# Installing an efficient window air conditioner inside a cargo van.

Santiago - 14 August 2018

Version 2 - 16August 2018 – new data on DC fan power consumption

This part of my van conversion project deals with adding an efficient (EER 12.2) inside van with condenser intake and exhaust through floor.

**Acknowledgement:**
A shout out to engineer Gary who runs http://www.buildagreenrv.com website for his help and encouragement with my inside van window air conditioner install. His site is outstanding and I encourage all RVers to visit, I guarantee you will learn something new and come back for more. This DIY site is open to all DIY aspects of build common to all RVs. To top it off, Gary is a decent fellow.

**Goals:**

1. Be completely inside van. Not visible from outside.
2. Be able to run for hours off house batteries when not on shore power.
3. Be a lot quieter than roof mounted units.

**Requirements:**

1. Have sufficient space to house air conditioner AND supporting plenum.
2. Have large enough floor area near by to cut condenser air cooling intake and exhaust ports.
3. For smaller units less than 8,000 Btu/hr rated, have sufficient van insulation.
4. Not have expectations to be cooled as quickly as a 13,000 Btu/hr roof unit.
5. Not have expectations that it will cool great in 110 F ambient, parked in full sun.
6. Mount as high as possible to lessen temperature stratification.

**Problem with using a window air conditioner inside van:**
They are great when installed as designed, big rectangular condenser freely blowing hot air to atmosphere and air intake on three sides freely supplying condenser with cooler air.

If you install it in a van like that, it will be an easy and efficient install. However, many of us don't want it protruding out our van. We want it inside and that's where it gets tough if you want to keep some semblance of efficiency.

What I found out through testing is that condenser air flow is key. DO NOT judge performance by cold evaporator air flowing out the front of the evaporator grill. It will remain as cold even if the condenser is seriously overheating, compressor struggling and power consumption skyrockets. Under these conditions, plan on a replacement soon. Your install should be such that condenser air flow is to be as high as possible. Goal is for flow to be as high as when the unit runs with no air restrictions.

With my need to restrict condenser inlet and exhaust port diameters to 8", air flow was greatly reduced from 480 cfm baseline to 225 cfm during test. When turning on helper fan air flow increased 130 cfm to 355 cfm. This extra "booster" flow reduced Air conditioner power consumption by 60 watts. While testing, the DC fan itself consumed 32.5 watts (2.67 amps) this indicates booster fan does not add to overall energy consumption, in fact it saves air conditioner use energy especially in light of the DC to AC conversion losses.

**Alternate window air conditioner installs in order of my preference:**

1. Break up the window air conditioner into two, evaporator coil and fan/controls stay inside and condenser coil with fan mounts outside, often mounted underneath the vehicle. Drawback will be condenser coil fins getting plugged with mud, road debris and potential to be physically hit with rocks and the like. If I ever change system this would be a contender. I would build a protective enclosure that will need to manually open when using the air conditioner and remain closed when not in use.

2. Install inside but allow condenser to exhaust through very large side wall vent. Supply cooling air through floor. Not a bad solution if you don't mind the wall grill.

3. Install high up in rear if possible same as RoadTrek has been doing. Good condenser cooling, no exposed unit only grill showing on back.

4. Allowing rear of unit to protrude through wall enough to expose condenser air inlet grill on three sides. The air outlet is at the end of unit. This is most efficient install but has obvious drawback.

5. Install under a seat bench using a couple of 4" diameter inlet and couple of 4" diameter exhausts. From my limited experience testing with 8" ports I am sure the condenser will run very hot, consume much more power and likely not last as long. Even with my 8" diameter ports I still need a booster fan for decent performance. Roughly speaking on vent areas, two 4" vents have 25 square inches while one 8" has 50 square inches.

**Equipment when installed :**

1. My van is a 2018 Promaster 159" wb high top. Air conditioner will be installed under rear cross wise bed in garage/utility compartment. Evaporator grill is 24 inches from floor and facing forward down the hall. There is sufficient free unobstructed floor space to cut two 8" diameter vent holes. I can cut 10" diameter vents but need to be practical.

2. The window air conditioner is a Frigidaire 6,000 Btu/hr model FFRE 0633S1 EER 12.2, 115vAC 56 dbA, 4.5 amp 490 watts. I noticed during out of the box testing with 91F ambient power consumption was 484 watts.

3. The booster fan is an Orion 12 vDC fixed speed (2000 rpm) axial fan. Model OD254AP-12MB. 690 cfm @ 0 iwc, 47 db, 23 watts. PWM speed control with tach output is available but long lead time forced me to a fixed speed. Testing with 10" fan mounted on inlet and 8" exhaust port, using fan produced 355 cfm. Per Orion fan performance curve this is about 0.16 iwc.

4. Plenum will be all 30 gage galvanized sheet metal most all hand formed, riveted and screwed. One purchased reducer 8" diameter floor opening to 10" diameter 26 gage galvanized sheet metal.

    a. Cooling side begins at floor level as 8". Runs past aluminum die cast gate shut off valve. Expands diameter to 10" to match axial fan. From fan plenum supplies air to all three sides of the air conditioner. The compressor being on opposite side needs good supply of cooling air flow. All 90 deg bends will have radius at throat and heel.
    b. Hot condenser exhaust will capture the 15.5"x 11" finned coil area and direct it to 8" port below. This port is above a second aluminum die cast gate shut off valve then straight through van floor.
    c. Plenum will be insulated with Thinsulate.

5. Two 8" diameter die cast aluminum gate valves BlastGateCo brand model BGF08. These will completely isolate outside environment when not running the air conditioner and manually operated from inside van.

**Major test equipment :**

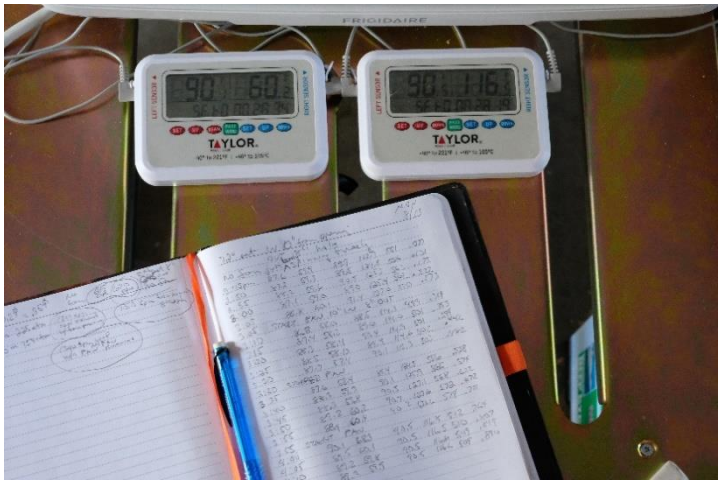
1. Air velocity meter is Gary's recommended Kestrel 1000 meter. Very accurate and easy to use.

2. Temperature readings made with Taylor model 1442 recorders with dual probes. Using two for four probe total. Not data logger but accurate and responsive while not as pricey.

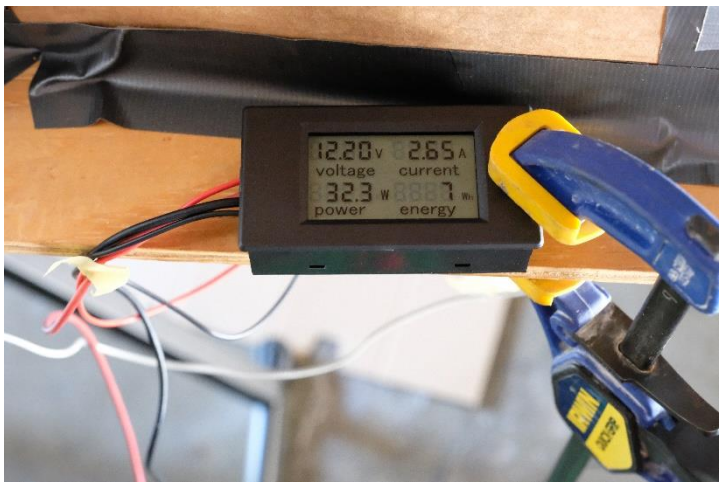
3. Uniwood Energy Usage Monitor, Electricity Power Meter Outlet - Watt Voltage Amps. Part # Unitec-05.

4. Bayite DC 6.5-100v 0-20a LCD Display Digital Ammeter Voltmeter Multimeter Current Voltage Power Energy Battery Monitor Amperage Meter Gauge with Built-in Shunt.

5. Testing cardboard plenum mockup. Taped and air tight. Condenser inlet is 10" DC fan (will soon be reduced to 8" diameter on fan inlet). Outlet is approximately where actual one will be and 8" diameter.







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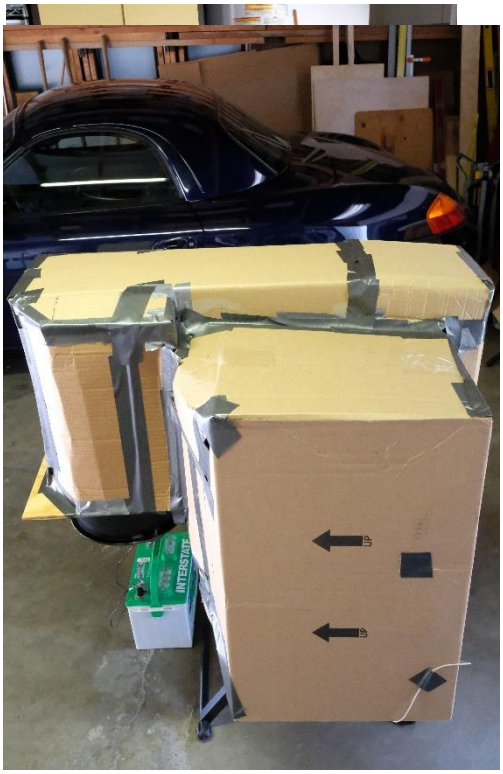
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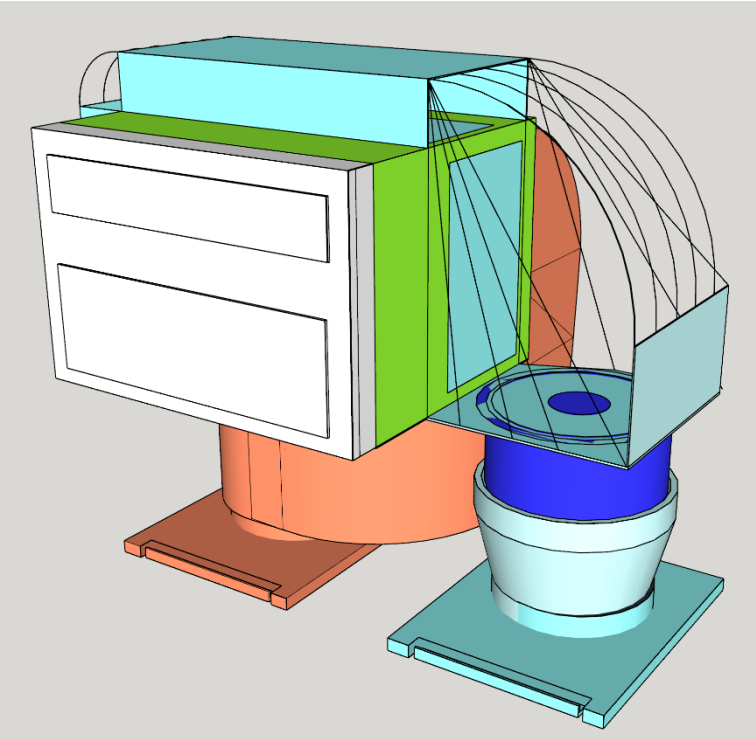
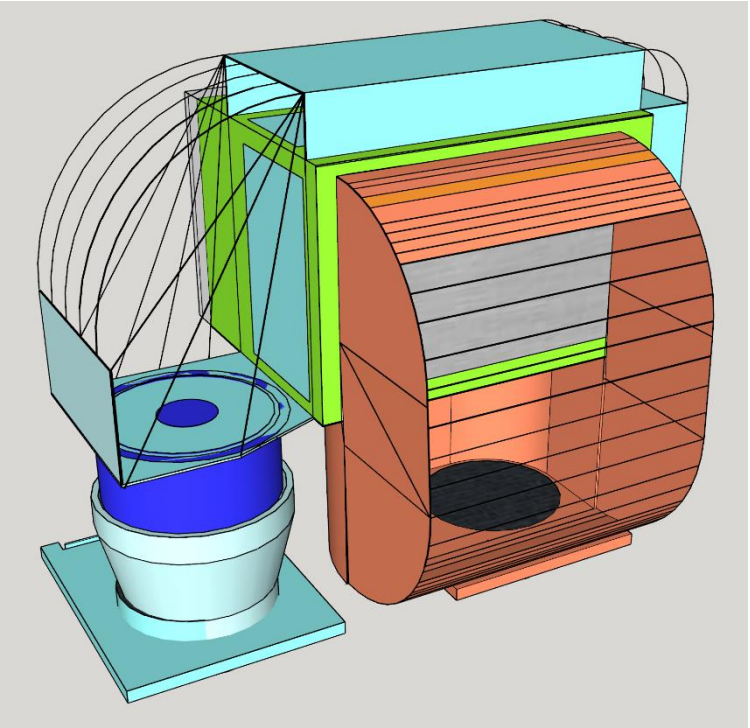
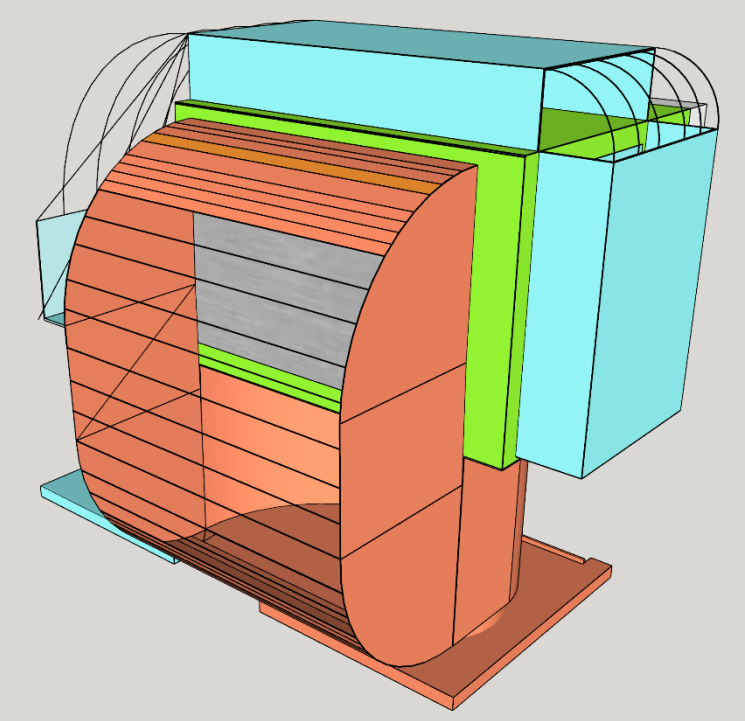
**Proposed plenum - rough sketch :**

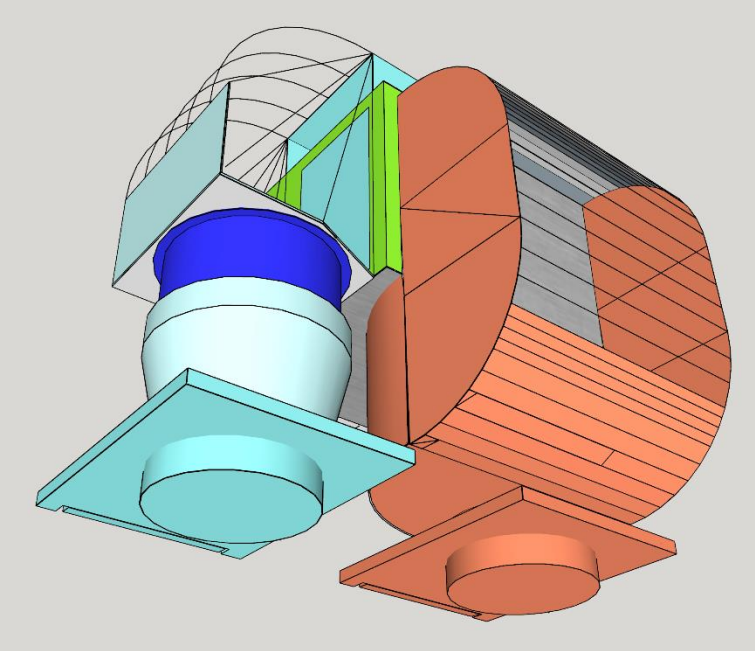
Finding that drawing curves especially compound curves challenging, resorted to simple lines and flat planes.
Van floor will be 2-1/2” thick above floor ridges.

1. 3/8” closed cell between ridges.
2. 1-1/2” polyiso thermal board.
3. ½” stall/gym rubber mat.
4. ½” plywood.









# Bench testing AC unit right out of the box, no air flow restrictions

Saturday 8/11/2018 AC is stock = on bench no plenum, NO restrictions on condenser intake and exhaust

**Measured condenser air flow = 480 cfm** ( using velocity average over entire condenser fin area )
Measured condenser exhaust area = 1.18 square feet.

## NOTE :

1. **Unfortunately, Mother Nature decided to cool us off after several weeks of record high temperatures.**
2. **When we get 3 figure ambient tempertatures again, will run tests again even if AC is installed then.**
3. **Consider Condenser Inlet Temperature to be Ambient ( shown in Red )**
4. **DIY performance Index = Power/Ambient F (Cond Inlet) - needed marker due to varying ambient temperature LOADS.**
5. **When FAN OFF, the negative pressure caused by AC propeller fan causes fan blade to slowly spin, a small power robber.**
6. **Goal is to reduce 10" fan inlet down to 8" diameter through van floor matching 8" diameter condenser vent through van floor.**
7. **With detailed tabular data below, no need for Excel generated graphs.**
8. **Using condenser inlet as Ambient F as that is to be outside air used to cool condenser.**
9. **Evaporator inlet is a little lower due to being in vicinity of cold evaporator exit.**
10. **Yellow bars selected closely matched Ambient temperatures for quick comparisons.**

(Ambient temp)

| Time | Evaporator F | | Condenser F | | AC Power | Cummulative | Evap F | Cond F | DIY Performance |
|---|---|---|---|---|---|---|---|---|---|
| | Inlet | Exhaust | Inlet | Exhaust | Watts | Whr | Delta F | Delta F | Index |
| 9:30am | 80.1 | 54.7 | 83.0 | 107.7 | 459 | 0.106 | 25.4 | 24.7 | 5.5 |
| 9:45am | 81.2 | 56.3 | 83.8 | 103.9 | 468 | 0.222 | 24.9 | 20.1 | 5.6 |
| 10:00am | 81.2 | 56.6 | 84.3 | 105.1 | 470 | 0.349 | 24.6 | 20.8 | 5.6 |
| 10.15am | 81.7 | 56.6 | 85.0 | 104.1 | 465 | 0.480 | 25.1 | 19.1 | 5.5 |
| 10:30am | 83.8 | 57.4 | 85.8 | 104.1 | 466 | 0.575 | 26.4 | 18.3 | 5.4 |
| 10:45am | 83.7 | 57.7 | 86.3 | 105.1 | 469 | 0.697 | 26.0 | 18.8 | 5.4 |
| 11:00am | 84.4 | 57.9 | 87.1 | 105.8 | 470 | 0.812 | 26.5 | 18.7 | 5.4 |
| 11:15am | 85.5 | 57.9 | 87.4 | 105.5 | 467 | 0.937 | 27.6 | 18.1 | 5.3 |
| 11:30am | 84.3 | 58.1 | 86.6 | 105.8 | 470 | 1.045 | 26.2 | 19.2 | 5.4 |
| 11:45am | 85.1 | 58.6 | 88.3 | 106.7 | 471 | 1.153 | 26.5 | 18.4 | 5.3 |
| 12:00pm | 87.1 | 59.7 | 89.8 | 108.1 | 478 | 1.278 | 27.4 | 18.3 | 5.3 |
| 12:15pm | 87.4 | 60.0 | 90.4 | 108.8 | 480 | 1.401 | 27.4 | 18.4 | 5.3 |
| 12:30pm | 86.2 | 59.9 | 89.0 | 108.3 | 478 | 1.512 | 26.3 | 19.3 | 5.4 |
| 12:45pm | 88.0 | 60.7 | 90.3 | 109.2 | 485 | 1.640 | 27.3 | 18.9 | 5.4 |
| 1:00pm | 88.8 | 61.4 | 90.9 | 109.9 | 486 | 1.753 | 27.4 | 19.0 | 5.3 |
| 1:15pm | 89.4 | 61.7 | 91.2 | 110.5 | 484 | 1.045 | 27.7 | 19.3 | 5.3 |
| 1:30pm | 89.1 | 61.5 | 90.2 | 109.9 | 481 | 2.009 | 27.6 | 19.7 | 5.3 |
| **Average** | **85.1** | **58.6** | **87.6** | **107.0** | **473** | | **26.5** | **19.4** | **5.4** |

# Bench testing AC unit with and without DC fan supplementing condenser

AC housed in make shift cardboard plenum with 10" fan inlet and 8" condenser exhaust opening.

Monday 8/13/2018 AC condenser intake = 10" fan opening - condenser exhaust = 8" hole in plenum

**Measured condenser air flow** using velocity average over 8" diameter opening in the exhaust part of the plenum.
Measured condenser exhaust area = 0.35 square feet.
**FAN OFF air flow = 225 cfm**
**FAN ON air flow = 355 cfm ( per Orion fan curve about 0.16 iwc )**

| | Time | Evaporator F | | Condenser F | | AC Power | Cummulative | Evap F | Cond F | DIY Performance |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Inlet | Exhaust | Inlet | Exhaust | Watts | Whr | Delta F | Delta F | Index |
| Fan OFF | 2:45pm | 87.6 | 59.9 | 89.9 | 122.9 | 551 | 0.077 | 27.7 | 33.0 | 6.1 |
| | 2:50pm | 87.2 | 59.3 | 89.5 | 124.5 | 556 | 0.131 | 27.9 | 35.0 | 6.2 |
| | 2:55pm | 88.2 | 59.6 | 90.5 | 125.3 | 563 | 0.175 | 28.6 | 34.8 | 6.2 |
| | 3:00pm | 87.1 | 59.0 | 89.0 | 125.4 | 562 | 0.222 | 28.1 | 36.4 | 6.3 |
| | 3:05pm | 88.8 | 60.1 | 91.4 | 127.0 | 570 | 0.273 | 28.7 | 35.6 | 6.2 |
| | **Average** | **87.8** | **59.6** | **90.1** | **125.0** | **560** | | **28.2** | **35.0** | **6.2** |
| Fan ON | 3:10pm | 86.8 | 58.0 | 88.5 | 114.1 | 499 | 0.314 | 28.8 | 25.6 | 5.6 |
| | 3:15pm | 87.4 | 58.2 | 89.0 | 114.0 | 501 | 0.353 | 29.2 | 25.0 | 5.6 |
| | 3:20pm | 88.3 | 58.4 | 90.4 | 114.9 | 501 | 0.394 | 29.9 | 24.5 | 5.5 |
| | 3:25pm | 88.5 | 58.0 | 89.9 | 114.6 | 502 | 0.442 | 30.5 | 24.7 | 5.6 |
| | 3:30pm | 87.7 | 57.4 | 90.1 | 115.3 | 503 | 0.482 | 30.3 | 25.2 | 5.6 |
| | **Average** | **87.7** | **58.0** | **89.6** | **114.6** | **501** | | **29.7** | **25.0** | **5.6** |
| Fan OFF | 3:35pm | 87.6 | 58.4 | 89.4 | 124.5 | 556 | 0.528 | 29.2 | 35.1 | 6.2 |
| | 3:40pm | 88.3 | 59.3 | 90.1 | 125.9 | 565 | 0.574 | 29.0 | 35.8 | 6.3 |
| | 3:45pm | 88.3 | 59.8 | 90.5 | 127.1 | 568 | 0.622 | 28.5 | 36.6 | 6.3 |
| | 3:50pm | 89.2 | 60.2 | 90.7 | 127.6 | 572 | 0.672 | 29.0 | 36.9 | 6.3 |
| | 3:55pm | 88.4 | 60.4 | 90.2 | 127.6 | 574 | 0.722 | 28.0 | 37.4 | 6.4 |
| | **Average** | **88.4** | **59.6** | **90.2** | **126.5** | **567** | | **28.7** | **36.4** | **6.3** |
| Fan ON | 4:00pm | 90.1 | 68.3 | 90.5 | 116.8 | 512 | 0.764 | 21.8 | 26.3 | 5.7 |
| | 4:05pm | 89.5 | 60.1 | 90.5 | 116.5 | 510 | 0.807 | 29.4 | 26.0 | 5.6 |
| | 4:10pm | 89.2 | 59.8 | 90.5 | 116.6 | 509 | 0.849 | 29.4 | 26.1 | 5.6 |
| | 4:15pm | 89.2 | 59.9 | 90.5 | 116.6 | 509 | 0.890 | 29.3 | 26.1 | 5.6 |
| | 4:20pm | 89.6 | 60.3 | 90.4 | 116.7 | 510 | 0.935 | 29.3 | 26.3 | 5.6 |
| | **Average** | **89.5** | **61.7** | **90.5** | **116.6** | **510** | | **27.8** | **26.2** | **5.6** |
| Fan OFF | 4:25pm | 88.6 | 60.4 | 91.4 | 127.5 | 575 | 0.982 | 28.2 | 36.1 | 6.3 |
| | 4:30pm | 89.1 | 60.8 | 91.3 | 128.8 | 579 | 1.038 | 28.3 | 37.5 | 6.3 |
| | 4:35pm | 89.1 | 60.9 | 91.7 | 129.0 | 580 | 1.077 | 28.2 | 37.3 | 6.3 |
| | 4:40pm | 89.7 | 61.0 | 91.8 | 129.2 | 583 | 1.128 | 28.7 | 37.4 | 6.4 |
| | 4:45pm | 89.2 | 61.0 | 91.8 | 129.3 | 583 | 1.168 | 28.2 | 37.5 | 6.4 |
| | **Average** | **89.1** | **60.8** | **91.6** | **128.8** | **580** | | **28.3** | **37.2** | **6.3** |
| Fan ON | 4:50pm | 90.6 | 60.8 | 91.0 | 118.2 | 516 | 1.123 | 29.8 | 27.2 | 5.7 |
| | 4:55pm | 90.4 | 60.9 | 91.0 | 117.2 | 515 | 1.310 | 29.5 | 26.2 | 5.7 |
| | 5:00pm | 90.6 | 61.0 | 91.0 | 117.2 | 515 | 1.310 | 29.6 | 26.2 | 5.7 |
| | 5:05pm | 90.0 | 60.7 | 90.9 | 117.2 | 514 | 1.349 | 29.3 | 26.3 | 5.7 |
| | 5:10pm | 90.7 | 60.9 | 90.9 | 117.3 | 513 | NA | 29.8 | 26.4 | 5.6 |
| | **Average** | **90.5** | **60.9** | **91.0** | **117.4** | **515** | | **29.6** | **26.5** | **5.7** |

# FAN ON vs FAN OFF summarized results

| | | Evaporator F | | Condenser F | | AC Power | Cummulative | Evap F | Cond F | DIY Performance |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Inlet | Exhaust | Inlet | Exhaust | Watts | Whr | Delta F | Delta F | Index |
| Fan OFF | Sub Ave | 87.8 | 59.6 | 90.1 | 125.0 | 560 | | 28.2 | 35.0 | 6.2 |
| | Sub Ave | 88.4 | 59.6 | 90.2 | 126.5 | 567 | | 28.7 | 36.4 | 6.3 |
| | Sub Ave | 89.1 | 60.8 | 91.6 | 128.8 | 580 | | 28.3 | 37.2 | 6.3 |
| | **Average** | **88.4** | **60.0** | **90.6** | **126.8** | **569** | | **28.4** | **36.2** | **6.3** |
| Fan ON | Sub Ave | 87.7 | 58.0 | 89.6 | 114.6 | 501 | | 29.7 | 25.0 | 5.6 |
| | Sub Ave | 89.5 | 61.7 | 90.5 | 116.6 | 510 | | 27.8 | 26.2 | 5.6 |
| | Sub Ave | 90.5 | 60.9 | 91.0 | 117.4 | 515 | | 29.6 | 26.5 | 5.7 |
| | **Average** | **89.2** | **60.2** | **90.3** | **116.2** | **509** | | **29.1** | **25.9** | **5.6** |

1. Power difference between FAN ON and FAN OFF = ( 569 - 509 ) watts = **60 watts**
2. **DC fan power consumption was measured as 32.5 watts.**
3. NET savings is 60w - 32.5w = 27.5 watt savings. This does not take into account DC to AC conversion losses.