Commercial-in-Confidence

Analysis of RAPID/X6 Load Capacity

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The analysis is based on information supplied by Aquatech Solar Technologies Pty Ltd and manufacturer data.

Executive Summary

Aquatech Solar Technologies Pty Ltd has commissioned EnergyAE to conduct an analysis of the heating output of their RAPID/X6 model under multiple operating modes and power supply tariffs in Sydney.

The purpose of this analysis is to determine the potential suitability and optimum running mode selection of the RAPID/X6 for different household occupancies.

This data is of interest to Aquatech Solar Technology in assisting owners of the RAPID/X6 with maximum household occupancy recommendations under the systems four primary heating modes and multiple power supply tariffs. The data will be used by Aquatech to ensure that potential purchasers/owners of the RAPID/X6 can size the system heating output to predicted household hot water demand, in order to prevent "running out" of hot water supply.

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Introduction

Aquatech Solar Technologies Pty Ltd have commissioned EnergyAE to conduct an analysis of the heating output of their RAPID/X6 model, under multiple operating modes and power supply tariffs.

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TRNSYS Model Creation

In order to determine the ability of the RAPID/X6 to meet different hot water load sizes, EnergyAE created a TRNSYS model based on the following parameters

A TRNSYS model of the system was developed, and the TRNSYS input file is based on the template deck structure provided by Clean Energy Regulator.

These models include the following components:

- Water tank with wrap-around coil heat exchanger.
- The tank heat loss was determined in accordance with AS/NZS 4692.1, as described in report GZES190902378431.
- A set of equations representing the heat pump while in operation.
- The air source heat pump Coefficient of Performance (COP) and power consumption performance coefficients were obtained from AS/NZS 5125.1 test report GZES190902378831.
- The heat pump is suitable for low temperature operation down to -5°C, below which an auxiliary heating element is used with a thermostat set temperature of 70°C and deadband of 5K – this heating mode is separate to the normal heating modes described below
- A Type 11 Tempering Valve to calculate the load volume required to meet the prescribed energy load.
- Means to comply with section AS 3498-2009 7.1(j) "inhibit the growth of Legionella bacteria" was achieved by heating at least 45% of the water in the tank to 60°C daily.

A schematic of the system is provided in Figure 1.

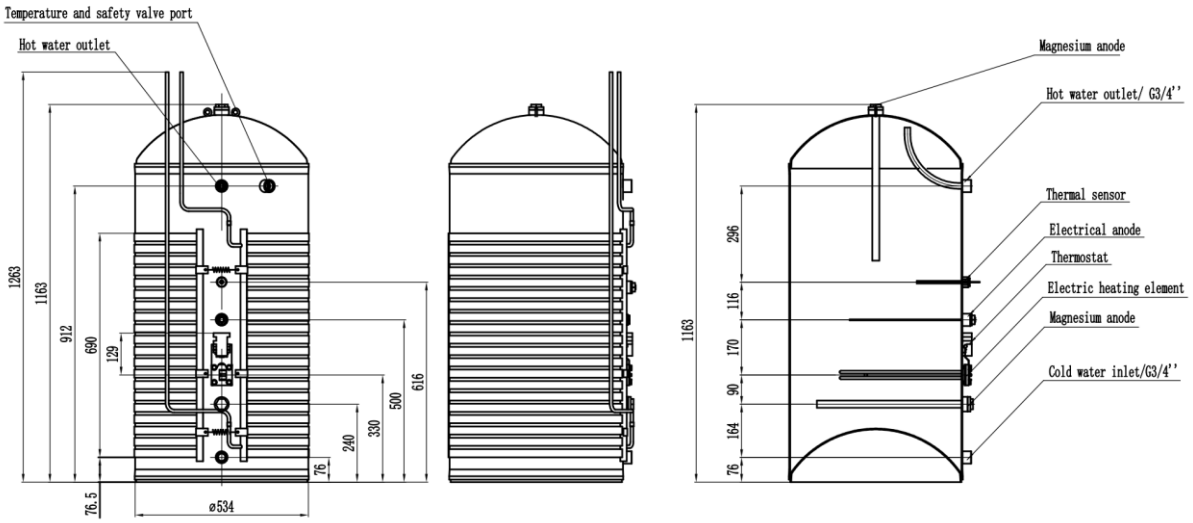

Figure 1 RAPID/X6 tank model TY-ND-00-041

Hot Water Load Sizes

The TRNSYS model provides a means by which the heating output of the RAPID/X6 can be simulated against the peak winter daily load as per AS/NZS 4234:2008 Table H9.3 using the draw-off profile outlined in Table A4 of same standard.

For the purpose of this analysis, all results were simulated in Australian climate zone 3 which translates to a RAPID/X6 being installed in Sydney.

The three peak winter load profiles against which the RAPID/X6 has been assessed are outlined in the below table.

Table 1 Load sizes

Load size	Peak Load (kWh)	Estimated Household Occupancy
Small	7	2 person
Medium	11.67	4 person
Large	17.5	6 person

RAPID/X6 Heating Modes

Further updates were made to the RAPID/X6 TRNSYS model to simulate the system's four primary heating modes.

These modes can be selected by the owner via the systems LCD controller. Depending on the mode selected the RAPID/X6 controller will auto adjust the temperature to trigger a heating cycle and the final end temperature per heating cycle. These two parameters have a significant impact on the system's hot water output.

For low ambient electric heating, when the ambient temperature drops below the heat pump cut off temperature of -5°C, the electric element set point temperature is 70°C for all heating modes.

The four selectable heating modes and parameters are outlined in Table 2.

Table 2 Heating modes

Mode ID	Heat pump set point (°C)	Electric element set point increase (K)	Final temperature (°C)	Reheat Trigger Temperature (°C)
ECO	60	0	60	48
STANDARD	60	0	60	55
HYBRID	60	5	65	55
HYBRID +	60	10	70	50

For hybrid modes, a daily sterilisation boosting is also modelled which ensures the final temperature is reached at least once for 30 minutes within every 24 hours. This is included to cover the occasions when the heat pump alone is unable to reach the 60°C set point during a 24 hour period due to load draw-offs, in which case the additional electric boosting would not be triggered. Thus, if at any moment during the simulation the tank top temperature has not reached the threshold temperature of 68°C, then an automatic electric boost will occur immediately up to the electric set point for at least 30 minutes.

Note: the threshold temperature of 68°C is chosen only as a modelling construct to be just less than 70°C, because the Type 138 TRNSYS tank model does not output the tank temperature at the thermostat level, only at the top and bottom of the tank, average tank temperature, and the average temperature of water adjacent to the heat exchanger. During an electric boost with no load draw offs, the top of the tank reaches 69.9°C, slightly lower than at the electric element thermostat position, thus 68°C was chosen to provide a small buffer.

Power supply options

Additional adjustments where made to the TRNSYS model to simulate three separate power supply options to determine the suitability of the RAPID/X6 to meet load profiles under a continuous supply tariff , off-peak 2 supply tariff and limited timer window for system heating only during daytime hours.

For SOLAR TIMER power supply, the RAPID/X6 LCD controller allows owners to select a pre-programmed timer function that limits the system heating to pre-set window being 6:00am - 6:00pm. Under this function the system heating parameters are defined by the selected heating mode being either ECO - STANDARD - HYBRID - HYBRID+.

The three power supply parameters are outlined in Table 3.

Table 3 Power supply options

Power Supply	Daily duration	Power Supply Window
Continuous	24 hours	
Off-peak 2 (Shoulder Tarrif)	19 hours	10pm-5pm
Solar timer	12 hours	6am-6pm

Results

A total of 36 TRNSYS 36 simulations were run, for all four heating modes against three load sizes and three power supply options. The results output has been defined as PASS or FAIL.

PASS: The RAPID/X6 met the load profile under specified heating mode and power supply with a minimum output temperature of at least 45°C being maintained at the hot water outlet. The RAPID/X6 is predicted to meet the estimated household occupancy under the selected heating mode and power supply.

FAIL: The RAPID/X6 failed to meet the load profile under specified heating mode and power supply with the supply temperature from the outlet dropping below 45°C at some point. This is the equivalent to the household experiencing a failure of hot water supply. A Fail will result in Aquatech Solar Technologies not recommending the RAPID/X6 for estimated household occupancy under the selected heating mode and power supply.

Pass scenarios are highlighted in green and fail scenarios are highlighted in red. The minimum delivery temperature for each scenario is shown in the tables.

The results are outlined in the three sets of tables below. The first set shows minimum delivery temperatures. The second set shows STC values. The third set shows energy savings values.

Table 4 Minimum Delivery Temperatures

Continuous 24h

Heating Mode	SMALL	MEDIUM	LARGE
ECO	48.8	50.1	47.7
STANDARD	54.8	54.2	47.8
HYBRID	54.5	53.3	47.7
HYBRID+	51.1	52.2	47.8

OP2 10pm-5pm

Heating Mode	SMALL	MEDIUM	LARGE
ECO	48.8	47.2	43.7
STANDARD	54.7	52.1	44.6
HYBRID	54.8	50.9	45.3
HYBRID+	49.7	51.2	43.6

Solar Timer 6am-6pm

Heating Mode	SMALL	MEDIUM	LARGE
ECO	48.5	44.8	39.4
STANDARD	52.2	47.0	39.4
HYBRID	52.0	45.4	39.5
HYBRID+	50.1	46.1	39.8

Table 4 shows that ECO and STANDARD modes perform similarly, it is only in the Solar Timer mode that ECO fails the minimum temperature requirement, as the low re-heat trigger temperature does not prepare the tank well enough for the evening loads during winter.

Similar with the Hybrid vs Hybrid+, it is the higher re-heat trigger temperature which allows a system to satisfy the minimum temperature requirement, rather than a higher final set point temperature. This is shown in the OP2 scenarios where Hybrid satisfies the Large load but Hybrid+ fails.

Table 5 STC values

Continuous 24h

Heating Mode	SMALL	MEDIUM	LARGE
ECO	17.6	30.0	41.5
STANDARD	17.1	29.5	40.9
HYBRID	10.3	22.5	33.1
HYBRID+	11.7	21.9	30.1

OP2 10pm-5pm

Heating Mode	SMALL	MEDIUM	LARGE
ECO	17.8	30.2	41.8
STANDARD	17.2	29.6	41.2
HYBRID	11.8	23.8	31.5
HYBRID+	12.2	22.2	29.6

Solar Timer 6am-6pm

Heating Mode	SMALL	MEDIUM	LARGE
ECO	17.9	30.5	42.6
STANDARD	17.3	29.9	42.1
HYBRID	14.3	23.5	31.4
HYBRID+	12.0	23.1	30.6

Table 5 shows that STCs are higher in the ECO and Standard modes. The higher the dead-band, the greater the STCs, so long as minimum delivery temperature is also met. Hybrid modes lose STCs based on the extra energy demand of the electric heating.

For almost all cases, highest efficiency is found with the solar timer 6am-6pm when comparing for a particular heating mode. This is due to the restriction of unnecessary heating except when only needed by aligning with heating draw-offs, which has the effect of minimising overnight tank heat loss.

Table 6 Energy Savings values (cells highlighted based on whether they meet 60% energy savings requirement in Zone 3)

Continuous 24h

Heating Mode	SMALL	MEDIUM	LARGE
ECO	68.5	70.7	70.9
STANDARD	66.4	69.5	69.8
HYBRID	39.8	53.1	56.4
HYBRID+	45.6	51.6	51.4

OP2 10pm-5pm

Heating Mode	SMALL	MEDIUM	LARGE
ECO	69.3	71.3	71.3
STANDARD	66.7	69.9	70.3
HYBRID	45.9	56.2	53.7
HYBRID+	47.4	52.4	50.4

Solar Timer 6am-6pm

Heating Mode	SMALL	MEDIUM	LARGE
ECO	69.4	71.9	72.6
STANDARD	67.1	70.6	71.8
HYBRID	55.7	55.5	53.5
HYBRID+	46.5	54.4	52.2

However, Table 6 shows that the model would not be eligible to claim STCs under either Hybrid mode for any load size or power supply option due to the higher auxiliary energy usage of the electric element.

Discussion

For Continuous electric supply, the RAPID/X6 is able to satisfy the large load size for 6 person occupancy in all heating modes and all power supply options.

For Off-peak 2 electric supply, the large load is only met with Hybrid Mode, but it is very close to being met for Standard mode. It's possible that an optimised electric heating strategy could be implemented to target these almost-met loads in the Hybrid+ mode. For standard and hybrid+ heating modes, these failures occurred during August.

As seen below in Figure 2, in OP2, Hybrid+, Large Load, the compressor is running up until 5pm when the OP2 electric supply ends, and there is a load failure at 6pm. There are a total of 4 load failures for this scenario, with the minimum delivery temperature of 43.6°C.

Figure 2 Load failure for OP2, Hybrid+, Large Load. Tout is the outlet temperature to the load. Comp_on is a signal indicating whether the compressor is on. The load events can be seen as small orange step waves.

For Solar Timer power supply the RAPID/X6 was able to meet the small and medium loads under Standard, Hybrid and Hybrid+ modes. The timer window under this power supply can be

useful for owners looking to limit the system heating to coincide with Solar P.V output. For these owners it maybe necessary to adjust the pre-set window to a later start or earlier finish depending on their solar array size and orientation.

Based on the modelling results against the CER hot water load profile draw down, small or medium households should allow at least one hour of heating prior to morning hot water draw offs. For example, if the first morning shower does not commence until 8:00am adjusting the timer on, from preset 6:00am to 7:00am may still meet hot water delivery.

It is therefore possible that small or medium households of up to 4 persons could meet their hot water demands by limiting the timer window further than the pre-set 6:00am - 6:00pm, depending on the home's daily usage and draw profile.

For homes with a large draw profile or more than 4 occupants the RAPID/X6 is unlikely to be sufficient to provide enough hot water under any of the system heating modes when run on Solar Timer power supply.

Future Work

It may be of interest in a further study to include a PV array and battery in the model to identify what size of solar timer system would be required for the RAPID/X6 to satisfy a particular household heating demand. This would be possible with TRNSYS and may provide useful information for those interested in investing in solar in combination with their RAPID/X6 heat pump system.