UCONS Ductless Heat Pump Sacramento Field Demonstration

Draft Metering Protocol
Last update: 6-17-15

Overview

This demonstration is designed to evaluate the energy performance, temperature distribution, and occupant comfort of high efficiency, single-head, ductless heat pumps (DHP) installed in four Sacramento area manufactured homes.

The DHPs will be sized and installed to accommodate the open central living/kitchen areas of the homes. The existing HVAC (central, direct-expansion air conditioning) will be left in place and used on alternating weeks over the study duration. This study design, also known as a "flip-flop" study (each system is used on alternating weeks), will allow for system performance comparison over similar weather patterns for the study duration.

The occupant will have control over both of the installed systems, but encouraged to only operate one system at a time according to a predetermined schedule. In the event the DHP will not satisfy occupant comfort, the existing system can be re-energized and operated. The proposed metering will capture all system energy use, including when/if both systems are energized.

While not a statistically significant sample, this demonstration will help to inform the energy performance, occupant comfort, and the technical/practical aspects of using a single-head DHP system to displace and/or supplement central air conditioning systems in the manufactured home setting.

The demonstration is expected to run during the months of July, August, and September, 2015.

Research Questions

1. What fraction of the total cooling load will a single-head DHP be able to satisfy over the cooling season in four manufactured homes in Sacramento, CA?

2. Of the fraction of cooling load displaced, what are the resulting energy savings in comparison to the existing central air conditioning system?

3. What are the differences in zonal temperature distributions (DHP versus existing AC) across the major living zones (living room, kitchen/dining, and bedrooms) over the study duration?

4. In comparison to the central AC, how well does the DHP provide for occupant comfort? This research question will be answered through occupant surveys.

Evaluation Goals

- Evaluate the cooling system energy use and savings via panel-level, true-power metering of the existing central AC system and the DHP, as operated in a flip-flop study protocol.
- Using the time-series power measurements, evaluate the fraction of cooling energy effectively displaced by the DHP.
- Employing a series of stand-alone temperature data loggers, record and evaluated zonal temperature distribution (up to 7 zones/areas per home) for each system over the study duration.
    - Relative humidity will be recorded and evaluated in the central living HVAC zone.
- Assess occupant comfort and system satisfaction through deployment of an occupant survey at the outset and completion of the demonstration.
    - Survey instrument will be developed specific to system design, installation, control, usability, and comfort. Appendix A presents a sample survey – this will be modified specific to this study.

Monitoring Approach

- End-use metering at electrical panel of existing central AC (compressor, condensing fan, air handler, and auxiliaries) and DHP circuit.
- Whole building/mains electrical metering
    - Recommend true power, root mean square (RMS), measurements and data recording for all electrical metering.
- Request 30-day (i.e., typical billing cycle) electric utility data. Target 2 years pre-retrofit and duration of post-retrofit period.
    - If available, request any utility interval (i.e. 15 minute) data.
    - All utility data access will require customer consent.
- Space temperature and relative humidity (RH).
    - Multiple point temperature and RH logging of affected zones. Locations to be considered:
        - Partitioned zones (bedrooms/other)
        - Main living space
        - Thermostat location
- Air delivery temperature. Delivered air temperature for existing and DHP pump systems
        - Delivery head of DHP
        - Existing duct supply air diffuser, validate use and when/if ducts are to be used for distribution

- Demonstration site outdoor air temperature (optional - data can be downloaded from local weatherstation).

All metering proposed to use 1- 5 minute integration interval for a higher resolution data set. Appendix B presents proposed metering equipment.

Table 1 presents proposed locations. Actual deployments will be made after home audits are completed.

Table 1. Temperature/RH Metering Locations and Names

Point name	Measurement	Notes
T1	Existing thermostat temperature	Gives control point of occupant setting
T2	Main living space temperature	Temperature affected by DHP
T3	Bedroom 1 temperature	Bedroom temperature
T4	Bedroom 2 temperature	Bedroom temperature
T5	DHP delivery temperature	Delivery air temperature of DHP
T6	Existing system delivery temperature	Delivery air temperature of existing system
RH	Main living space relative humidity	Single point RH in main living space

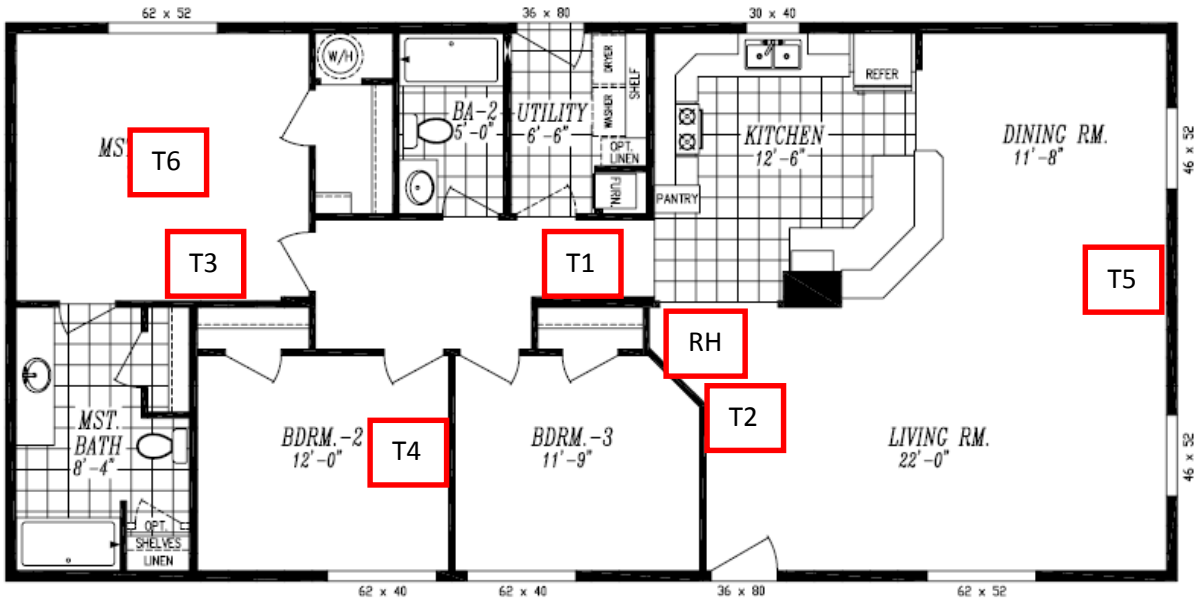

Figure 1. Sample Logger Placement Points – Typical Manufactured Home

Deployment Protocol

Logger logistics. Loggers will be pre-labeled and come in groups of seven. Each group will be allotted to one home.

- Loggers 1-6 are temperature loggers and placement will be dictated as described in Table 1 and shown in Figure 1.
- Logger 7 is the relative humidity (RH) logger and this should be installed in the main living space served by the DHP.
- Logger installation guidance is provided below in "Installation Notes."

Installation Notes

- All space temperature loggers to be placed on "interior" space/walls at height between 3' and 5' from floor.
    - Discount locations where logger will be influenced by heat/cooling sources, e.g., sun light, outside doors/windows, lighting, TVs, AV equipment, kitchen appliances, HVAC ducts, etc.
    - Consider locations where device does not have to be physically attached to surface, e.g., shelf, bookcase, top of thermostat, etc.
    - Where attachment is necessary, consider side tabs, wire ties, double sided tape, magnets (all included).

- "DHP Delivery" and "Existing System Delivery" loggers need to be attached to the respective supply diffuser such that the logger thermister (black circle on top) "sees" the delivered air when system is operating.
    - For attachment to diffuser, consider Velcro strap (included) or wire ties for affixing to diffuser hardware/supports.

- Documentation left with the customer should include instructions of <u>not to move the loggers</u> and a <u>UCONS point of contact</u> for issues and questions.

Appendix A. Sample Customer Survey – please note that this is provided as a sample-only. Final survey instrument will be developed upon system selection and installation.

UCONS DHP Pilot. Sample Customer Survey

Home Number: _____

Home Address: _____

Person filling out survey: _____ Date:_____

1. **Did the installers and evaluator teams address your questions and needs during the evaluation program?**
   - ○ Yes
   - ○ No

2. **How would you rate the ductless heat pump (DHP) on the following?**

	Poor	Below Average	Average	Above Average	Excellent	Don't Know
Ease of use	○	○	○	○	○	○
Comfort	○	○	○	○	○	○
Quietness of head	○	○	○	○	○	○
Quietness of compressor	○	○	○	○	○	○
Air Distribution	○	○	○	○	○	○
Temperature Distribution	○	○	○	○	○	○
Appearance	○	○	○	○	○	○

3. **During the DHP portion of the pilot evaluation did you use supplemental cooling?**
   - ○ Existing central AC
   - ○ Window/wall unit
   - ○ Did not use supplemental cooling **(skip to question 7)**

4. **How often did you use supplemental cooling?**
   - ○ Seldom (less than 10% of the time)
   - ○ Somewhat often (10% to 25% of the time)
   - ○ Often (25% to 50% of the time)
   - ○ Very Often (50% to 75% of the time)

5. **In what rooms (choose all that apply)?**
   - ○ Entire home (central system)
   - ○ Main living area
   - ○ Bedroom 1
   - ○ Bedroom 2
   - ○ Bedroom 3
   - ○ Other

6. **Under what circumstances was the supplemental cooling system used and why?**

_____

_____

7. **What were the primary benefits when the DHP system was running?**

_____

_____

8. **Did you have any problems with the DHP?**
   - ○ Yes
   - ○ No **(skip to question 10)**

9. **What were they?**

_____

_____

10. **How did you use the DHP to benefit your needs?**

_____

_____

11. **Did you notice any changes in comfort or temperature in any areas, rooms, or zones during the DHP portion of the pilot?**
    - ○ Yes
    - ○ No **(skip to question 13)**

12. **If yes, what areas of your home were these noticeable, and with what outcome?**

_____

_____

13. **Over the course of the pilot, did you tend to change the temperature set point of the DHP?**
    - ○ During the day
    - ○ During the evening
    - ○ Overnight
    - ○ Other _____
    - ○ Did not change the temperature set point

14. **What did you like best about the DHP system?**

_____

_____

15. **What did you like least about the DHP system?**

_____

_____

16. **In what ways could the DHP system be improved for better use in a home like yours?**

_____

_____

17. Overall, how satisfied are you with the ductless heat pump you received?

- ○ Very satisfied
- ○ Somewhat satisfied
- ○ Neutral
- ○ Somewhat dissatisfied
- ○ Very dissatisfied

18. If you are dissatisfied, please tell us why:

_____

_____

19. Additional Comments:

_____

_____

_____

Appendix B. Metering Equipment

Data Loggers

A. Temperature Monitoring

Consider Onset Computer "Hobo" data logger series for temperature measurements.

1. **Temperature only. Hobo UX 100-001**

- **Range:** -20° to 70°C (-4° to 158°F)
- **Accuracy:** ±0.21°C from 0° to 50°C (±0.38°F from 32° to 122°F)
- **Memory:** 84,650 readings – 58 days at 1 minute intervals
- **Size**: 3.66 x 5.94 x 1.52 cm (1.44 x 2.34 x 0.6 in.)

- **Price:** TBD

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2. **Temperature and relative humidity. Hobo UX 100-003**

- **Range:** -20° to 70°C (-4° to 158°F)
- **Accuracy:** Temp: ±0.21°C from 0° to 50°C (±0.38°F from 32° to 122°F),
  RH: ±3.5% from 25% to 85% over the range of 15° to 45°C (59° to 113°F) including hysteresis
- **Memory:** 84,650 readings – 58 days at 1 minute intervals
- **Size**: 3.66 x 8.48 x 2.29 cm (1.44 x 3.34 x 0.9 in.)

- **Price:** TBD

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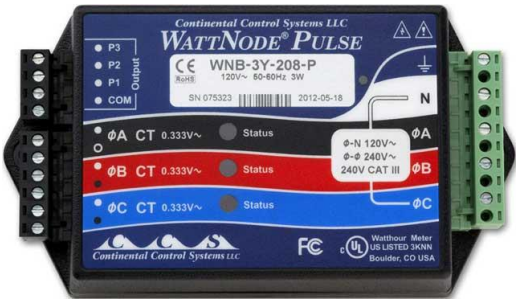
3. **Outdoor Temperature and relative humidity. Hobo UX 23-001**

- **Range:** -20° to 70°C (-4° to 158°F)
- **Accuracy:** Temp: ±0.21°C from 0° to 50°C (±0.38°F from 32° to 122°F),
  RH: ±2.5% from 10% to 90% RH (typical), to a maximum of ±3.5% including hysteresis.
- **Memory:** 21,000 readings – 15 days at 1 minute intervals, 840 days at 1 hour intervals
- **Size**: 10.2 × 3.8 cm (4.0 × 1.5 in.)

- **Price:** TBD

B. Energy Monitoring

1. Consider Wattnode "pulse" true RMS meter (one for each 240 load)



Price: TBD

Specs: http://www.ccontrolsys.com/w/WattNode_Pulse_-_Models

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2. Current transformers (two for each 240 load)

Price: TBD

Specs: http://www.ccontrolsys.com/w/Current_Transformers

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3. Pulse collecting data logger (1 per home)

Price: TBD

Specs: http://www.onsetcomp.com/products/data-loggers/ux120-017