SYSTEMS MANUAL

AVALON TOWERS BELLEVUE

This manual describes ideas and procedures to help the maintenance team keep the facility running efficiently and cost-effectively. The top maintenance and energy efficiency guidelines are listed below, in order of importance:

1.	**Apartment Thermostat Programming**	Section 1 – Heat Pumps Appendix A – Thermostat Instructions
2.	**Central Plant Temperature Cooling Valve**	Section 1.1 – Cooling Valve Appendix C – Water Loop Description of Operations Appendix D – Cooling Valve Commissioning Results
3.	**Variable Frequency Drives**	Section 6 – Garage Exhaust System Appendix C – Water Loop Description of Operations
4.	**Common Areas**	Section 2 – Table 1
5.	**Electric Heaters**	Section 4 – Table 2

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SECTION 1. RESIDENTIAL WATER LOOP HEAT PUMPS

Apartments are not connected to the central Johnson Controls (JCI) building controls; instead, each apartment has a single heat pump controlled by a thermostat. Figure 2 shows typical heat pump efficiencies, with notes that describe the factors that are important to heat pump efficiency and illustrate the importance of monitoring the water loop temperature. To help avoid high loop temperatures, alarms are programmed into the JCI system.

Another important maintenance procedure is programming the thermostats. For the first two years, the apartment thermostats were reset to factory default whenever a tenant moved out. This procedure was changed to include a custom thermostat program designed to increase the tenant's comfort and decrease the wear and tear on the heat pumps. The instruction page for the thermostat program is provided in Appendix A.

The HVAC system is divided into two water loops, the West Tower and the East Tower. Each system has a central indirect evaporative fluid cooler and a bank of modulating natural gas heaters to moderate the water loop (see Appendix B for diagrams of the mechanical rooms). One pump in each loop circulates water to apartments and common area units. The pumps switch operation on Monday mornings. On very hot or very cold days, the standby pump turns on to maintain pressure.

Each loop extends down to Level 1 where it serves common areas and retail spaces. Figures 3 and 4 show how the central plants are connected to each heat pump. Appendix C includes a detailed description of operations.

1.1 COOLING DIVERTING VALVE

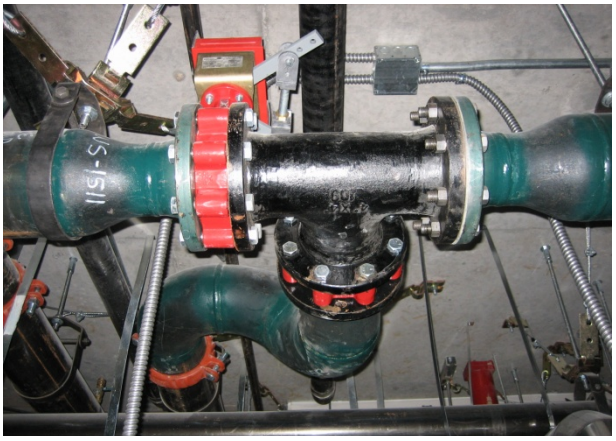

Figure 1. The West Tower cooling diverting valve should respond automatically to the JCI system; however, extensive testing shows that it is unreliable.

A central component of the system is the cooling diverting valve located in each mechanical room (see Figure 1). These valves had unreliable operation despite extensive investigation and testing. At the end of commissioning in 2013, we believe the solution is to change the installation of the valve linkage. The West Tower has been changed and the East Tower is awaiting replacement parts. If the installation change does not work, the valves may have to be manually controlled. The goals of the manual control were to leave them open in the summer (to prevent the system from overheating) and to leave them 10% open during freezing weather (to prevent the fluid cooler coils from freezing). Appendix D provides detailed testing results.

1.2 WATER LOOP OPERATING GOALS

This equipment should be reliable as long as the loop temperature follows the guidelines in Figure 2 and the apartment thermostats are programmed per Appendix A. System corrections will be needed if the goals below are not being met:

- No more than one call per month is due to failed heat pump components.
- There are no hot or cold calls from apartments after tenant orientation is provided.
- Condenser water heaters do not operate May to September.
- During the winter, the condenser water heaters run twice as long as they are OFF. The minimum OFF time should be 30 minutes.

Performance Data – TS H/V 012A (PSC Blower)

350 CFM Nominal (Rated) Airflow Cooling, 350 CFM Nominal (Rated) Airflow Heating — Performance capacities shown in thousands of Btuh

EWT °F	GPM	WPD		Cooling - EAT 80/67°F							Heating - EAT 70°F					
		PSI	FT	Airflow CFM	TC	SC	Sens/Tot Ratio	kW	HR	EER	Airflow CFM	HC	kW	HE	LAT	COP
20	3.5	4.0	9.2	Operation not recommended							265	7.7	0.89	4.9	97.1	2.5
	3.5	4.0	9.2								350	8.0	0.82	5.2	91.0	2.8
30	1.8	0.6	1.4	265	12.1	6.5	0.5	0.50	13.8	24.4	265	8.9	0.92	5.9	101.0	2.8
	1.8	0.6	1.4	350	12.6	7.8	0.6	0.51	14.4	24.6	350	9.1	0.85	6.3	94.1	3.2
	2.6	2.1	4.8	265	12.3	6.6	0.5	0.48	13.9	25.9	265	9.3	0.94	6.2	102.4	2.9
	2.6	2.1	4.8	350	12.8	7.9	0.6	0.49	14.5	26.1	350	9.5	0.86	6.6	95.1	3.3
	3.5	3.8	8.8	265	12.7	6.8	0.5	0.47	14.3	27.3	265	9.5	0.94	6.4	103.1	2.9
	3.5	3.8	8.8	350	13.3	8.1	0.6	0.48	14.9	27.5	350	9.7	0.86	6.8	95.7	3.3
40	1.8	0.6	1.3	265	12.7	6.9	0.5	0.55	14.6	23.3	265	10.3	0.97	7.2	106.0	3.1
	1.8	0.6	1.3	350	13.2	8.2	0.6	0.56	15.2	23.5	350	10.6	0.88	7.6	98.0	3.5
	2.6	2.0	4.6	265	12.8	6.9	0.5	0.52	14.6	24.8	265	10.7	0.98	7.5	107.4	3.2
	2.6	2.0	4.6	350	13.3	8.3	0.6	0.53	15.2	25.0	350	11.0	0.89	8.0	99.1	3.6
	3.5	3.6	8.3	265	12.9	6.9	0.5	0.50	14.6	25.6	265	10.9	0.98	7.7	108.1	3.2
	3.5	3.6	8.3	350	13.5	8.3	0.6	0.52	15.2	25.8	350	11.2	0.90	8.1	99.6	3.6
50	1.8	0.5	1.1	265	12.7	6.9	0.5	0.61	14.8	21.0	265	11.5	1.00	8.2	110.2	3.4
	1.8	0.5	1.1	350	13.2	8.3	0.6	0.63	15.4	21.2	350	11.8	0.92	8.7	101.2	3.8
	2.6	1.9	4.3	265	12.9	7.0	0.5	0.57	14.8	22.6	265	11.9	1.01	8.5	111.5	3.4
	2.6	1.9	4.3	350	13.4	8.3	0.6	0.59	15.4	22.7	350	12.2	0.93	9.0	102.2	3.9
	3.5	3.4	7.9	265	12.9	7.0	0.5	0.55	14.8	23.4	265	12.0	1.02	8.7	112.1	3.5
	3.5	3.4	7.9	350	13.5	8.4	0.6	0.57	15.4	23.5	350	12.4	0.93	9.2	102.7	4.0
60	1.8	0.4	1.0	265	12.5	6.9	0.5	0.67	14.8	18.6	265	12.5	1.03	9.0	113.6	3.5
	1.8	0.4	1.0	350	13.0	8.2	0.6	0.69	15.4	18.8	350	12.8	0.94	9.6	103.9	4.0
	2.6	1.8	4.1	265	12.7	6.9	0.5	0.63	14.9	20.2	265	12.8	1.04	9.3	114.6	3.6
	2.6	1.8	4.1	350	13.3	8.3	0.6	0.65	15.5	20.3	350	13.1	0.95	9.9	104.7	4.0
	3.5	3.2	7.4	265	12.8	7.0	0.5	0.61	14.9	20.9	265	12.9	1.05	9.4	115.1	3.6
	3.5	3.2	7.4	350	13.4	8.4	0.6	0.63	15.5	21.1	350	13.3	0.96	10.0	105.1	4.1
70	1.8	0.4	0.9	265	12.0	6.7	0.6	0.75	14.5	16.1	265	13.2	1.06	9.7	116.1	3.7
	1.8	0.4	0.9	350	12.5	8.0	0.6	0.77	15.1	16.2	350	13.5	0.97	10.3	105.8	4.1
	2.6	1.6	3.8	265	12.3	6.8	0.6	0.70	14.7	17.5	265	13.4	1.06	9.9	116.9	3.7
	2.6	1.6	3.8	350	12.8	8.1	0.6	0.73	15.3	17.7	350	13.8	0.97	10.5	106.4	4.1
	3.5	3.0	6.9	265	12.5	6.9	0.5	0.68	14.8	18.3	265	13.5	1.07	9.9	117.2	3.7
	3.5	3.0	6.9	350	13.0	8.2	0.6	0.70	15.4	18.4	350	13.9	0.98	10.6	106.7	4.2
80	1.8	0.3	0.7	265	11.3	6.5	0.6	0.83	14.1	13.6	265	13.7	1.07	10.1	117.8	3.7
	1.8	0.3	0.7	350	11.7	7.8	0.7	0.85	14.7	13.7	350	14.0	0.98	10.7	107.1	4.2
	2.6	1.5	3.5	265	11.7	6.6	0.6	0.78	14.3	15.0	265	13.8	1.08	10.2	118.2	3.8
	2.6	1.5	3.5	350	12.2	7.9	0.6	0.81	14.9	15.1	350	14.2	0.98	10.8	107.4	4.2
	3.5	2.8	6.5	265	11.9	6.7	0.6	0.76	14.5	15.7	265	13.8	1.08	10.2	118.3	3.8
	3.5	2.8	6.5	350	12.4	8.0	0.6	0.78	15.0	15.8	350	14.2	0.98	10.9	107.6	4.2
85	1.8	0.3	0.7	265	10.9	6.4	0.6	0.87	13.8	12.5	265	13.8	1.08	10.2	118.1	3.8
	1.8	0.3	0.7	350	11.3	7.6	0.7	0.90	14.4	12.6	350	14.1	0.98	10.8	107.4	4.2
	2.6	1.5	3.4	265	11.3	6.5	0.6	0.82	14.1	13.8	265	13.8	1.08	10.2	118.4	3.8
	2.6	1.5	3.4	350	11.8	7.8	0.7	0.85	14.7	13.9	350	14.2	0.98	10.9	107.6	4.2
	3.5	2.7	6.3	265	11.5	6.5	0.6	0.80	14.2	14.5	265	13.9	1.08	10.3	118.5	3.8
	3.5	2.7	6.3	350	12.0	7.8	0.7	0.83	14.8	14.6	350	14.2	0.98	10.9	107.7	4.2
90	1.8	0.3	0.6	265	10.4	6.2	0.6	0.91	13.5	11.4	265	13.9	1.08	10.3	118.5	3.8
	1.8	0.3	0.6	350	10.9	7.5	0.7	0.94	14.1	11.5	350	14.3	0.99	10.9	107.7	4.2
	2.6	1.4	3.3	265	10.9	6.4	0.6	0.87	13.9	12.6	265	13.9	1.08	10.3	118.6	3.8
	2.6	1.4	3.3	350	11.4	7.6	0.7	0.89	14.4	12.7	350	14.3	0.98	10.9	107.7	4.3
	3.5	2.6	6.0	265	11.1	6.4	0.6	0.84	14.0	13.2	265	13.9	1.07	10.3	118.6	3.8
	3.5	2.6	6.0	350	11.6	7.7	0.7	0.87	14.6	13.3	350	14.3	0.98	10.9	107.8	4.3
100	1.8	0.2	0.5	265	9.5	6.0	0.6	1.00	12.9	9.5	Operation not recommended					
	1.8	0.2	0.5	350	9.9	7.2	0.7	1.04	13.4	9.5						
	2.6	1.3	3.0	265	10.0	6.1	0.6	0.96	13.3	10.5						
	2.6	1.3	3.0	350	10.4	7.3	0.7	0.99	13.8	10.5						
	3.5	2.4	5.6	265	10.2	6.2	0.6	0.93	13.4	11.0						
	3.5	2.4	5.6	350	10.7	7.4	0.7	0.96	14.0	11.1						
110	1.8	0.1	0.3	265	8.5	5.7	0.7	1.10	12.3	7.7	Operation not recommended					
	1.8	0.1	0.3	350	8.9	6.9	0.8	1.14	12.8	7.8						
	2.6	1.2	2.7	265	9.0	5.9	0.7	1.05	12.6	8.6						
	2.6	1.2	2.7	350	9.4	7.0	0.7	1.09	13.1	8.6						
	3.5	2.2	5.1	265	9.3	5.9	0.6	1.03	12.8	9.0						
	3.5	2.2	5.1	350	9.6	7.1	0.7	1.06	13.3	9.1						
120	1.8	0.1	0.2	265	7.5	5.5	0.7	1.20	11.6	6.2						
	1.8	0.1	0.2	350	7.8	6.6	0.8	1.24	12.0	6.3						
	2.6	1.1	2.5	265	8.0	5.6	0.7	1.15	11.9	6.9						
	2.6	1.1	2.5	350	8.3	6.7	0.8	1.19	12.4	7.0						
	3.5	2.0	4.6	265	8.2	5.7	0.7	1.13	12.1	7.3						

Airflow is set on the CXM board. Original setting is per drawings.

1-ton units (size 012) have 3.0 gpm valves, so the middle set of numbers in each section is correct.

Piping is not insulated, so water should not be below 60F.

Cooling is most efficient at 60F water temp.

Heating is most efficient at high air flow setting. Water temp doesn't change efficiency very much.

Units will break down if water temperature is over 100F in heating mode.

Figure 2. The ClimateMaster efficiency table shows how airflow and loop temperature affect efficiency.

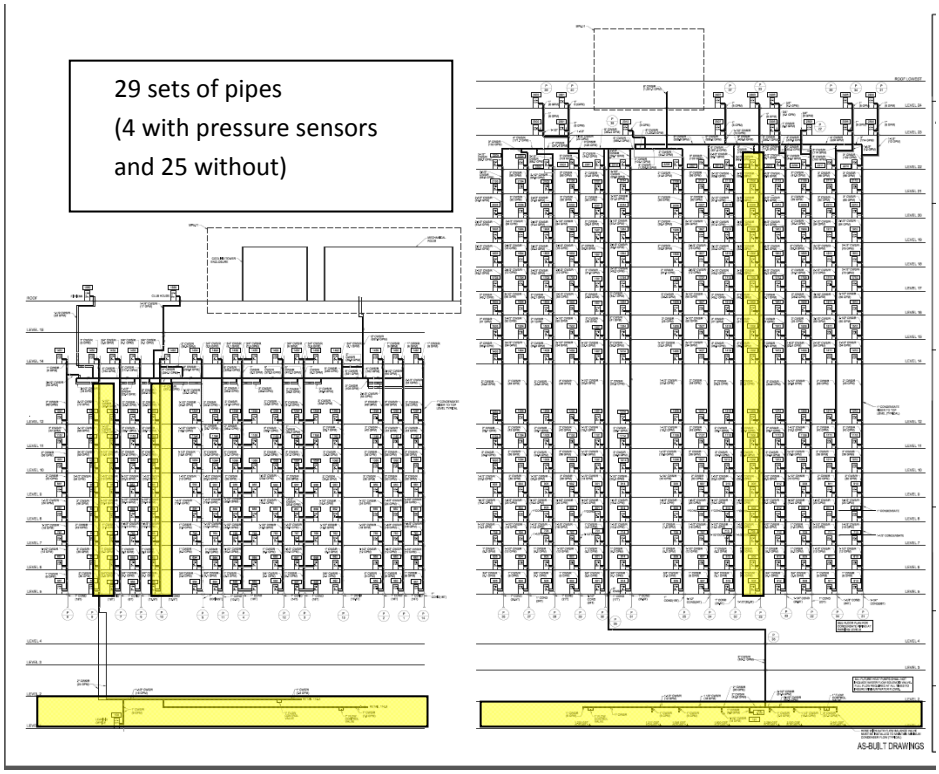

Figure 3. Elevation of AvalonTowers showing mechanical room pump control.

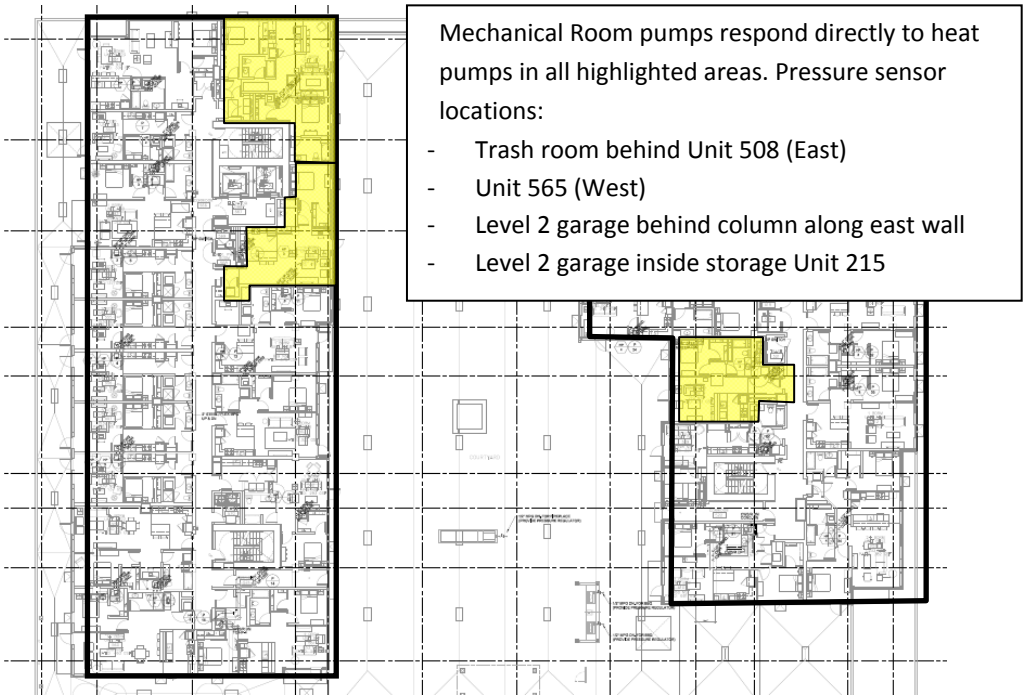

Figure 4. Floor Plan showing the mechanical room pump control.

SECTION 2. COMMON AREA WATER LOOP HEAT PUMPS

Fifteen heat pumps provide heating and air conditioning to common areas and retail spaces. Seven are connected to both the apartment water loop and to the JCI control system. These units should be controlled via temperature schedule to provide greater efficiency at night. Table 1 shows energy efficiency tips for each unit.

The remaining heat pumps are "stand-alone," so they have their own air-cooled outdoor condensers and thermostats which are not connected to the JCI system. These units are in unoccupied rooms, and the original drawings show that they should be programmed for cooling-only operation with a cooling temperature of 80°F.

Table 1. Heat pumps for common areas and retail spaces

Location / Heat Pump ID	Basic Operation	Efficiency Tips
East corridor: RTU-1 & -5	Fan on 24-7 for building pressurization. Provides fresh air to apartments. Only 1 thermostat per unit. 100% outdoor air; heated by gas; cooled by heat pump.	Use a JCI schedule to adjust temperature at night (midnight to 4:30am), especially in winter, because the gas heater is not very efficient.
West corridor: RTU-2		
Leasing office, front desk, mail room: HP-1	Fan on 24-7 because the front desk is occupied. Thermostat in leasing office.	Use a JCI schedule to close the outdoor air damper at night (unoccupied mode). Consider a schedule to adjust temperature at night (midnight to 4:30am).
Clubhouse: HP-5	Space is open 24-7, so it can't get too cold or hot.	Consider a JCI schedule to adjust temperature at night. These schedules are already in the JCI system; they just need to be activated and fine-tuned.
Exercise room: HP-6		
Retail lobby: HP-8	Space is unoccupied.	Operate the fan on "auto" so it turns off when it's not needed. Use a JCI schedule to "setback" temperatures at night (5°F to 10°F).
East Tower elevator machine room	Stand-alone. Not connected to JCI system.	Set thermostat for 80°F cooling, no heating. Set fan to "auto" so it shuts off when not needed.
West Tower elevator machine room		
Fire pump room		
Fire control room		
Black bottle: 2 units	Stand-alone.	Operated by tenant.
JoS. A Banks	Stand-alone.	Operated by tenant.

SECTION 3. RESIDENTIAL WATER

Cold water is pumped to each apartment using booster pumps located in the northeast corner of Level P2. The system operates automatically to maintain a pressure of 150 psi (pounds per square inch), or approximately 350 feet of water head. Since the building is 250 feet tall, the water pressure on the Penthouse floor should be more than adequate. The pumps are programmed to switch each time more pressure is needed. Each pump typically runs for 8 minutes, then the system is off for 2 minutes before the next pump cycles on.

Hot water provision is divided into two systems. The equipment in the mechanical room on Level 4 provides hot water to the entire West Tower and up to Level 15 of the East Tower (see Figure 5). The mechanical room on Level 24 includes water heaters for Levels 16 through 24 of the East Tower (see Appendix B for a diagram). The Level 4 plant contains 3 modulating hot water heaters and 2 large storage tanks. The East Tower plant contains two heaters and two storage tanks. Small circulating pumps return water from the top floor of each system and are controlled with aquastats to 110°F with a 30-minute delay. In other words, every time the water temperature drops below 110°F, one of the pumps turns on and operates for a minimum of 30 minutes. These pumps are controlled by the JCI Metasys system. This system runs well with automatic control.

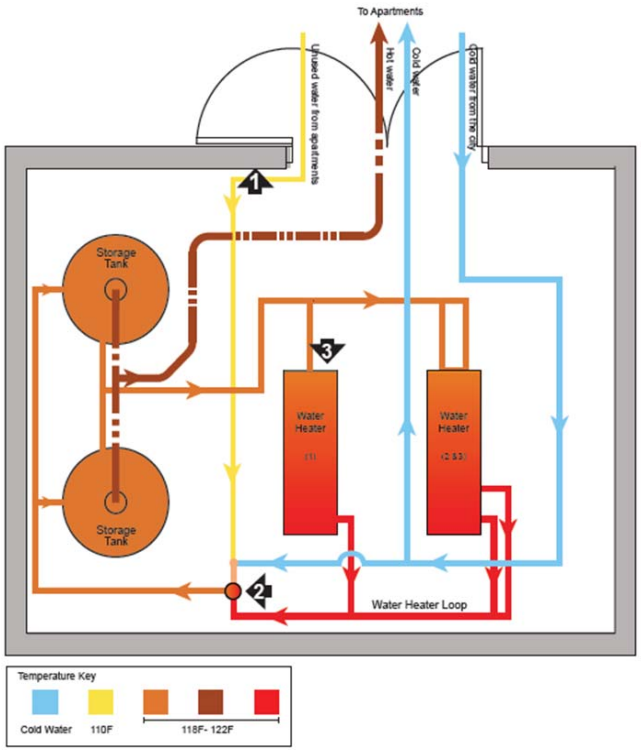

Figure 5. Level 4 mechanical room schematic. Appendix B includes the full diagram and photos of the numbered components.

Maintain the temperature setting at 120°F to utilize the condensing heater efficiently.

SECTION 4. ELECTRIC HEATING

A number of small electric heaters are installed throughout the garage. These heaters total almost 50 kW, which could account for more than 1/3 of the building's winter electricity use. Table 2 lists the location of each heater, its basic operation, and energy efficiency tips. This is a key area for energy efficiency since the garage does not need significant heating.

Table 2. Garage heating operation and efficiency tips

Location / Heat Pump ID	Basic Operation	Efficiency Tips
Garage elevator lobbies: Electric Duct Heaters -3, -4, -5, -8, -9, -10, -11, -12, -13	Fan on 24-7 for building pressurization. Provides fresh air to elevator lobbies.	Program thermostats for 65°F heating, no cooling. Make sure thermostat is set to "run," not "program" mode (dip switch is behind cover). See Appendix A for instructions.
Maintenance shop: Electric Duct Heaters -6, -7	Fan cycles with thermostat. Needs to be warm when maintenance team is working.	Install programmable thermostats so temperature can be adjusted at night (10°F lower).
Stairwell heaters (1 per stair, at bottom level)	Operates at 100%, 24 hours a day if dial turned to high. Unoccupied, unused.	Keep units on low or off. Remove dials to prevent tampering.
Baseboard heaters in storage rooms (2 in P203*, and 1 each in P208, P109, 229, & 322)	Controlled by tamper-resistant thermostat. Unoccupied, unheated storage.	Turn thermostats to mid-range (~65°F) or lower. See Figure 6 for illustration.
Baseboard heaters in bike storage rooms (2 in East, 1 in West)	Controlled by tamper-resistant thermostat.	Turn thermostats to mid-range (~65°F) or lower. See Figure 6 for illustration.
Baseboard heater in main electrical room	Controlled by tamper-resistant thermostat.	Heater should remain off: electrical room is always above 65°F.

*The heaters in P203 do not have thermostats. Since the storage is intended to be unheated, the wiring was disconnected as part of commissioning. Unless the wiring is reconnected, these heaters will not turn on.

4.1 TAMPER-RESISTANT ELECTRIC BASEBOARD HEATERS

Adjusting a tamper-resistant thermostat is easiest if you open the faceplate (screw at the bottom). Then the plastic cover over the thermostat dial must be removed by pinching the tabs on the inside of the faceplate (see red arrows in Figure 6). The manufacturer states that thermostat range is 45°F to 80°F. Turning the dial counterclockwise lowers the temperature setting.

Figure 6. Adjusting a tamper-resistant thermostat. Once the faceplate is open, the plastic cover may be removed by pinching the plastic tabs (see red arrows in inset photo).

SECTION 5. LIGHTING

The building's lighting is relatively efficient and runs automatically. Occupancy sensors are located in every residential corridor, stairwell landing, and common area. The sensors appear to work well and have correct timeouts according to their location and use. The exterior lighting is controlled by Intermatic astronomical time clocks that account for the amount of daylight on any given day of the year. These clocks are programmed with Bellevue's location as well as the day and time. Table 3 shows the location and basic operation of each clock.

Although lights are burning out and being replaced by maintenance staff, this appears to be normal wear and tear.

Table 3. Control of exterior lighting

Location / Area of Control	Basic Operation	Efficiency Tips
Main electrical room: Controls ground floor façade, main lobby entrance, Level 4 façade.	Lights stay on all night.	Consider turning Level 4 lights off at midnight. Other lighting needs to stay on for safety.
Level 2, 3, & 4 (1 clock per level): Controls interior lighting which shine onto translucent panels over the main lobby	On at dusk, off at 11pm.	None. These lights are working great.
Level 5, East Tower electrical room: Controls landscape lighting on the Level 5 patio, including the BBQ area	On all night, every night.	
Garage	On 24-7 for safety. Based on normal lamp life for these bulbs, replacement should be needed in 2014.	This is the single largest electricity use in the building; however, the lighting fixtures are the most efficient, cost-effective technology available in 2010. Be sure to replace burned-out lamps with the exact same type. Switching manufacturers or wattages can cause excess energy use and/or premature ballast failure.

SECTION 6. GARAGE EXHAUST SYSTEM

The garage exhaust system includes two large axial fans (located on Level P2 and Level 1) as well as many smaller fans connected to ductwork. The system is controlled by the JCI using several car exhaust (carbon monoxide) sensors. Per building code, the main exhaust fans run on low speed (20%) 24 hours a day. At this speed, the fans use very little energy. When any of the exhaust sensors gets above 25 ppm (parts per million), all of the smaller fans turn on and the large fans increase their speed to 50%.[1] When the system is in this mode, it uses about 10 times more energy. Alarms are programmed into the JCI system to alert maintenance staff when the system is running inefficiently (e.g. when the system is in "hand" rather than "auto" mode).

On a normal day, the system runs in high for about three hours. Typically, a car will get close to one of the sensors and send it above the high limit (150 ppm) for a few minutes. As long as the sensor returns to normal within 35 minutes, the system is working fine.[2]

The car exhaust (i.e. carbon monoxide) sensors in the garage are touchy. They seem to become unreliable at random. When this happens, a red symbol like this – ?! – appears in the JCI system. This can often be fixed by following this procedure:

1. Remove the cover.
2. Unplug the sensor card sticking out at the bottom part of the sensor. It is not wired to anything, so it can be pulled straight out. It may be warm.
3. Unplug the sensor's power. This is the black low voltage plug in the upper left.
4. "Air out" the sensor card by waving it around gently for 15 seconds.
5. Plug the power in BEFORE replacing the card. Press firmly on both the power plug and the sensor card. They should fit tightly.

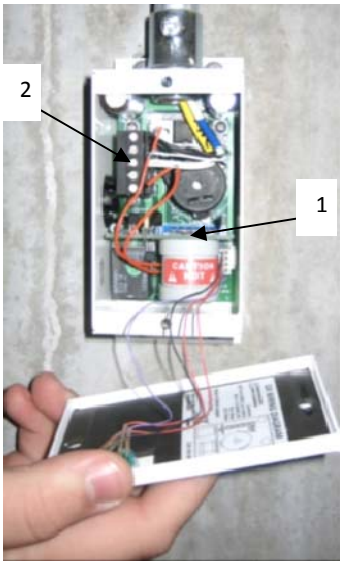

Figure 7. A typical carbon monoxide sensor. The arrows in the diagram are pointing to (1) the sensor card and (2) the sensor plug (a black low voltage connector).

Both the green power light and red sensor lights should illuminate. If the power light is blinking, there is an error with the device. Try unplugging the power again WITHOUT unplugging the sensor.

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[1] The fans are sized to assist with smoke evacuation, so they only run at 100% speed in an emergency condition when activated by the fire department.

[2] UL listing for household carbon monoxide levels allows detectors to wait 35 minutes before alarming at the 200 ppm level. Therefore, the garage system is safer than interior residential requirements.

SECTION 7. TRACKING ELECTRICITY AND NATURAL GAS USAGE

Electricity and natural gas bills are recorded in a website that all AvalonBay staff can access (see Appendix E), and the maintenance manager receives a monthly email showing the electricity and gas use information. Table 4 shows the email contents and the facility manager's analysis process. This table includes step-by-step instructions for how to determine whether the facility is operating efficiently.

Table 5 provides maximum gas and electricity use for Avalon Towers; the bills should be lower than these numbers unless the weather is extremely hot (over 100°F during the day) or cold (less than 30°F during the day). Also, since the cooling valve was not working during the winter of 2011 and was manually controlled during the 2012 winter, fixing the valve will probably decrease natural gas use. When the valve is fixed, these benchmark numbers may be too high.

Table 4. Monthly review of electricity and gas bills

Description	Units	Analysis
Daily Usage*: Current, Previous, %	Usage / day	Compare current & previous daily usage*. If current is 5% higher than previous, compare it with Table 5 (below). If it's higher than Table 5, schedule an efficiency review (see Section 8 for ideas).
Peak kW: Current, Previous	kW	Compare current & previous kW. If current value is 5% higher, compare with Table 5. If it is higher than Table 5, schedule an efficiency review (see Section 8 for ideas).
Billing Days: Current, Previous	Days	Compare current & previous billing days. If the number of days is different, the total usage will be different from last year.

*Usage refers to kWh for electricity reports and therms for natural gas report.

Table 5. Maximum Electricity and gas usage based on 2011 & 2012 bills and commissioning results

Email Report Values	January to March	April, May	June to October	November, December
Daily electricity kWh / day	<= 4,500	<= 3,800		<= 4,500
Daily natural gas therms / day	<= 400	<= 200	67	<= 400
Peak Electricity kW	<= 225	<= 205		<= 225

SECTION 8. ON-GOING COMMISSIONING PLAN

This section provides tools for maintenance staff to perform ongoing procedures, maintain efficient operation, and fine-tune the building for greater energy efficiency.

8.1 JCI SYSTEM TRENDS

The JCI system is capable of tracking many different settings, values, energy uses, etc. Table 6 describes the trend logs that are set up in the JCI to quickly verify whether the air conditioning and heating equipment is working properly. These "quick" trends can be viewed within Metasys under "Energy". These trends are limited to 5,000 data points. For some trends like outdoor air temperature, this will give a rolling 1 month history. The central plant trend will give about 6 months of history and the condenser water alarm will hopefully give several years of history. The JCI system also saves a detailed historical record, which is described in Appendix F.

Table 6. Quick reference trend logs: basic information about system operation

Type of Information	How to Use	Limitations
Outdoor air temperature	Compare electricity or gas usage with normal outdoor temperature.	
Central Plants	Track cooling tower & heater operation to fine-tune temperature ranges. Make sure heaters do not turn on from May through September.	Trends are "change of value" instead of trending every 10 minutes.
Condenser water temperatures	Determine whether loop is out of set parameters. Determine whether cooling valve is in the right position.	Does not give exact operating temperatures or system operation.
Condenser water alarm	Verify exact time when condenser water went out of parameters.	Use in combination with condenser water supply.
Space temperature: HP-1, HP-5, HP-6, HP-8, RTU-1, RTU-4, RTU-5	Review how system operation has changed over time.	Does not give exact operating temperatures.
Temperature setting: HP-1, HP-5, HP-6, HP-8, RTU-1, RTU-4, RTU-5	Determine how changes in setting affected temperature.	Use in combination with above space temperatures.

8.2 LIST OF EFFICIENCY CHECKS AND RECOMMENDED SETTINGS

Tables 7 and 8 summarize the energy efficiency tips described throughout the Systems Manual for electricity and for natural gas. These tables may be used as a checklist for maintaining and/or improving operational efficiency. See the specified sections for more information.

Table 7. Electricity efficiency checks

Equipment	Efficiency Check	Max Impact**	For More Information
Condenser water temperatures	Maintain the cooling temperature at 85°F (through the JCI). The heating temperature should be 65°F or less at the JCI. The heater control panel in the mechanical room sets the minimum water temperature so it should not exceed 75°F.	10 kW *	Section 1 Appendix B
Apartment thermostats	Program the apartment thermostats to minimize compressor cycling and limit occupant tampering. Commissioning showed that programmed thermostats greatly reduce maintenance calls & broken components.	10 kW *	Section 1 Appendix A
Common area heat pumps	Operate on a schedule to provide lower energy use at night (cooler temperature in winter, warmer temperature in summer).	5 kW	Section 2
Variable Speed Drives (VSDs)	Operate in “auto,” not “hand” mode.	15 kW	Section 6 Appendix C
Elevator lobby heaters	Set thermostat to 65°F (heating only) and operate in “run” mode.	28 kW	Section 3 Appendix A
Electric baseboard heaters	Set thermostat to middle of range, ~65°F. In underground unheated storage areas, consider shutting off the heaters; these rooms do not get below 60°F.	½ kW per heater	Section 3
Maintenance shop heater	Set thermostat to cooler temperature at night (60°F or lower).	5 kW	Section 3
Stairwell lighting	With a stopwatch, start at the top of each stairwell. Turn the stopwatch on and slowly walk down each flight. Take note of which light fixtures are do not turn ON correctly. Then, 10 minutes after starting, take the elevator back to the top floor and repeat the walk down stairs. Note which lights did not turn OFF after the correct time.	3 kW	Appendix H
Elevator machine & fire pump rooms	Set thermostat for 80°F cooling, no heating. Set fan to “auto” so it shuts off when not needed.	1 kW	Section 2

* Includes electricity savings for apartment heat pumps, which are paid for by occupants.

** kW impact occurs when the equipment would normally be running. The annual kWh depends on how many hours the equipment runs.

Table 8. Natural gas efficiency checks

Equipment	Efficiency Check	Estimated Impact per year	For More Information
Condenser water temperatures	Maintain the cooling temperature at 85°F (through the JCI). The heating temperature should be 65°F or less at the JCI. The heater control panel in the mechanical room sets the minimum water temperature so it should not exceed 75°F.	1,000 therms	Section 1 Appendix B
Rooftop units	Operate on a schedule to provide lower energy use at night (cooler temperature in winter, warmer temperature in summer).	1,000 therms	Section 2
Residential hot water	When upgrading system or performing major repairs, re-pipe both plants to have incoming cold water go through the heaters prior to being mixed with return water.	4,000 therms	Section 8.7

8.3 NATURAL GAS USAGE OF SPECIFIC EQUIPMENT

Table 10 shows the relative gas capacities of natural gas equipment in the common areas. The larger the piece of equipment, the more potential it has to use too much natural gas. The total amount, 13,225 MBH, is a peak value; the normal monthly billing demand should be much lower than this. The "summer therms" and "winter therms" in Table 5 should be close to the monthly usage.

These peak values can be used as a diagnostic tool if bills are higher than expected. For example, if the summer gas use suddenly increases, the first check should be the JCI quick trends to make sure the Hamilton water heaters (space heating boilers) are not coming on. The second check should be whether the residential water heaters are operating inefficiently.

Table 9. Gas-using systems in the common areas

Natural Gas End Use	Installed Capacity (MBH)	% Installed Capacity	Notes	Savings Available?*
Space heating boilers	5, 000 (East) 3,000 (West)	60%	Automatic control, enabled by JCI	Yes, cycling too often wastes gas
Residential water heaters	4,250	32%	High efficiency, automatic control	Limited, see Table 11 FMI
Corridor units (RTUs)	735	6%	Automatic control, by JCI	Yes, operate on temp schedule
Misc: clubhouse fireplace, BBQs	240	2%	Manually operated	No

*Savings available are based on post-commissioning results.

8.4 ELECTRICITY USAGE OF SPECIFIC EQUIPMENT

The building uses a minimum of 125 kW (kilowatts) all the time. This "base" load during mild weather includes many safety features such as parking garage lighting. Table 9 shows a breakdown of base load electricity usage as well as more typical load that includes exterior lighting and electric heating. If electricity bills are much higher than the benchmark numbers in Table 5, use the list below to identify the big electricity users in the building and review their operation.

Figure 9. Base Load Electrical Equipment

Electricity end use	Base Electrical Load (kW)	%, Base Load Total	Typical Load (kW)	% of Typical Total
Parking Garage				
Parking Garage Lighting	36.2	29%	36.2	23%
Garage Electric Heating	-	-	10.0	6%
Garage Fans	0.9	1%	0.9	1%
Non-Garage Lighting				
Exterior lighting	-	-	13.5	9%
Non-garage Interior Lighting (stairs, corridors)	15.0	12%	15.0	10%
Heating, Cooling, Ventilation				
Condenser Water Pumps	10.0	8%	10.0	6%
Cooling Tower, common area heat pumps	10.0	8%	15.0	10%
Exhaust Fans & Rooftop Units	9.3	7%	9.3	6%
Cooling Tower basin heaters	-	-	-	-
Other				
Panel H1-A (electric duct heater, gen block heater)	13.5	11%	13.5	9%
Panel L1-A (MDF room, misc plug loads)	9.7	8%	9.7	6%
Elevators	15.0	12%	15.0	10%
DW booster pumps, misc emergency systems	6.4	5%	6.4	4%

8.5 BILL TRACKING TOOL

The benchmark information in Table 5 was created based on 2011 and 2012. If future years are particularly hot or cold, the electricity and/or natural gas use will change, and the benchmark information will need to be normalized to the actual weather conditions. Puget Sound Energy provides a free bill-tracking tool for use with Microsoft Excel. This tool can perform weather correction to help AvalonBay verify whether changes in energy use are due to variations in weather. The PSE bill-tracking tool is provided with the CD of this Systems Manual, and is saved in the "Systems Manual 2013" folder on the JCI computer's desktop. Additional information is in Appendix G.

8.6 FUNCTIONAL TEST PROCEDURES

Commissioning tests from the construction phase and the post-occupancy phase are provided in Appendix H These tests could be used as guidelines for future commissioning; however, some of them are outdated with regard to the current facility operation. Functional testing should be conducted if the information in Sections 8.1 through 8.5 does not provide the desired efficiency improvements.

8.7 ADDITIONAL ENERGY EFFICIENCY OPPORTUNITIES

Table 11 lists energy efficiency opportunities that were deferred during commissioning. In general, these actions require multiple rounds of investigation and/or equipment change out. AvalonBay should consider the items below when reviewing building operation and setting budgets for efficiency improvements.

Table 10. Additional energy efficiency opportunities

Location / System	Opportunity	Description	Recommendations
Cooling Tower	Run system with dry basins in winter	The condenser water loop does not need cooling for at least 6 months of every year so the water in the basin could be drained in the winter. As long as this is done every year, the basin heaters should be permanently turned off.	If this is done, make sure that the diverting valves continue to open when the outdoor air gets below 40F. Otherwise, the condenser water in the fluid cooler loop might freeze and break the piping.

Location / System	Opportunity	Description	Recommendations
Garage & mechanical rooms	Heat trace is operating incorrectly	Heat trace was found to be operating on Level P1 and in the West Tower mechanical room (at the back on the line that feeds the cooling tower). There is a freeze protection thermostat installed which should shut the heat trace off when the pipe is over 40°F. The heat trace in the West Tower was measured and found to be operating when the pipe was 60-70°F.	Inspect the wiring and compare it with the installation manual. Consider performing the commissioning tests listed in the installation manual.
Lighting	GEF room P207 occupancy sensor	The planned occupancy sensor is not installed, so two 60-watt light fixtures run 24-7 in this unoccupied room.	Install an occupancy sensor at the j-box near the ceiling to the left of the door.
Lighting	Fire Pump room on Level P2	It appears that the switch for this room was not wired correctly so five 60-watt light fixtures run 24-7. Although there is an occupancy sensor in the room, it does not control the lighting. The circuit labeled on the ceiling jbox above the sensor is labeled correctly and, when the circuit breaker is turned off, this turns off the lights.	Revise the metal conduit and re-wire the sensor to connect to the lighting within the room.
Common heat pumps	HP-8 thermostat air leakage	During the winter, a draft of cold air blows into the thermostat housing from the un-insulated exterior wall on which the thermostat is located.	Add insulation and/or caulk to the 2" wall penetration behind the thermostat. NOTE: This task is difficult because there is a lot of wiring and the housing appears to be permanently mounted to the base plate.
Common heat pumps	Corridor temperature settings	The corridor temperatures are set for a single cooling value (85F).	Instead of changing the setting manually, set up a schedule in the JCI program to provide a cooling temperature similar to the heating schedule.
Common heat pumps	HP-5, HP-6 schedule	The common area heat pumps run in occupied mode 24 hours per day, 7 days per week. HP-5 (clubhouse) has a 2°F deadband (it cools and heats at +/- 4°F from settings). HP-6 (exercise room) has a 4.5°F deadband so it operates +/-9°F.	Modify the operating schedule to allow the "unoccupied" set points which are already programmed into the JCI. Also, consider decreasing the exercise room deadband value so the unit is more responsive.
Common heat pumps	HP-1 schedule	The common area heat pumps run in occupied mode 24 hours per day, 7 days per week. For this unit, that means 10% outdoor air is brought in all the time. Since the lobby is only staffed with one person after 5pm, the outdoor air could be reduced significantly.	Modify the operating schedule to allow the "unoccupied" outdoor air settings after 5pm (keep the same temperature). This will save energy in the winter, when the outdoor air is being warmed 24 hours/day.

Location / System	Opportunity	Description	Recommendations
Residential hot water	Piping arrangement does not take advantage of condensing boiler capabilities.*	The Level 4 and Level 24 mechanical rooms were piped with cold water mixing into the main storage tanks. This means that the condensing boilers are operating at 118-122°F return water temperature, when peak efficiency is at under 100°F.	Consider re-piping the heaters when equipment is being replaced. We estimate that optimized piping would provide a 5-7% increase in annual natural gas efficiency for an annual savings of $3,000-$4,000.
Rooftop exhaust fans, elevator lobby heaters	Equipment with poor power factor	The rooftop exhaust fans' power factor is 0.2, but they only use 1/3 to 1/2 of their peak kW. The elevator lobby heater power factor is 0.3 when operating in partial heat, but they only use 1/5 of their peak kW. The building's overall power factor appears to add a reactive power charge of $100 per month to the electricity bill.	Consider installing power factor One way to decrease the elevator lobby heater power factor is to shut off the heaters during the summer. Modifying the exhaust fans is more difficult; installing a VFD on the fans would work, but is very costly.
Garage / Maintenance shop	5 kW duct heater operates too much	The duct heater thermostat maintains the shop at 68F 24/7 even though no one is in the shop over night.	Install a programmable thermostat and reduce the temperature from 10pm to 6am.

* Standard efficiency boilers must heat water without condensing the moisture in the exhaust stack. This means operating the machines hotter than the dew point of the outgoing air, which leads to heating energy going out the exhaust pipe instead of into the hot water. Avalon Towers' water heaters are able to condense the moisture out of the exhaust stack and operate much more efficiently. This is particularly true when they can operate at temperatures below 100°F.

SECTION 9. ONGOING TRAINING OPPORTUNITIES

The commissioning team and the maintenance team at Avalon Towers have identified priority areas for ongoing education and advancement, including ClimateMaster heat pump training, refrigeration technician certification, and education in HVAC service and boiler maintenance. Table 12 shows resources for getting more information on these training topics.

Table 11. Ongoing training opportunities

Training Topic & Website	Comments
ClimateMaster traveling sessions: http://www.climatemaster.com/commercial-training	These sessions are highly recommended for learning more about facility's heat pumps in a classroom setting.
Refrigeration technician exam at Seattle Central Community College: http://www.seattlecentral.edu/maritime/prog.php	Employing certified refrigeration technicians would decrease AvalonBay's out of pocket expenses when heat pumps break down.
Technician training at the Northwest HVAC/R Training Center: http://inwhvac.org/training_center.html	These full time school programs provide training on a wide range of topics. It would benefit AvalonBay to employ certified technicians; however, it would be difficult to have a current employee retain their position while attending school.
Boiler maintenance training at the Lake Washington Institute of Technology: http://www.lwtech.edu/academics/programs_of_study/building_and_plant_maintenance.html	

SECTION 10. APPENDICES

Appendix A	-	Thermostat Programming Instructions
Appendix B	-	Mechanical Room Diagrams
Appendix C	-	Heat Pump Water Loop Description of Operations
Appendix D	-	Cooling Valve Operation
Appendix E	-	Accessing Electricity and Natural Gas Bills
Appendix F	-	Historical Trend Logs
Appendix G	-	PSE Bill Tracking Tool
Appendix H	-	Functional Test Procedures

APPENDIX A. THERMOSTAT PROGRAMMING INSTRUCTIONS

1. Override the thermostat to reset it to factory default.

2. Programming Mode: Press MODE and UP ARROW to enter & exit. After each entry, press MODE.

- Occupied Mode 1
- Cooling Temperature 75°F
- Heating Temperature 65°F
- Cooling, unoccupied 78°F
- Heating, unoccupied 62°F
- Day of the week Monday
- Start Time 4:00am
- Stop Time 11:59pm
- On/Off On
- Copy Yes

Repeat copy for Tuesday through Sunday

3. Advanced Setup: Hold MODE and OVERRIDE at least 5 seconds to enter. The Step number is shown in the top right corner (see guide to steps in Table A1). If only Steps 1 and 2 are visible, the buttons were not held down long enough; press MODE and OVERRIDE to exit, then try again. After each step, press MODE. Press MODE & OVERRIDE to exit.

Table A1. Thermostat programming: advanced setup

Step	Description	Range	Default	Avalon Program
1	Time of Day	--	--	Set Time
2	Day of the Week	--	--	Set Day
3	Reset Service Filter Icon	--	--	Reset Filter
4	Service Filter Run Time	0 - 1,950 hrs	500 hrs	1,000 hrs
5	Fan Operation	Auto / On	Auto	Auto
6	Deadband	1 – 6°F	2°F	1°F
7	Forced Minimum Temperature Difference	0 – 6°F	2°F	6°F
8	Cycles per Hour	d, d1, 2 - 6	6	3
9	Fan Purge Time	0:00 – 3:00	0:00	0:00
10	Backlight	Off / On	On	On
11	Soft Start	0 – 99	0	0
12	Temperature Units	F / C	F	F
13	Outside / Duct Sensor	Yes / No	No	No
14	Security Level	0 – 3	0	2
15	Max Allowable Heat Temp	35 – 99°F	80°F	75°F
16	Min Allowable Cooling Temp	35 – 99°F	65°F	65°F
17	Reversing Valve Polarity	O/B	O	O

Configure Advanced Setup — To enter the advanced setup screens (
the thermostat, press the Mode and Override buttons simultaneously. The displa
will change. Continue to hold down the buttons for 5 more seconds. If only Ac
vanced Setup Steps 1 and 2 are accessible, then the buttons were not held dow
long enough. The Advanced Setup Step number is shown in the top right corn
of the thermostat screen. Use the Mode button to advance through the step
There are 19 Advanced Setup Steps. See Table 2. Press the Mode and Overric
buttons at the same time to exit the Advanced Setup mode.

NOTE: Refer to the Set Clock section for Advanced Setup Steps 1 and 2.

Set Clock — The Set Clock function allows the user to change the time and day displayed on the thermostat. Press and hold the Mode and Override buttons at the same time until the display changes. The display will show the Setup annunciator. The current time will blink on and off. Press the UP ARROW and DOWN ARROW buttons until the correct time is shown. Hold down the buttons to quickly move through the time display. The AM and PM annunciators will automatically change. To scroll through by hours instead of minutes, hold down the Override button while pressing UP ARROW or DOWN ARROW. To ensure the schedules are properly followed, make sure that AM or PM is correct for the time chosen. When the correct time is shown, press the Mode button to modify the day of the week. The current day will blink on and off. Press the UP ARROW and DOWN ARROW buttons until the correct day is shown. Press the and hold the Mode and Override buttons at the same time again to exit the Set Clock mode.

SERVICE FILTER (Steps 3 and 4) — Step 3 allows the user to reset the Service Filter counter to zero and remove the "SERVICE FILTER" icon (if displayed on the thermostat screen). Press the Override button while in Setup Step 11 and the counter is reset to zero. Press the Mode button to adjust the number of hours the blower will run before the "SERVICE FILTER" icon is displayed. The range is 0 to 1950 hours. Set the variable to 0 to disable this function. The default is 500 hours.

FAN CONFIGURATION (Step 5) — The fan configuration can be set to On or Auto. When the configuration is set to On, the fan will run continuously during the occupied schedule and all other modes except OFF. The fan will be off during the unoccupied schedule except during heating or cooling operation.

If Auto is selected, the fan will run only during heating or cooling operation. The default is Auto.

DEADBAND (Step 6) — The deadband is the difference in temperature above the cooling set point or below the heating set point that the thermostat will wait before turning on the first stage of heating or cooling. For example, if the cooling set point is 82 F (28 C) and the deadband is 2 degrees, the first stage of cooling will not be energized until the temperature reaches 84 F (30 C). The range of values is 1 to 6 degrees. The default is 2 degrees.

SET POINT MINIMUM DIFFERENCE (Step 7) — The minimum difference between heating and cooling set points can be user-configured. The range is from 0 to 6 degrees. The default is 2 degrees. The minimum difference is enforced during Auto-changeover and Program On operation.

CYCLES PER HOUR LIMIT (Step 8) — The number of times that heating or cooling can be energized per hour can be configured. Set the variable to "d" for no limit. Set the variable to "d1" to disable the 5-minute compressor lockout. The variable can also be set from 2 to 6 cycles per hour. The default is 6 cycles per hour.

⚠ CAUTION

Damage to compressor could result if 5-minute compressor lockout is disabled or compressor is allowed unlimited cycles. Do not set thermostat Advanced Setup Step 8 to "d" or "dl" unless specifically recommended for the application.

PRE-OCCUPANCY PURGE TIMER (Step 9) — The preoccupancy purge allows fresh outside air to be brought into the space before the Occupied 1 time period. The timer limits the amount of time that the purge can operate. The timer can be set from 0 to 3 hours with 15-minute intervals. The default is 0 hours (disabled).

BACKLIGHT DISPLAY (Step 10) — The display backlight can be set to ON (always on) or OFF (turn off 8 seconds after usage). The default is ON.

SOFT START (Step 11) — The soft start is used when multiple units are used in an application. The soft start staggers the start-up times of the units in the event of power loss and restart. Each unit should be assigned a unit ID number. The 30-second delay time is multiplied the unit ID number to get the total soft start delay time for each unit. For example, if the unit ID number is 10, set the Soft Start function to 10, the start-up delay time is 30 seconds x 10 = 300 seconds (5 minutes). The range is 0 to 99 (ID numbers). A value of 0 disables the function. The default is 0 (ID number).

FAHRENHEIT/CELSIUS OPERATION (Step 12) — The thermostat can be set to operate in Fahrenheit or Celsius degrees. Set the variable to "F" for Fahrenheit operation. Set the variable to "C" for Celsius operation.

SENSOR TYPE CONFIGURATION (Step 13) — The sensor type configuration can be set to YES or NO. If it is set to NO, any sensor wired to the RS and RS+5 terminals will be automatically detected and used as a remote temperature sensor (thermostat controls to sensor temperature reading). If the sensor type configuration is set to YES, any sensor wired to the RS and RS+5 terminals will be used as an outside or duct sensor (thermostat will not control to sensor temperature reading). The default is NO.

SECURITY LEVEL (Steps 14 to 18) — The Security Level limits the actions that the user can perform at the thermostat. There are 4 security levels. When the security level is set to "0," no security will be in effect. When the security level is set to "1," the set point range is limited by the settings of Steps 17 and 18. When the security level is set to "2," the set point range is limited by the settings of Steps 17 and 18 and the Program thermostat operation mode is always in effect. When the security level is set to "3," the set point range is limited by the settings of Steps 17 and 18, the Program On mode is always in effect, and set point changes are prohibited. The default is 0.

NOTE: The Fan button is ignored when security levels 2 or 3 are in effect.

Security Maximum Heat Set Point (Step 15) — If the Security Level is not set to 0, the maximum heating set point will be in effect. The user will not be allowed to set the heating set point over the specified value. The range of values is 35 to 99 F (1 to 37 C). The default is 80 F (27 C).

Security Minimum Cool Set Point (Step 16) — If the Security Level is not set to 0, the minimum cooling set point will be in effect. The user will not be allowed to set the cooling set point below the specified value. The range of values is 35 to 99 F (1 to 37 C). The default is 65 F (18 C).

HEAT PUMP CONFIGURATION (Steps 17 and) — The thermostat is provided from the factory in heat pump mode. To set the thermostat for heat pump operation, Advanced Setup Step 4 must be configured to ON. Use the UP and DOWN ARROW buttons to configure the step. The default is ON. Press the mode button to continue to Step 5. Step 5 is used to set the reversing valve polarity for the heat pump. The variable can be set to either "B" or "O." Set the reversing valve polarity to the correct value depending on the application. The default is "O."

Figure A1. Thermostat advanced setup instructions from manufacturer's manual (re-organized to match the actual thermostats in Avalon Towers).