Silent & Full Power Operation

December 20th, 2024

Summary

The LG ThermaV heat pump has a silent mode capability that is used to reduce the noise output of the unit. In this operating mode the maximum operating frequencies of the compressor and evaporator fan(s) are reduced. A consequence of this operating mode is that the unit cannot deliver as much thermal power as it could otherwise achieve. However, with a reduction in peak power output then the LG is able to more readily deliver constant low power levels that are necessary to achieve more efficient operation.

With many installations having heat pumps that are significantly oversized relative to the property heat loss, then the use of silent mode can reduce cycling, resulting in improvements in efficiency.

When delivering continuous low output power then the full capacity mode had a regular high power spike that was not present during silent mode operation. The cause of this spike is currently unknown. There are no limitations placed on the use of silent mode in any LG documentation found to date in the public domain. Units that are essentially running in this mode continuously should consider scheduling normal power mode for 2 or 3 hours a day to allow the unit to perform a 'spike' operation.

Note that during defrost operation silent mode is 'escaped' and the unit will deliver sufficient power to defrost the evaporator and surrounding fins as quickly as possible.

Equipment

LG ThermaV

A 12 kW Series 4 ThermaV running controller software revision 3064a was used during this investigation. The property heat loss had been calculated at 6.2 kW for an outdoor temperature of -2°C, located in South Yorkshire, England.

The original install had been reworked to help overcome some of the issues associated with the oversizing of the heat pump. In particular the typical 4-port buffer configuration has been reworked as a 2-port volumiser with closely spaced tees providing the hydraulic separation to 3 UFH manifolds (3 separate tees and re-circulating pumps).

The LG has been set for 24x7 operation with weather compensation mode using inlet water as the control sensor. The parameters for WC being outdoor [-4°C,16°C] and associated water temperatures of [29°C,21°C]. Pump capacity was set to 70% which delivers ~ 24 l/min as the nominal flow rate, and flow control was set to fixed rate with 20 l/min for heating and 27 l/min for DHW. Space heating hysteresis was set at -1°C,+4°C. A single daily DHW cycle was scheduled for 45°C between 6-15 and 7 am. A further hotter DHW cycle was set for 60°C every Monday between 1 and 2-30 pm to provide some Legionella protection.

At 24 l/min, with no heating active, then the LG water pump (the OH-SUNG model in this unit) consumes approximately 70W and at 20 l/min approximately 50W.

Monitoring

Collection of data was achieved using a custom monitoring solution:

- ESP32 microprocessor running bespoke software
- Data collected from the LG via the modbus interface
- Electricity power measurement using PZEM-016 module with current clamp
- Flow and Return temperatures from DS18B20 (genuine MAXIM parts)
- Thermal Power estimation from mass flow equation using flow rate from the LG, flow and return temperatures from the DS18B20's and an assumed specific heat capacity of 3.9 J/Kg°C (glycol mixture).

Given the lack of MID certified equipment then absolute values of electrical and thermal power, and subsequent COP, should be treated with caution. However relative measurements are at least a useful guide to performance etc.

Data was sampled every 30s and uploaded to the open energy monitoring server at emoncms.org for subsequent viewing and analysis.

Silent Mode

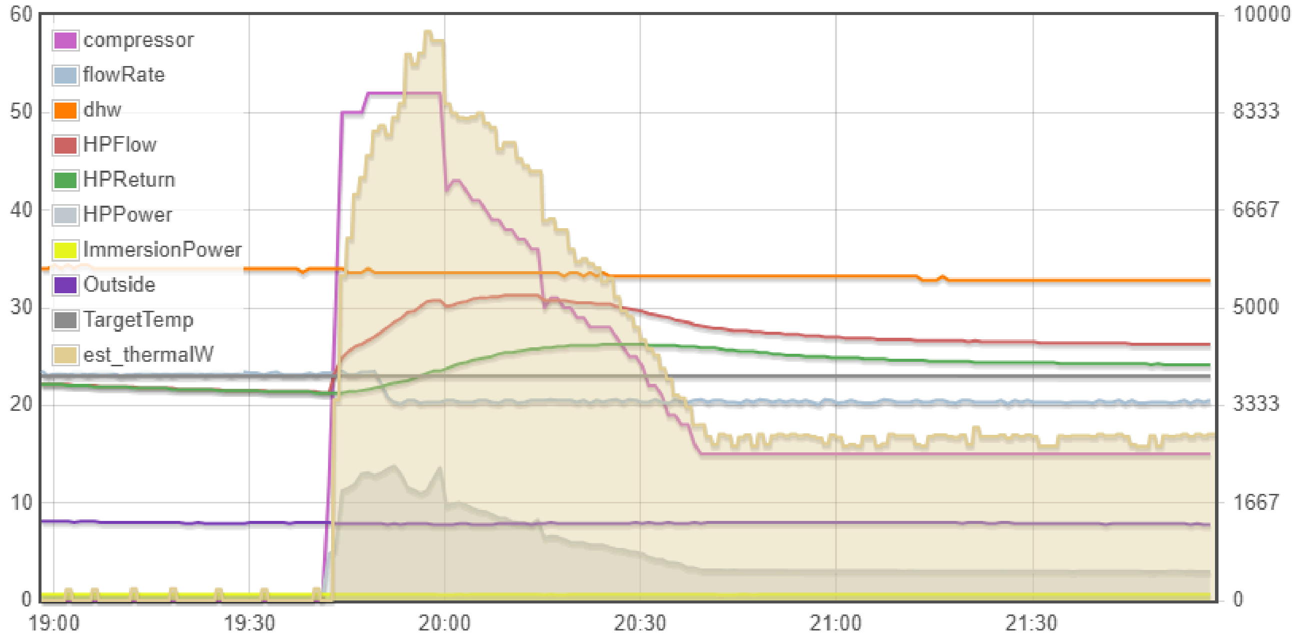
The unit has been operating in continuous silent mode for several months, including periods of sub-zero outdoor temperatures.

- The compressor maximum frequency appears to be approximately 52 Hz
- The minimum frequency of the compressor appears to be 15 Hz.
- The noise from the unit becomes noticeable around 35 Hz.
- Lowest sustained (> 3 hours) electrical consumption ~ 470W, with 2.7 kW thermal power generated
- Highest sustained electrical consumption observed ~ 1.4 kW.
- Peak thermal power appears to be ~ 9 kW

Cycle Start Phase

The LG appears to deliver high power at the start of every compressor cycle. If the target temperature, plus its associated hysteresis, is exceeded then the current cycle will stop. If this occurs before the LG has managed to modulate the power level to a value that is commensurate with the current thermal load then it is essentially short cycling. Of course no heat pump can modulate down to any level, but it is reasonable to believe that 30% of nominal power should be achievable.

By using silent mode then the peak power that the LG will deliver is lower, and this helps the start phase of a heating cycle.



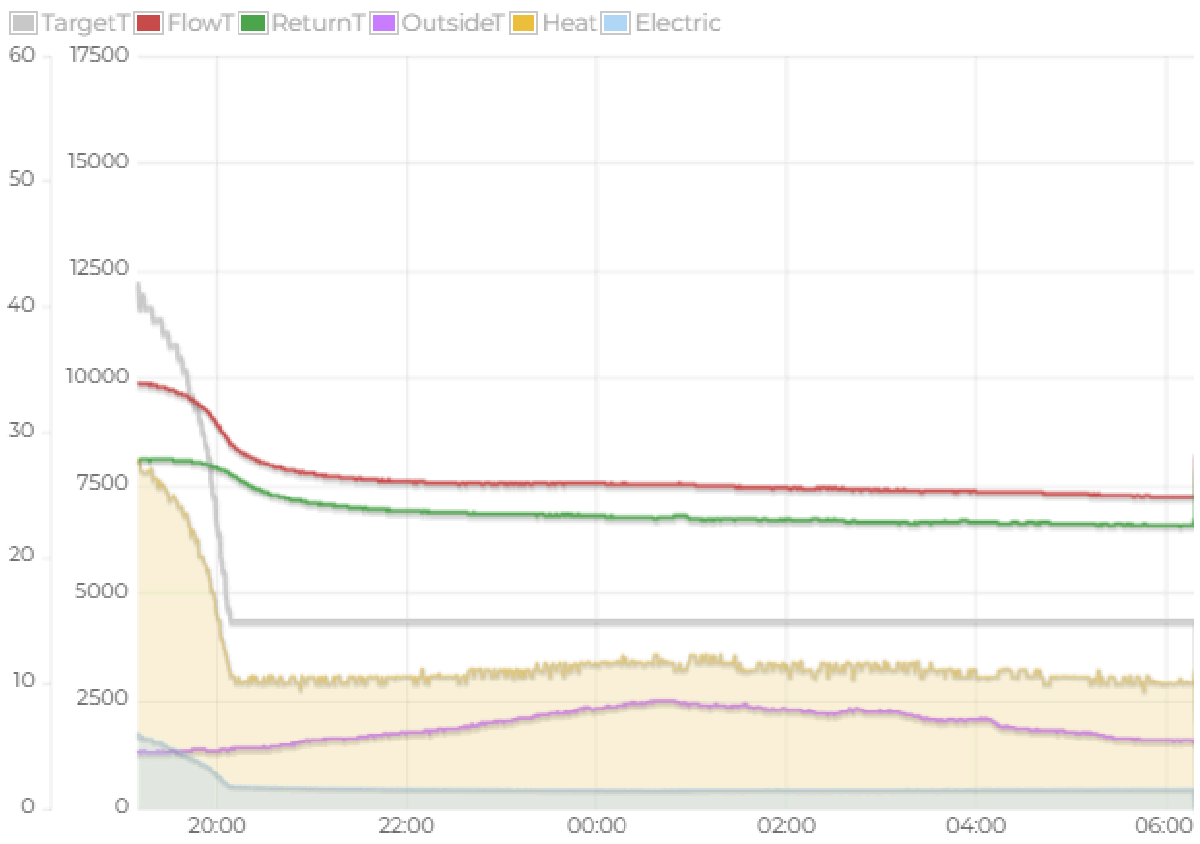
Here the cycle starts as the inlet temperature is below the target (minus hysteresis). The LG ramps the compressor rapidly to the maximum frequency and the outlet temperature rapidly rises, followed by the delayed inlet (due to the thermal load on the property at 8°C outside, equivalent to a heat loss of approximately 3.5 kW).

After 10 minutes the flow rate begins to modulate down from the nominal 24 l/min to the fixed flow rate target of 20 l/min - and the compressor falls to 43 Hz after 15 minutes. As the thermal power reduces, the rate of increase of the inlet temperature begins to fall. Ultimately the cycle manages to stabliise at the lowest compressor frequency and electrical power consumed.

During this cycle the inlet did rise 3.6°C above the target, but below the 4°C hysteresis threshold.

Low Power Operation

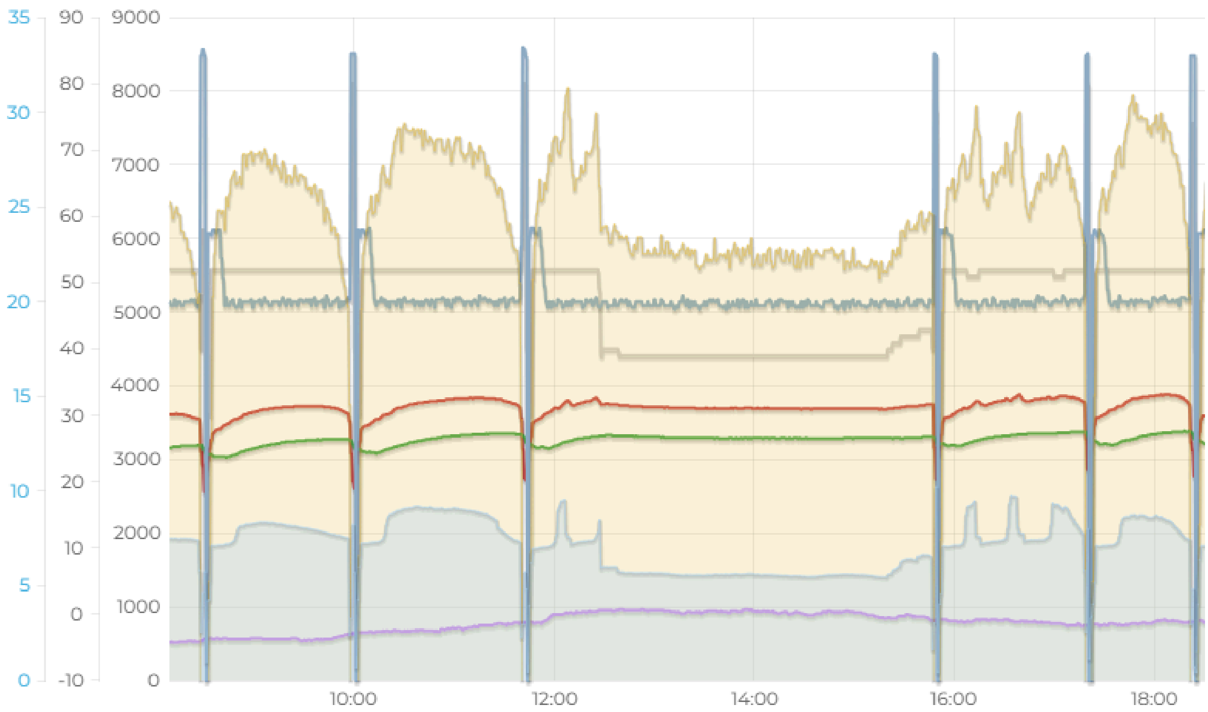
The following shows the system operating continuously at low power overnight, with an average outdoor temperature of 7°C. The Target temperature on this chart has been repurposed and is actually the LG's compressor frequency. This is broadly the same behaviour following the cycle start shown previously.



High Power Operation - including Defrost

During this cold period, with the minimum temperature being -3.8°C, we see the unit maintaining a sustained steady higher output between defrosts. The longest period between defrosts shows the compressor falling to 40 Hz.

Note that during defrosts the flow rate increases to the nominal 100% (~33 l/min in this installation) and the compressor also increases to 80 Hz.



The property heat loss was calculated at 6.2 kW. This chart shows that for this particular installation it is likely that silent mode can be used throughout a heating season and deliver sufficient power. But if there are prolonged periods of sub-zero temperatures then the effects of defrost may require higher power output to recover energy lost by the property to the heat pump.

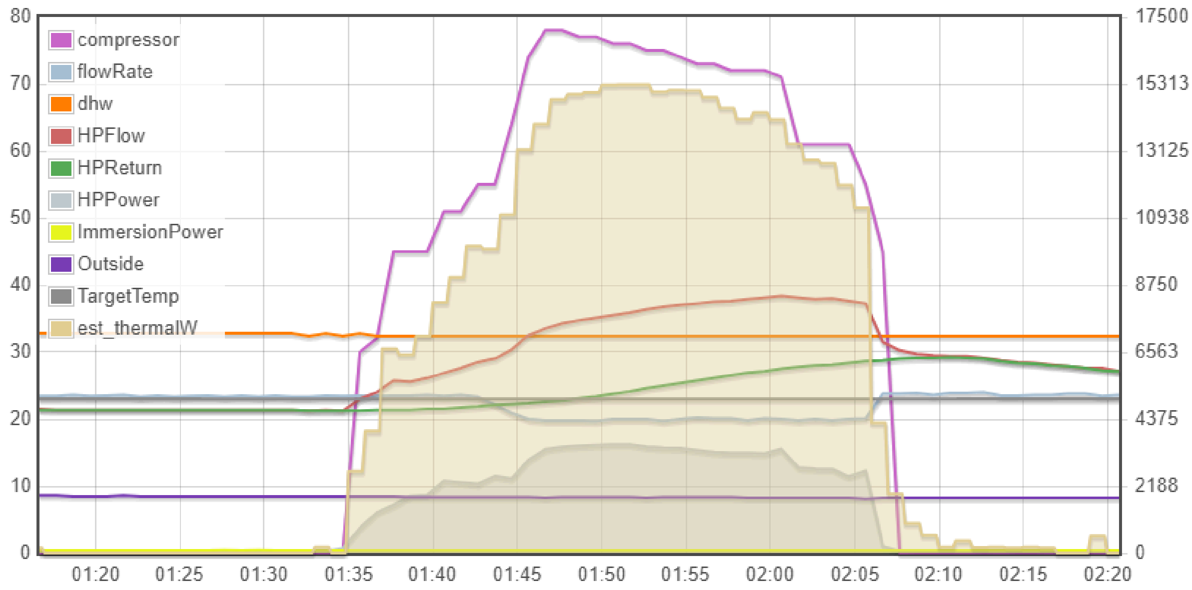
Normal Power Mode

The silent mode operation of the unit was temporarily disabled for a few days to observe system behaviour.

- The compressor maximum frequency appears to be approximately 95 Hz
- The unit can still reduce the minimum frequency of the compressor to 15 Hz
- The noise levels above 50Hz are considerably higher
- Lowest sustained (> 3 hours) electrical consumption ~ 600W, with 2.7 kW thermal power generated
- Highest sustained electrical consumption ~ 1.4 kW.
- Peak thermal power appears to be ~ 15 kW
- Higher output results in faster recovery from defrost effects

Full power - cycle

This chart shows different behaviour than the silent mode operation under essentially the same conditions.

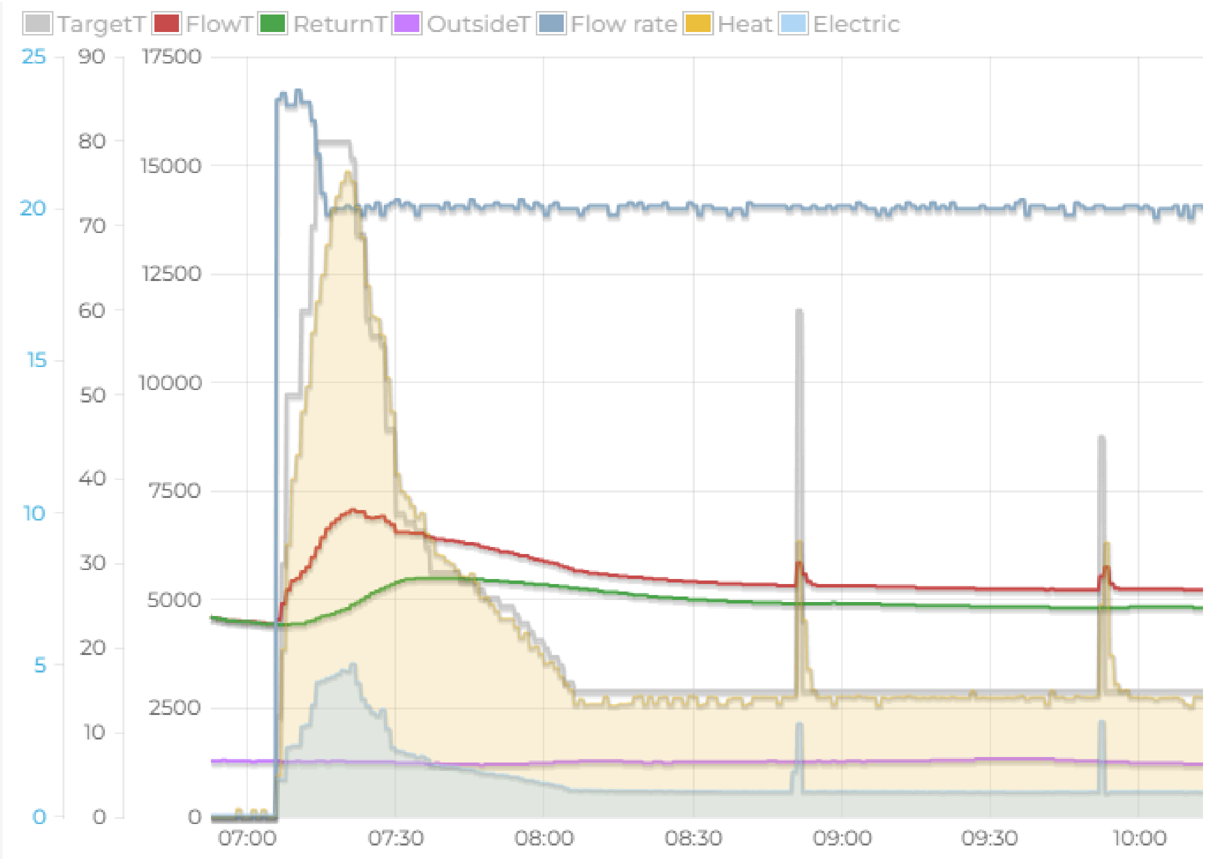


The cycle starts again as the inlet is below the threshold, but in this mode the compressor continues to ramp up to a near peak of 80 Hz, with peak electrical consumption at 3.5 kW. The high power output is maintained for too long and despite bringing the compressor to below 60Hz the effect of depositing that amount of thermal power into the property results in the inlet continuing to rise. At the point when the LG stopped the cycle the inlet was actually 5.6°C above target temperature - considerably higher than the 4°C hysteresis.

Despite the ability of the unit to operate continuously at less than 3 kW (generation) this cycle stopped before full modulation occurred. This can therefore be viewed as a short cycle despite the fact that the compressor was active for approximately half an hour.

Low Power Operation

If outside conditions are such that more power is required then the normal power mode can establish full modulation. In this case the outdoor temperature was a couple of degrees below the previous cycle start example.



Once again the 80 Hz compressor frequency is observed with the high input power (3.4 kW peak) - but the system manages to get through the startup and the power reduces accordingly.

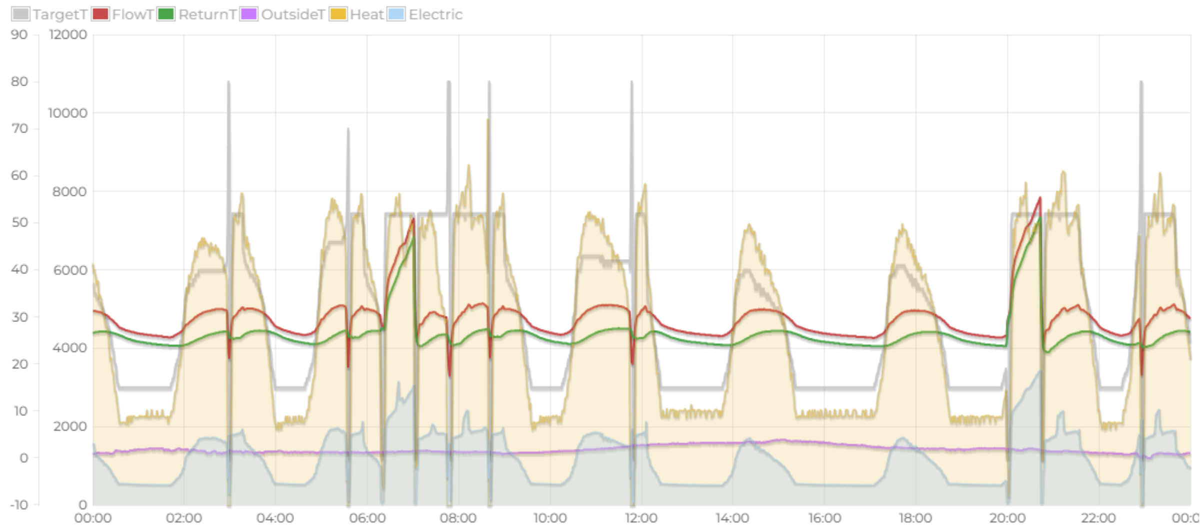
Here the input power was around 600 W, despite the same output power being generated as the silent mode equivalent. This may be due to increased fan speed, possibly more refrigerant in circuit so the compressor has to work slightly harder ? This increased power consumption will adversely impact the COP, by a factor of 25% in the lowest power output state.

One note here are the clear spikes in power consumption, compressor speed (60 Hz) and the effect on the flow temperature. It may be an important part of the cycle that could impact on longevity of the unit. It is possible that this behaviour is only apparent on systems that are managing to operate for long continuous periods, as the start-up phase of any compressor cycle will be high power and likely has an oil management element to it. The Appendix contains a view of LG sensors during a 'spike'.

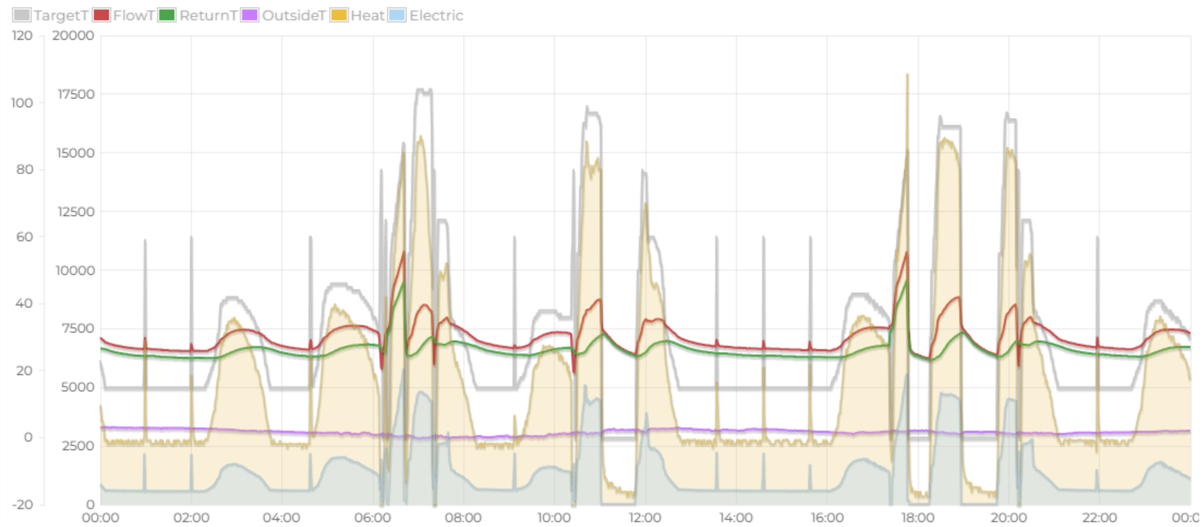
COP Comparison

Due to the limited duration of the normal power mode it was only possible to compare one day's equivalent operation. These charts show the daily operation in both modes at similar temperatures.

Silent Mode:



Normal Power:



The summary, with average data presented:

Mode	Whr used	WHr Output	Flow °C	Return °C	Outdoor °C	COP
Silent	1200	4605	29.8	26.4	1.8	3.8
Normal	1345	5165	30.2	26.4	1.7	3.8

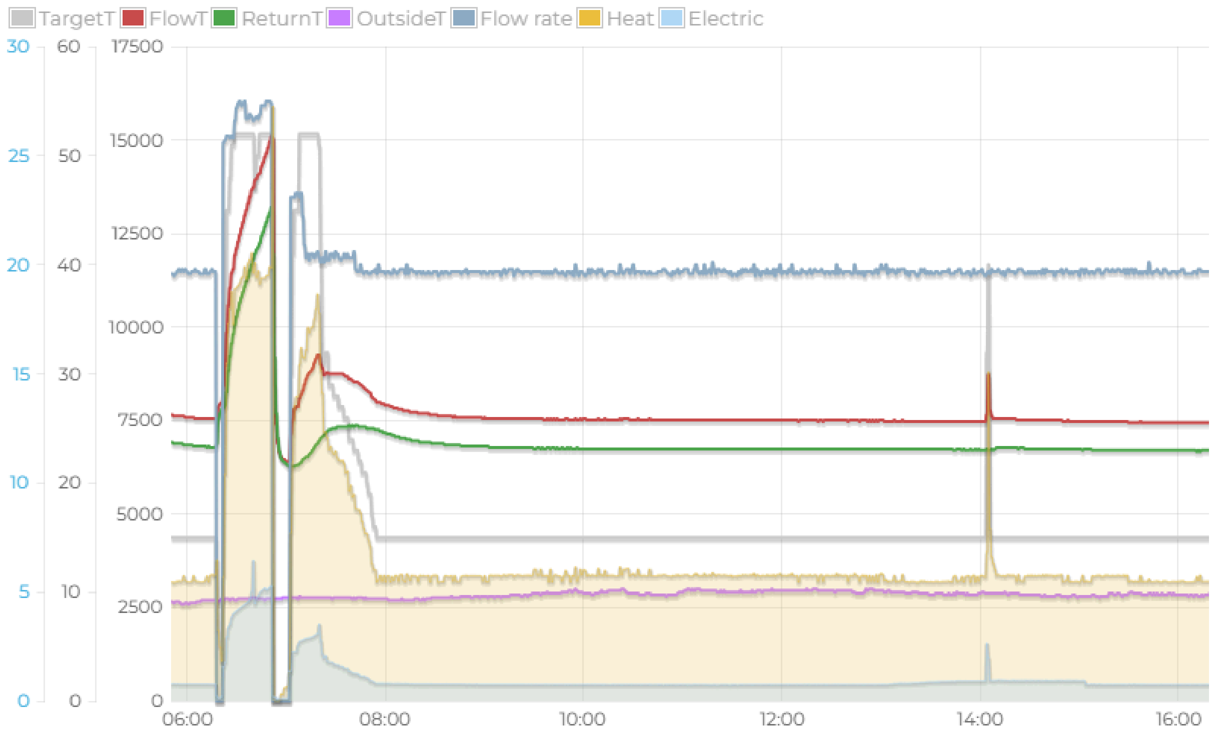
Normal mode generated more thermal power at a slightly cooler temperature outside, with an increased flow temperature.

A single day is not really sufficient to be able to draw any significant conclusions. The assumption was that silent mode would be more efficient at cycle start-up, but as the system has few starts it is not evident in this result. The investigation would have to continue when outdoor conditions were warmer and therefore cycling behaviour would be more prevalent.

What is clear is that there is no obvious negative behaviour in either mode relative to each other. And an overall COP of 3.8 with an outdoor temperature of slightly less than 2°C can be compared with LG's published figure of 4.6 at 2°C outside for 30°C flow (12 kW unit at 35 l/min).

Silent Mode With Scheduled Normal Power

Due to the observed power spikes in normal power behaviour the system was configured to add a 2 hour non-silent operation in the afternoon.



Here the power spike previously observed is seen again at around 2pm. This spike does not always occur at the same time in the normal power schedule window. It does however show that at least such a schedule can be assigned to provide an opportunity for this operation to take place daily. Note that the silent mode scheduling can only have 1 period assigned to it. Another method would be to enforce short duration cycle stop periods throughout the day that would result in new high power compressor start-ups.

Conclusions and Recommendations

Silent mode will help the LG overcome its aggressive startup phase that often results in short cycles. This will be true especially for those installations when the model is significantly oversized for the property.

It isn't possible to say from this limited data set whether COP is improved when running in silent versus normal mode, especially if the unit readily achieves good modulated output in normal operation. It is known however that cycling is less efficient than continuous operation. Therefore systems that struggle to modulate effectively will benefit from silent mode.

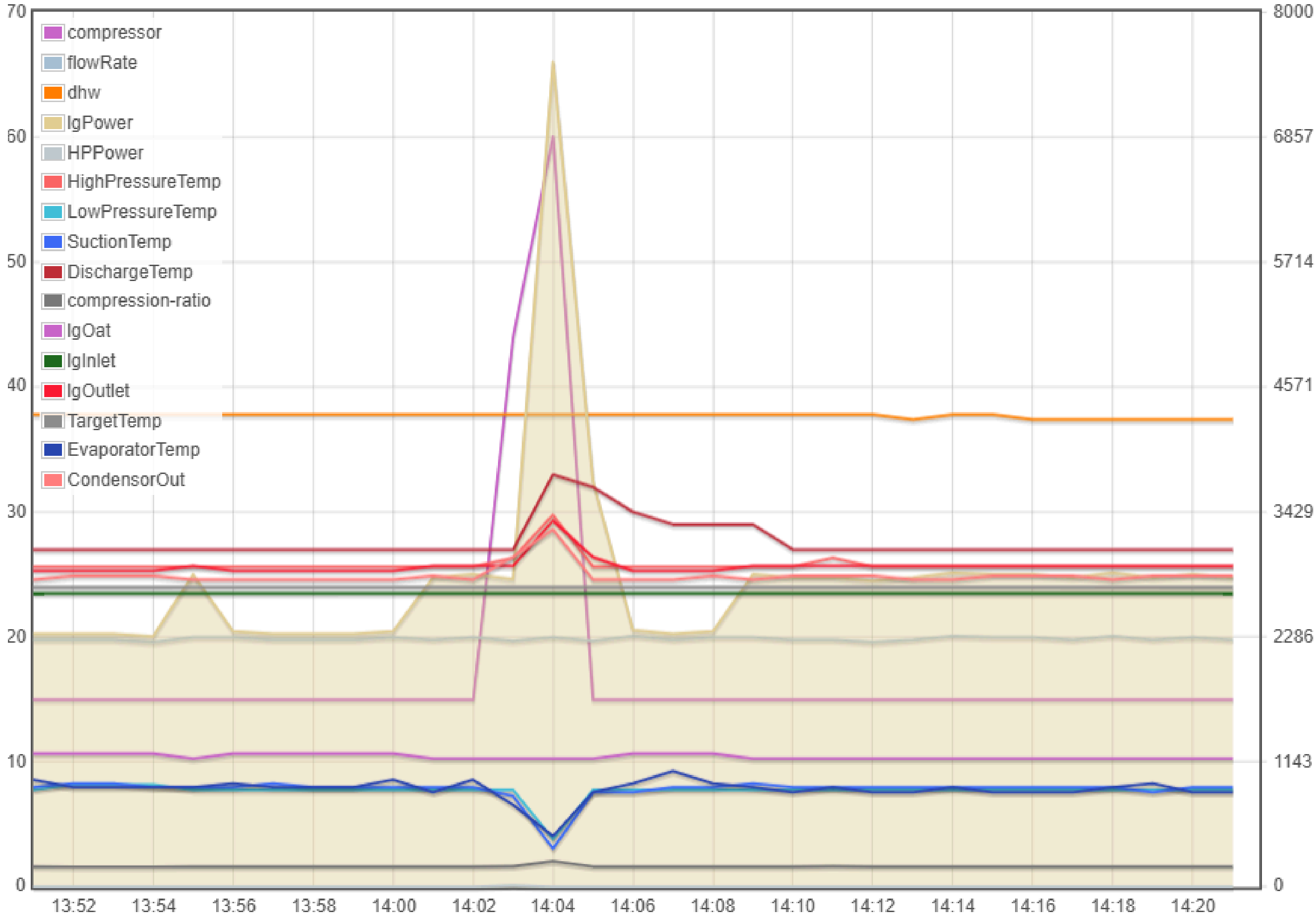
Maximum power is reduced and this may compromise the ability to heat the property at cold temperatures, including the recovery following defrost operations. Therefore the homeowner should consider reverting back to normal power operation when outdoor temperatures fall below a minimum, set according to their property heat loss and unit size.

There are 6 different power output models in the R32 monoblock ThermaV range. The 5.7 and 9 kW are housed in a single fan unit, whilst the larger 12,14 and 16 kW have dual fans. The larger units have more refrigerant available. There may be other differences between these units beyond the rated power output. It wouldn't be too surprising if the 5,7 and 9 units were actually the same but limited in their power output by some factory software (or hardware) setting - and similarly for the 12,14 and 16 kW variants. The silent mode output will be different for each unit, specifically the compressor maximum frequency will most likely differ from that reported in this investigation.

Operating continuously in silent mode may have some unknown unwanted effect on the heat pump. There is no public domain information regarding prohibiting the continuous use of silent mode, and there are many homeowners that are using silent mode on a 24x7 basis during the heating season. However, it would seem prudent to allow the unit to escape silent mode for a daily period. For many installations that have multiple cycles through the day, for example due to DHW top-up's, or simply long (or short) cycles, then perhaps a daily 'escape' isn't necessary. This should be discussed with the installer.

Appendix - ‘Spike’ Operation

The following shows some additional data recorded during ‘spike’ power intervals that occur when operating continuously in normal power operation.



Samples in this chart are taken at 1 minute intervals so there isn’t a great deal of resolution with this data.

The cycle had been well established prior to the spike. But we see an increase in compressor frequency from 15 to 60 Hz, the evaporator side drives down to the cold side (from ~8°C to 4°C) and the hotter compression/condensing side of the circuit increases in temperature. Electrical power consumption climbed from ~600W to 1.7 kW during this brief window.

How can both cold and hot ‘sides’ of the cycle extend their temperatures ? Increased compression will raise the ‘hot’ side and opening the expansion valve(s) further would decrease pressure and thereby the refrigerant will cool further. But no information found regarding why this should occur on a regular basis when the system is nicely balanced and operating continuously.