53**	**- 3.17**	**- 2.84**	**+ 65%**	**+ 55%**	**+ 46%**

Discussion of the model

The foregoing charts and summaries illustrate - if such be needed - the way in which controller settings and stocking level can influence the temperature and ventilation outcomes.

I should emphasise that these are model *simulations* and not measurements from actual buildings (only the outside temperatures are "real"). However, it operates according to relatively simple physical principles, and the results correspond closely to what is observed in practice.

The model is somewhat simplified and in particular ignores a couple of significant factors -

- structural heat loss or gain
- diurnal variation in animal heat output

In the situations illustrated, and in normally insulated buildings, structural heat loss would account for a relatively small change from the conditions shown. It would amount to around the equivalent of about 3 - 5% of effective fan power. That is, as if there was about 3 to 5% fan ventilation in addition (which would reduce the fan power requirement). Hence, a calculated requirement of 20% means only 15 or 17% is actually needed. The model could be revised to take account of this, though the effect would be marginal.

Solar gain is more difficult to account for, as it varies considerably from day to day and season to season, and is rarely allowed for in designing ventilation systems. In the conditions shown, it would have a marginal effect, mostly to raise the temperature lift slightly when systems are in any case running at full power.

Animal heat output does vary on a diurnal basis, being higher during the day. The effect would be that a building which is "fully stocked" during the day becomes less than fully stocked at night, and night time temperatures would be liable to be lower at night than shown.

The detailed model has been used to produce charts to illustrate the effects of the settings and other circumstances in a clear visual way. It is not, practice, necessary to go into such detail to measure the effects on any building. Since ambient temperature is generally sinusoidal in nature, a reasonable approximation could be achieved in most cases using daily mean values. The detailed model does, however, mean it is possible to overlay other issues such as varying costs of electricity (day/night tariff) and diurnal animal heat variation.

Discussion of results

Lower set temperatures and narrower proportional control bands result, on average, in lower room temperatures.

Conversely, they result in higher fan power requirement with correspondingly higher fan running costs, and greater daily temperature ranges.

Whilst narrower operating bands may be assumed to produce tighter and more accurate control, they also tend to produce wider and faster changing diurnal variations, especially in "mild" weather.

Whilst it is easy to see the physical effects in terms of temperature and running costs, effects on the animals in terms of comfort and FCR are much less easy to see, and somewhat less certain.

It is easy enough to propose, and accept the notion of, an "optimum environmental temperature" for pigs of any age, feed intake, group size, etc. And, so simple logic goes, to say that the closer temperature is kept to this optimum, the better and more efficient production will be. Therefore, that there is a "proper" temperature the pigs should be kept at, and therefore a "correct" set temperature.

However, models do not predict optimum temperatures, they offer a "range" of (calculated) acceptable temperatures - LCT to UCT - within which they animals expected to be able to maintain body temperature adequately. One might take the middle of the LCT-UCT as "optimum", but such a choice is arbitrary, with no particular evidence to support the idea that marginally either side of this is any better or worse.

It is often found that users reduce set temperatures in warmer weather so as to "get the fans to come on quicker". This somewhat betrays a misunderstanding of the difference between static heat balance effects and dynamic response but in any case, there is no clear indication that it produces better results as such.

In this, as in so many other aspects of temperature control, it is often found the situation is dominated by human perception and limited understanding, rather than an objective appraisal of technical requirements. That is, they are often set so as to do what the human user wants it to do, or feels it should do, irrespective of whether this is actually either necessary, or best as far as animal requirements are concerned.

As well as having an effect on temperature - such as it can - ventilation systems for growing and finishing pigs have an inevitable effect on air speed, because of the very high maximum ventilation rates. It is almost impossible to replace the air in a building completely within a minute or less (60 to 80 air changes an hour, typical) without higher air speeds at stock level.

For example, 21ºC travelling at 1 m/s (200 fpm) has a much lower perceived temperature than air of 20ºC at 0.3 m/s (60 fpm). This is particularly so at earlier stages of growth. Air speed is not detected by ventilation control systems (and would be difficult and expensive to detect reliably because of the dust laden environment). There is some reason, therefore, to set proportional bands wider than seems to desirable, so as to resist this tendency to "blast" the animals at only slight rises above target temperatures. Similarly, there is justification for increasing set temperatures in warmer weather so as to inhibit the otherwise tendency for animals to be subjected to high air speeds for large parts of the time.