# Carl R. Darnall Army Medical Center


Marissa Caldwell

Mechanical Option


# Carl R. Darnall Army Medical Center

- Building overview
- Thesis Goals
- Depth
  - Dedicated Outdoor Air System
  - Variable Refrigerant Flow
  - Water Source Heat Pump
  - Air Quality Analysis
  - Energy Comparison
- Structural Breadth
- Construction Breadth
- Conclusion

CARL R. DARNALL ARMY MEDICAL CENTER FORT HOOD, TX



# BUILDING OVERVIEW

OWNER: ARMY CORPS OF ENGINEERS

DEPARTMENT OF DEFENSE – UFC STANDARD 4-510

LOCATED ON FORT HOOD BASE, OUTSIDE OF KILLEEN, TX

FLOOR AREA: 900,000 SQ FT

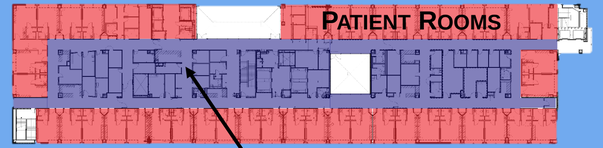
REPLACING THE CURRENT CARL R. DARNALL ARMY MEDICAL CENTER ACROSS STREET

Carl R. Darnall Army Medical Center

Fort Hood, TX



# Building Overview



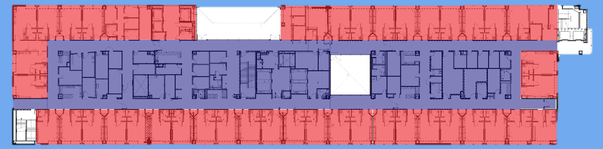

Level 5


Level 6

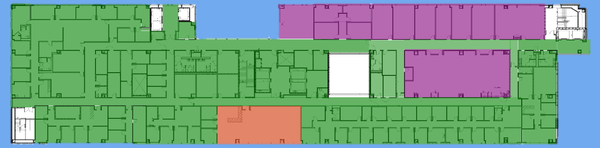
Carl R. Darnall Army Medical Center
Fort Hood, TX



# Building Overview



Level 5



Level 6

Carl R. Darnall Army Medical Center
Fort Hood, TX



# Mechanical System

## Cooling System

(4) 1,300 ton centrifugal chillers
(4) 18,000 MBH cooling towers
(1) 200 ton heat recovery chiller
Domestic hot water & chilled water
Provides 44°F to AHUs

## Heating System

(4) 11,700 MBH steam boilers
Low Nox burner & boiler stack economizer
(3) Steam to water heat exchanger
Steam for humidification & sterile equipment
Provides 140°F to AHUs and CAVs

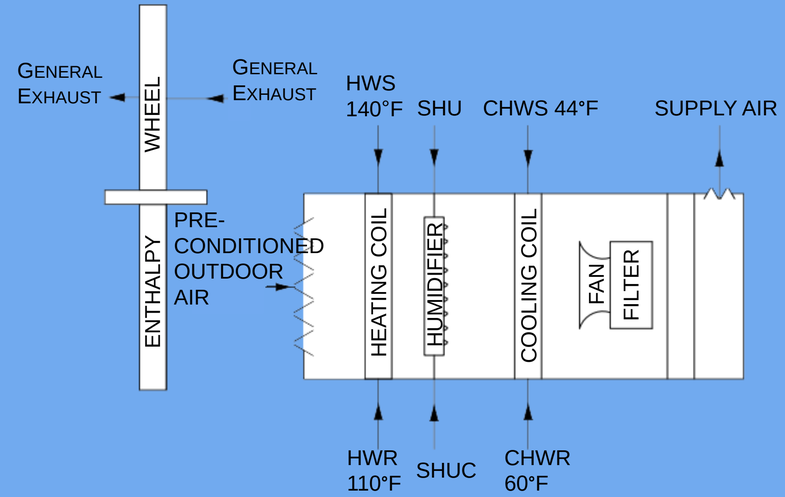
CARL R. DARNALL ARMY MEDICAL CENTER FORT HOOD, TX

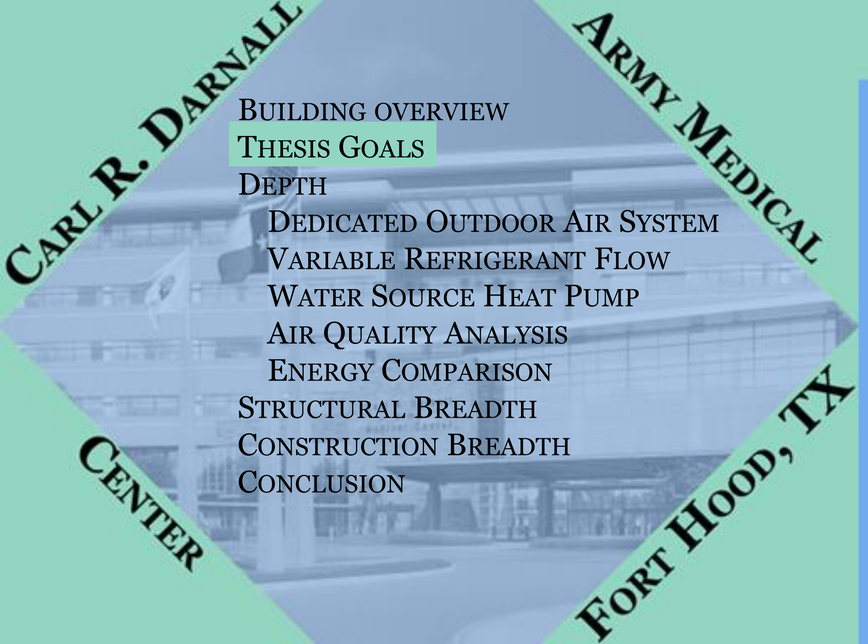


# MECHANICAL SYSTEM

## AIRSIDE SYSTEM

ENTHALPY WHEEL TO PRECONDITION OUTDOOR AIR
(2) 45,000 CFM AIR HANDLER PROVIDING 55°F AIR
CONSTANT AIR VOLUME TERMINAL UNITS WITH REHEAT








## Reduce Energy

## Economically Feasible

## Safe Community

## Structurally Stable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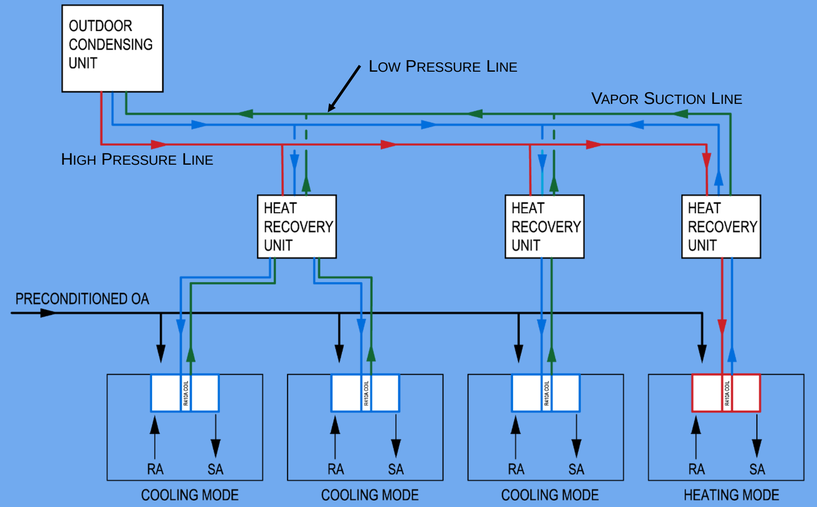
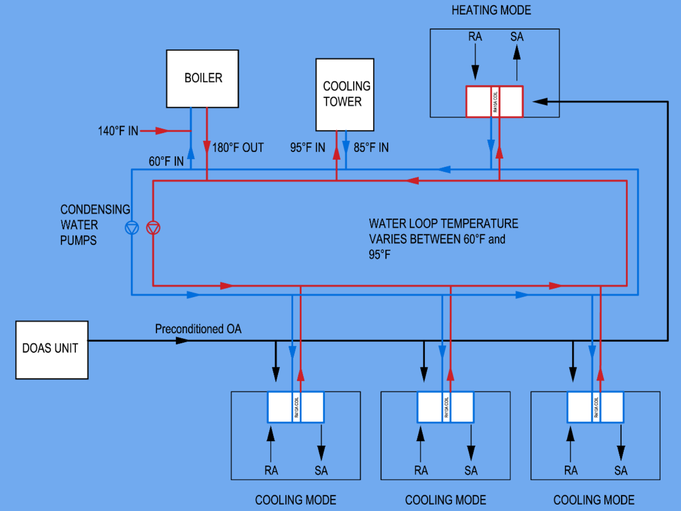
# Variable Refrigerant Flow



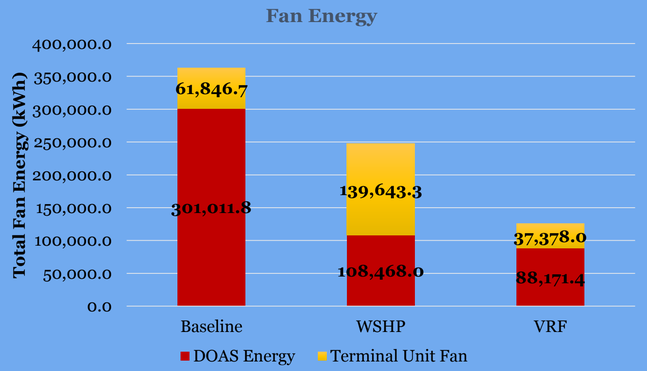

# Water Source Heat Pump



CARL R. DARNALL ARMY MEDICAL CENTER FORT HOOD, TX



# DEDICATED OUTDOOR AIR SYSTEM

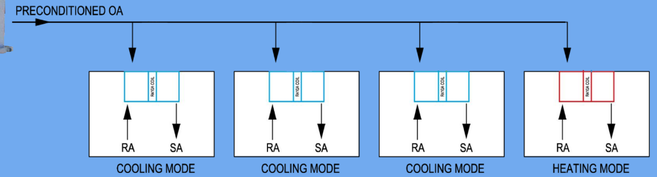



DOAS DELIVERS AIR DIRECTLY TO THE SPACE IN VRF SYSTEM

ENTHALPY WHEEL WITH GENERAL EXHAUST

WSHP REDUCES BY 32%, VRF REDUCES BY 60%

| DOAS Unit | Baseline Design | DOAS Unit | DX Cooling Coil | Natural Gas Coil |
|---|---|---|---|---|
| | Supply OA (cfm) | OA Supply (cfm) | Total Capacity (MBH) | Total Capacity (MBH) |
| L5 AHU | 26,090 | 7,380 | 360 | 80 |
| L6 AHU | 37,075 | 10,366 | 300 | 60 |






# Variable Refrigerant Flow

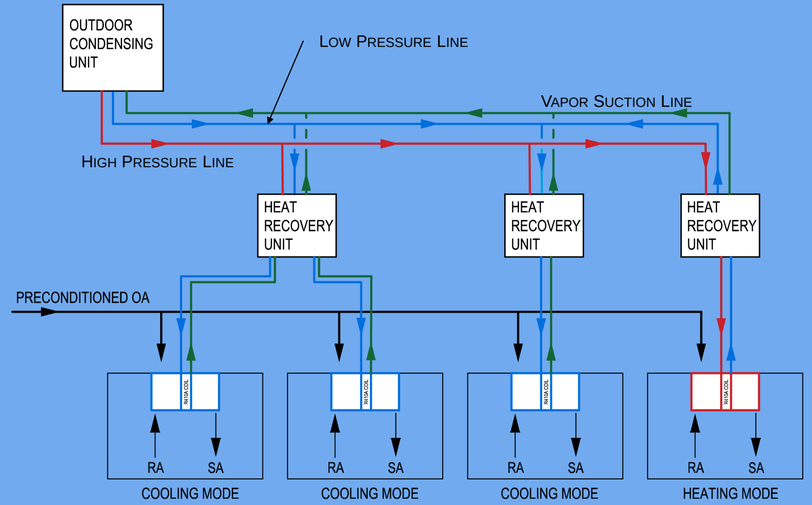
Variable Refrigerant Flow With R-410A

Indoor VRF units have the ability to operate as a condenser and a evaporator

Consists of 3 pipes: low pressure, high pressure & vapor suction line

Heat recovery Vs. heat pump

Defrost Operation



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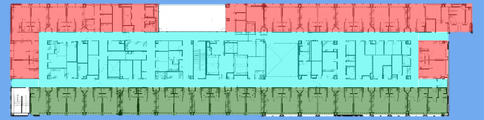
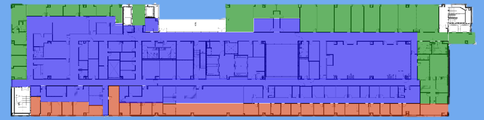
# ASHRAE 15 COMPLIANCE



LEVEL 5



LEVEL 6

INSTITUTIONAL OCCUPANCY & INDIRECT CLOSED SYSTEM

CONCENTRATION MAY NOT EXCEED 50% LISTED IN TABLE 4-1

MULTI-V REFRIGERANT CHARGE CALCULATOR

SMALL ROOMS USE IN-DUCT VRF INDOOR UNITS

## ASHRAE 15 REFRIGERANT CHARGE LIMIT

| | OEL (ppm/v/v) | Safety Group | RCL ppm v/v | RCL lb/Mcf | RCL g/m^3 | Highly Toxic or Toxic Under Code Classification |
|---|---|---|---|---|---|---|
| R-410A | **1,000** | A1 | 140,000 | **13** | 420 | Neither |

## REFRIGERANT CHARGE CALCULATIONS

| Zone Configuration | Zone | Outdoor Unit Cooling | Outdoor Unit Heating | Capacity (tons) | # Indoor Units | RCL (lb/Mcf) | Comply with ASHRAE 15? |
|---|---|---|---|---|---|---|---|
| Zoning 1 | L5 South Exterior | 264,000 | 297,000 | 22 | 23 | 22.14 | NO |
| Zoning 2 | L5 South East Ext | 144,000 | 162,000 | 12 | 12 | 19.50 | NO |
| | L5 South West Ext | 120,000 | 135,000 | 10 | 11 | 19.76 | NO |
| Zoning 3 | L5 South West Ext | 96,000 | 108,000 | 8 | 11 | 12.17 | YES |
| | L5 S Exterior Zone | 96,000 | 108,000 | 8 | 10 | 12.15 | YES |
| | L5 SE Exterior Zone | 96,000 | 108,000 | 8 | 10 | 11.82 | YES |
| | L5 SE Corner Zone | 96,000 | 108,000 | 8 | 10 | 11.68 | YES |

# ASHRAE 15 Compliance

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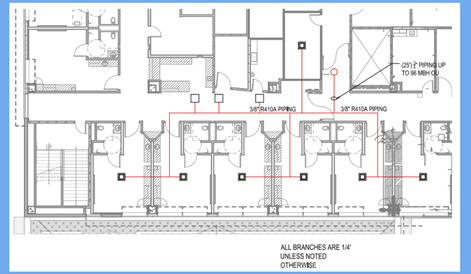


Institutional Occupancy & Indirect Closed System

Concentration may not exceed 50% listed in table 4-1

Multi-V Refrigerant Charge Calculator

Small rooms use in-duct VRF indoor units

## ASHRAE 15 Refrigerant Charge Limit

| | OEL (ppm/v/v) | Safety Group | RCL ppm v/v | RCL lb/Mcf | RCL g/m^3 | Highly Toxic or Toxic Under Code Classification |
|---|---|---|---|---|---|---|
| R-410A | **1,000** | A1 | 140,000 | **13** | 420 | Neither |

## Refrigerant Charge Calculations

| Zone Configuration | Zone | Outdoor Unit Cooling | Outdoor Unit Heating | Capacity (tons) | # Indoor Units | RCL (lb/Mcf) | Comply with ASHRAE 15? |
|---|---|---|---|---|---|---|---|
| Zoning 1 | L5 South Exterior | 264,000 | 297,000 | 22 | 23 | 22.14 | NO |
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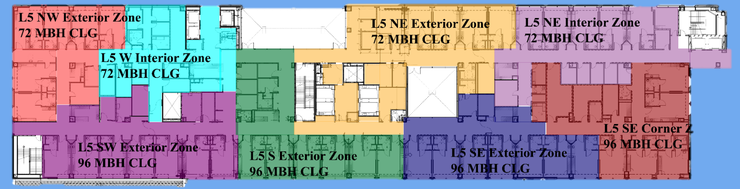
# ZONING




LEVEL 5


LEVEL 6

- INTERIOR & EXTERIOR ROOMS PLACED ON SAME SYSTEM
- ZONES BASED ON THE S EXTERIOR ZONE'S OUTDOOR UNIT'S CAPACITY
- FOUR WAY CASSETTES FOR PATIENT ROOMS, IN-DUCT FOR OFFICES

| Zone Configuration | Zone | Outdoor Unit | | Capacity (tons) | # Indoor Units | RCL (lb/Mcf) | Comply with ASHRAE 15? |
|---|---|---|---|---|---|---|---|
| | | Cooling | Heating | | | | |
| Zoning 1 | L5 South Exterior | 264,000 | 297,000 | 22 | 23 | 22.14 | NO |
| Zoning 2 | L5 South East Ext | 144,000 | 162,000 | 12 | 12 | 19.50 | NO |
| | L5 South West Ext | 120,000 | 135,000 | 10 | 11 | 19.76 | NO |
| Zoning 3 | L5 South West Ext | 96,000 | 108,000 | 8 | 11 | 12.17 | YES |
| | L5 S Exterior Zone | 96,000 | 108,000 | 8 | 10 | 12.15 | YES |
| | L5 SE Exterior Zone | 96,000 | 108,000 | 8 | 10 | 11.82 | YES |
| | L5 SE Corner Zone | 96,000 | 108,000 | 8 | 10 | 11.68 | YES |




# Sizing

| Zone | Critical Load | | Outdoor Unit | | | Number of Units | Max Number |
|---|---|---|---|---|---|---|---|
| | Load | MBH | Cooling | Heating | Derated Heating | | |
| L5 NW Exterior Zone | Cooling | 66,238 | 72,000 | 81,000 | 68,850 | 11 | 13 |
| L5 W Interior Zone | Cooling | 55,708 | 72,000 | 81,000 | 68,850 | 13 | 13 |
| L5 SW Exterior Zone | Cooling | 76,585 | 96,000 | 108,000 | 91,800 | 10 | 16 |
| L5 S Exterior Zone | Cooling | 78,562 | 96,000 | 108,000 | 91,800 | 13 | 16 |
| L5 SE Corner Zone | Cooling | 87,183 | 96,000 | 108,000 | 91,800 | 13 | 13 |
| L5 SE Exterior Zone | Cooling | 77,507 | 96,000 | 108,000 | 91,800 | 10 | 16 |
| L5 NE Exterior Zone | Cooling | 51,079 | 72,000 | 81,000 | 68,850 | 13 | 13 |
| L5 NE Interior Zone | Heating | 37,148 | 72,000 | 81,000 | 68,850 | 16 | 16 |
| L6 NW Interior Zone | Cooling | 51,814 | 72,000 | 81,000 | 68,850 | 13 | 13 |
| L6 Interior Zone | Cooling | 52,251 | 72,000 | 81,000 | 68,850 | 12 | 13 |
| L6 E Interior Zone | Cooling | 68,708 | 72,000 | 81,000 | 68,850 | 12 | 13 |
| L6 SW Exterior Zone | Cooling | 68,374 | 72,000 | 81,000 | 68,850 | 13 | 13 |
| L6 S Exterior Zone | Cooling | 45,069 | 72,000 | 81,000 | 68,850 | 13 | 13 |
| L6 SE Exterior Zone | Cooling | 55,377 | 72,000 | 81,000 | 68,850 | 13 | 13 |
| L6 NE Exterior Zone | Cooling | 82,378 | 96,000 | 108,000 | 91,800 | 14 | 16 |
| L6 NW Exterior Zone | Cooling | 59,672 | 72,000 | 81,000 | 68,850 | 9 | 13 |

Overall 16 Outdoor Condensing Units

Derated heating capacity based on 25°F winter conditions

Max Number of Indoor units for Outdoor unit depends on LG Multi-V

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# SIZING

| Room Name | Sensible from AHU (btu/h) | Room Load (btu/h) | Adjusted (btu/h) | Heating (btu/h) | VRF Indoor Unit | | WSHP Unit | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Cooling | Heating | Cooling | Heating |
| Medical Bed | 3,169 | 10,528 | 7,359 | 7,270 | 9,600 | 10,900 | 9,700 | 12,000 |
| Medical Bed | 2,868 | 10,528 | 7,659 | 7,270 | 9,600 | 10,900 | 9,700 | 12,000 |
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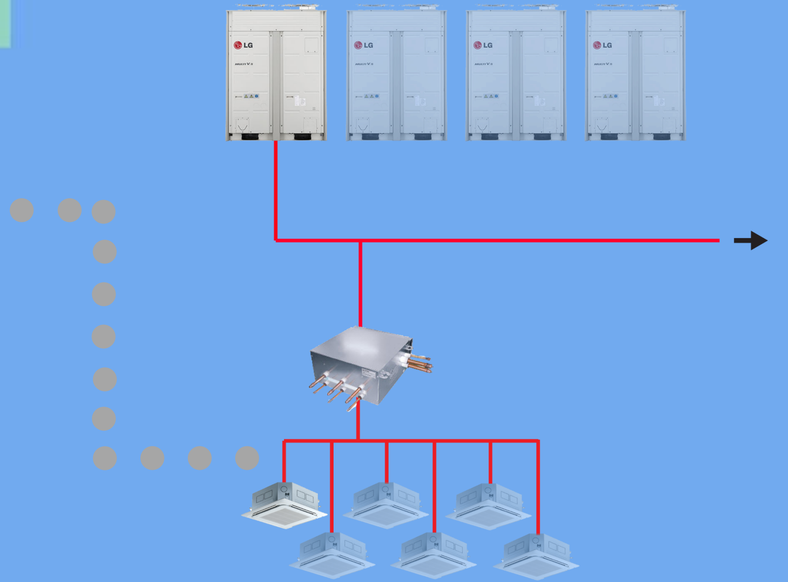
| Medical Bed | 3,169 | 10,528 | 7,359 | 7,270 | 9,600 | 10,900 | 9,700 | 12,000 |
| Pediatric Equipment | 1,036 | 2,649 | 1,613 | 39 | 7,500 | 8,500 | 8,000 | 9,800 |
| Soiled Utility | 216 | 135 | 135 | 0 | | | | |
| Nurse Team Center | 1,192 | 2,570 | 1,378 | 40 | 7,500 | 8,500 | 8,000 | 9,800 |
| Remote Monitor Station | 755 | 2,649 | 1,894 | 39 | | | | |
| Lab/SAT Poct | 265 | 2,649 | 2,384 | 39 | | | | |

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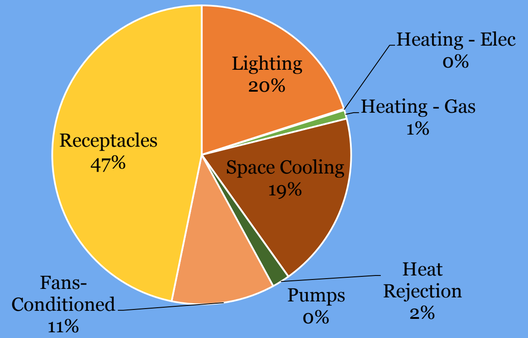
# Energy Consumption



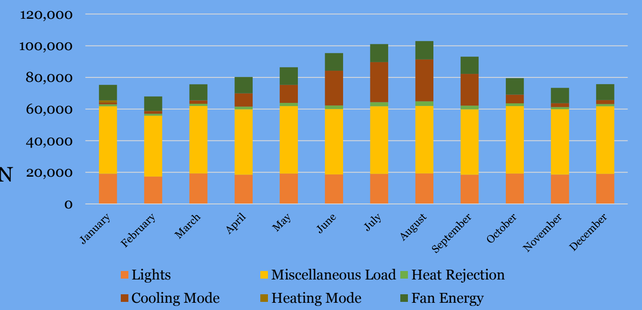

Receptacle & Lighting Dominate Energy

Space Cooling includes both cooling & heating mode

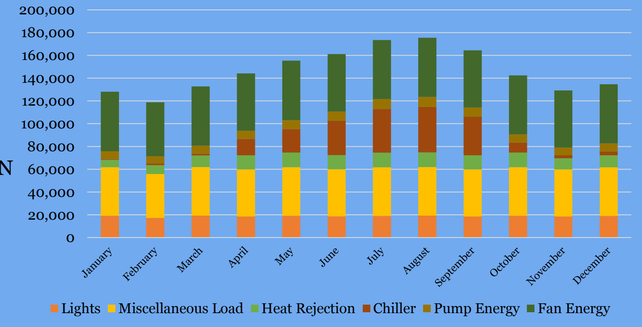
Heat Rejection energy of the condensing unit

VRF consumes 753,443 kwh fewer than Baseline

VRF: Electrical Energy Consumption



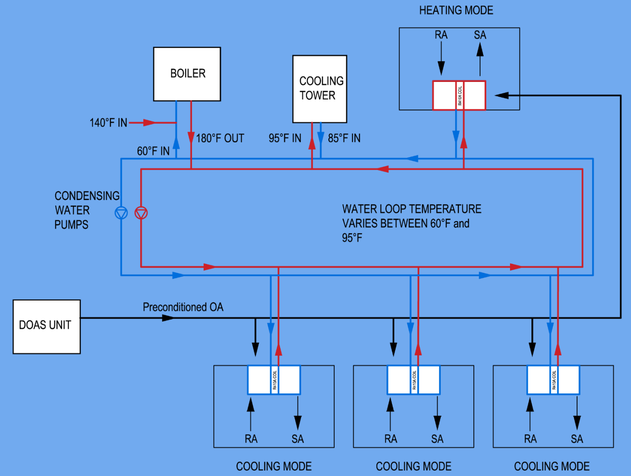

Baseline: Electrical Energy Consumption






# Water Source Heat Pump

- Water Loop remains between 60°F & 95°F
- Uses boiler & cooling tower when it cannot stay in the temperature range
- Connects to existing hot water system for 140F minimum flow
- All units on same loop, share between offices & patient rooms



CARL R. DARNALL ARMY MEDICAL CENTER FORT HOOD, TX



# BOILER

| Equipment Tag | Type | Capacity (Btu/h) | Boiler Horse Power (BHP) | Fluid Flow (gpm) | Primary Fuel | $NO_X$ Emissions (ppm) |
|---|---|---|---|---|---|---|
| Boiler - 01 | Gas Fired | 511,011 | 20.0 | 621.0 | Natural Gas | 40 |

- GAS FIRED HOT WATER BOILER
- MEETS PEAK HEATING LOAD DURING WINTER OPERATION
- PRIMARY FUEL IS NATURAL GAS, SECONDARY FUEL IS FUEL OIL
- ALL NEW EQUIPMENT WILL BE LOCATED IN CENTRAL UTILITY PLANT

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# Cooling Tower

| Equipment Tag | Design Nominal Tonnage | Motor Hp | Fluid Flow (gpm) | Design Ambient WB (°F) | Design EWT (°F) | Design LWT (°F) |
|---|---|---|---|---|---|---|
| Cooling Tower - 01 | 228.0 | 7.5 | 636 | 78 | 95 | 85 |

Marley Software used for cooling tower

Design for peak cooling load during summer

Design entering water temperature of 95°F WB

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# WATER SOURCE HEAT PUMP

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| Medical Bed | 2,868 | 10,528 | 7,659 | 7,270 | 9,600 | 10,900 | 9,700 | 12,000 |
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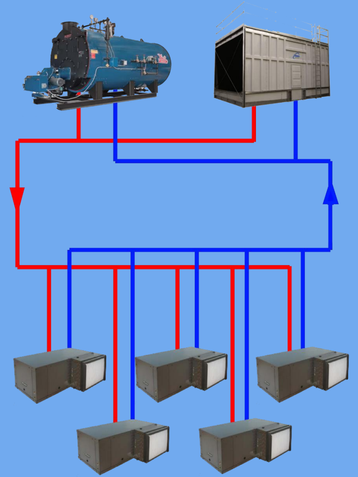

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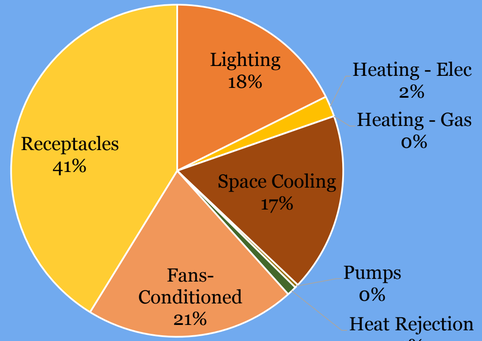
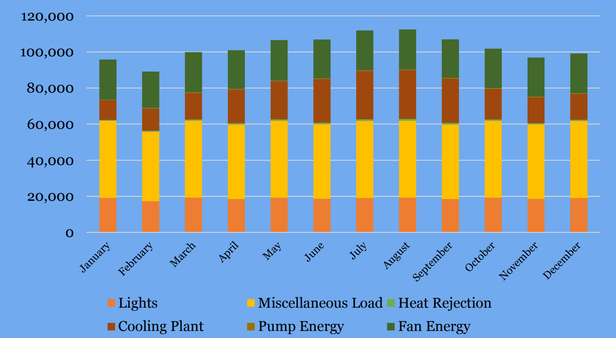
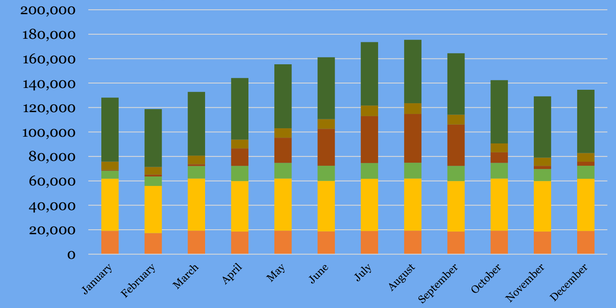



- Receptacle & fans dominate energy consumed
- Space cooling includes both cooling & heating mode
- Heat Rejection energy of the Cooling Tower
- WSHP saves over 531,242 kWh than baseline

WSHP: Electrical Energy Consumption




Baseline: Electrical Energy Consumption



# Air Quality Analysis

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  - Water Source Heat Pump
  - Air Quality Analysis
  - Energy Comparison
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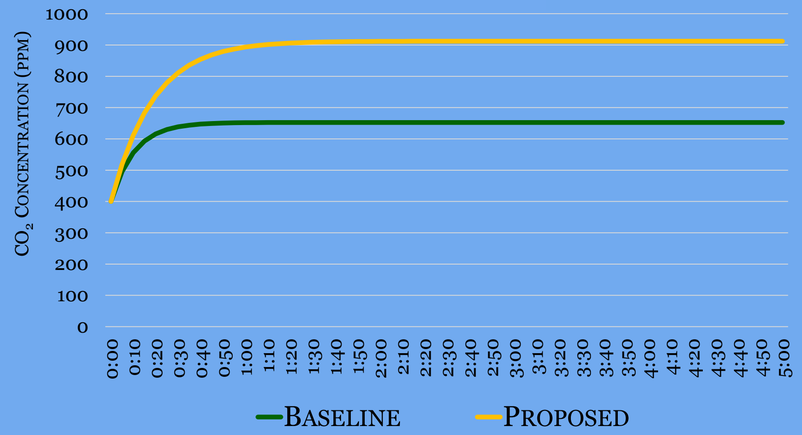
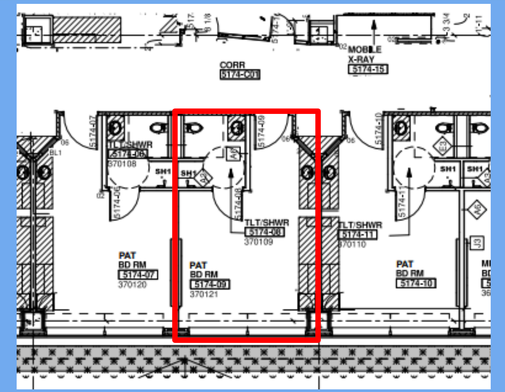
- Construction Breadth
- Conclusion




Baseline $CO_2$ Concentration of 652 ppm
Proposed $CO_2$ Concentration of 912 ppm
OSHA OEL of 5,000 ppm

CARL R. DARNALL ARMY MEDICAL CENTER FORT HOOD, TX

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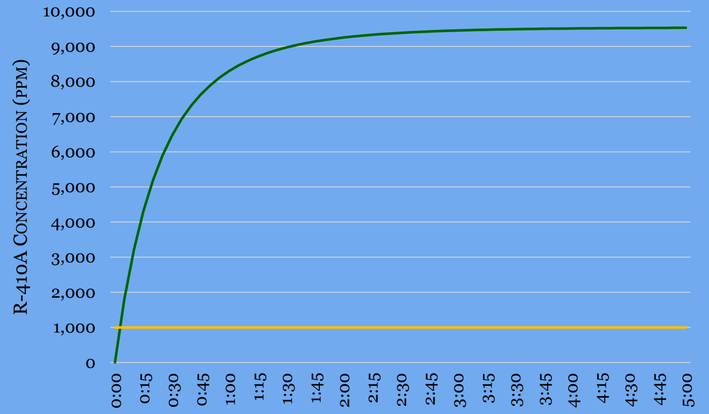
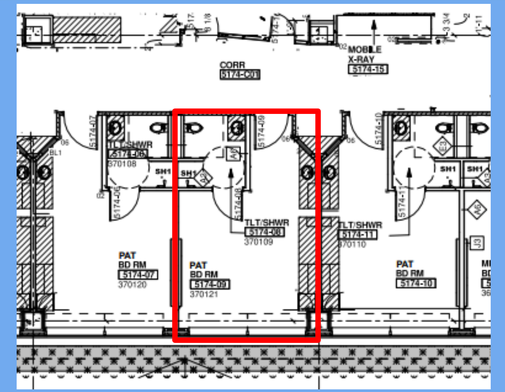
# AIR QUALITY ANALYSIS




ASHRAE 15 OEL OF 1,000 PPM

PASSES THE OEL OF R410A WITHIN THE FIRST HOUR




REFRIGERANT LEAK BASED ON ASHRAE 15 APPENDIX B: TESTING LEAK AT RATE OF 2% BY MASS OF THE STARTING CHARGE PER HOUR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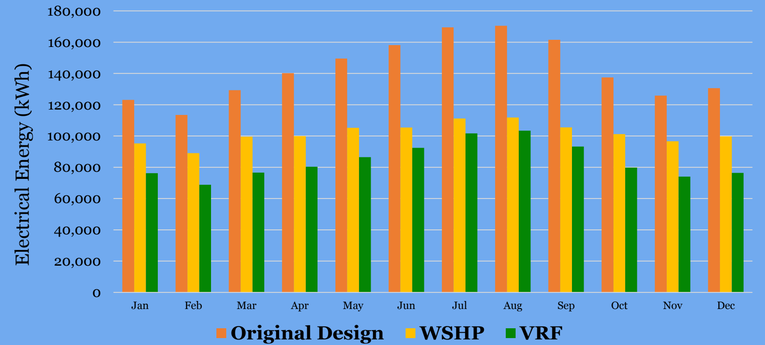
# Payback Period

| Initial Cost | VRF | WSHP |
|---|---|---|
| Expenses / Savings | Additional Costs | Initial Costs |
| Cooling Tower | -$29,868 | $0 |
| Boiler - 765 MBH | -$17,800 | $0 |
| Outdoor Condensing Unit | $528,000 | $0 |
| Chiller 270 ton | -$190,500 | -$190,500 |
| Terminal Units | $170,825 | $285,600 |
| Piping | $74,176 | $426,920 |
| DOAS Unit | -$361,000 | -$361,000 |
| Costs | $173,833 | $161,020 |
| Maitnenance Costs | | |
| 16 Air Cooled Condensers | $138,480 | $0 |
| Cooling Tower | -$8,872 | $0 |
| Chiller - 270 ton | -$104,744 | -$104,744 |
| Boiler - 765 MBH | -$5,835 | $0 |
| Maitnenance Costs | $19,030 | -$104,744 |
| Expenses | $245,596 | $56,276 |
| Annual Energy Costs | $71,763 | $69,108 |
| Simple Payback Period | 3.42 | 0.81 |
| Discounted Payback Period | 8.72 | 2.96 |
| Life Cycle Cost | $2,025,861.00 | $2,631,110.00 |
| Savings | $784,351.66 | $179,102.66 |




- Longer payback period for VRF system than WSHP
- Similar initial costs for both
- Vary within the maintenance costs of larger equipment
- 20 year life cycle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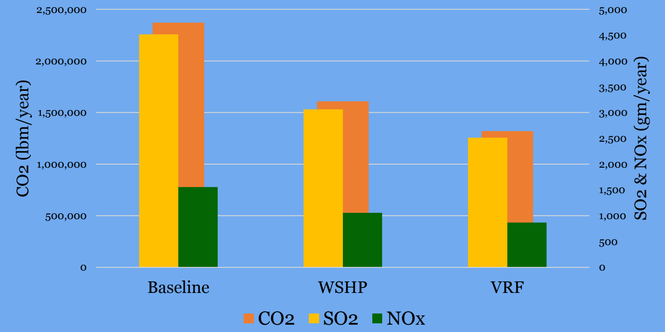
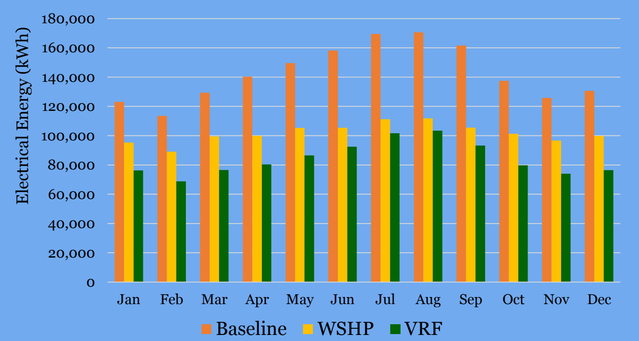
# Energy & Emissions Comparison

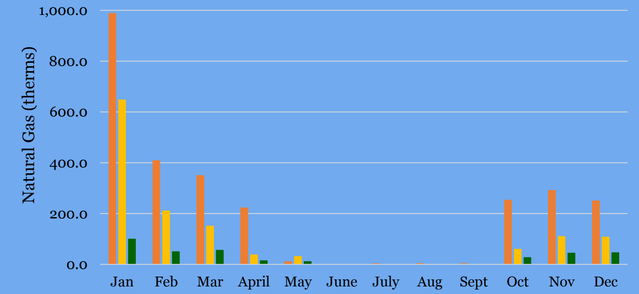



- Low Nox Burner For Boilers – 30 ppm, 40 ppm For Proposed
- VRF Only uses Natural Gas for DOAS unit
- WSHP saves 51% on natural gas, VRF saves 72%

## Electricity Consumption




## Natural Gas Consumption



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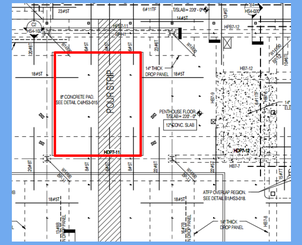
# STRUCTURAL BREADTH

| | Rebar Size | lb/ft | Number | Weight (lb) | Cost | Total | Savings |
|---|---|---|---|---|---|---|---|
| Baseline Design | #6 | 1.50 | 24 | 1,219.9 | $1,205 | $7,542 | $4,248 |
| | #11 | 5.28 | 47 | 8,443.7 | $6,337 | | |
| Proposed Design | #6 | 1.50 | 44 | 2,236.5 | $2,209 | $3,294 | |
| | #8 | 2.66 | 16 | 1,445.8 | $1,085 | | |

| Design | Column Strip | | Middle Strip | |
|---|---|---|---|---|
| | Neg. Moment | Pos. Moment | Neg. Moment | Pos. Moment |
| Baseline | 11 (#11) | 18 (#11) | 24 (#6) | 18 (#11) |
| Reduced Load | 16 (#7) | 18 (#6) | 12 (#6) | 14 (#6) |

- COST SAVINGS OF $4,248 FOR REDUCING LOAD
- ORIGINAL AHUS HAD 22,000 LB OPERATING WEIGHT
- DOWNSIZED STRUCTURAL SYSTEM BY ELIMINATING ANTI-FORCE PROTECTION & PROGRESS COLLAPSE RESISTANCE LOADS
- ANALYSIS COMPLIES WITH ACI 318 & DIRECT DESIGN METHOD



| Equipment | Cooling Capacity (Btu/h) | Number | Operating Weight (lb) |
|---|---|---|---|
| Outdoor Condensing Unit | 72,000 | 11 | 4,972 |
| | 96,000 | 5 | 2,865 |
| L5 DOAS Unit | 360,000 | 1 | 4,284 |
| L6 DOAS Unit | 300,000 | 1 | 4,282 |




# Construction Breadth

| Removal of IBS Floor | | | | | | | |
|---|---|---|---|---|---|---|---|
| Material | Unit | Amount | Crew | Daily Output | Labor-Hours | Total Incl. O&P | Total |
| W6x20 | ft | 4,148 | 8 | 600 | 0.093 | 43 | $178,364 |
| Floor Decking (3" deep, 18 ga) | sq-ft | 39,304 | 5 | 2850 | 0.011 | 4.29 | $168,614 |
| Polypropylene Fiber Rebar Mat | $ft^3$ | 6,550 | 4 | 9500 | 0.004 | 1.07 | $7,009 |
| LW Concrete, 2-1/2" | sq-ft | 39,304 | 8 | 2585 | 0.022 | 3.3 | $129,703 |
| | | | | | Total | | $483,690 |
| | | | | | Entire Building | | $6,046,125 |

Removing IBS floors gained 18 days

Average installation rate of terminal units in a interstitial floor is 30 minutes quicker

Piping Installation does not take interstitial floor into account

| Task | Duration - Man Days | | | | | |
|---|---|---|---|---|---|---|
| | Baseline | | VRF | | WSHP | |
| | Man - Days | Total Days | Man - Days | Total Days | Man - Days | Total Days |
| FR&P Interstitial Floors | 79.96 | 10 | 0.00 | 0 | 0.00 | 0 |
| Install Interstitial Floor Deck | 65.36 | 8 | 0.00 | 0 | 0.00 | 0 |
| Install terminal units | 51.00 | 26 | 76.98 | 38 | 76.98 | 38 |
| Piping | 66.29 | 4 | 16.82 | 17 | 12.83 | 13 |
| Sheetmetal | 32.00 | 11 | 21.33 | 11 | 21.33 | 11 |
| | Total | 58 | Total | 66 | Total | 62 |
| | | | Difference in Duration | -8 | | -4 |

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# RECOMMENDATIONS

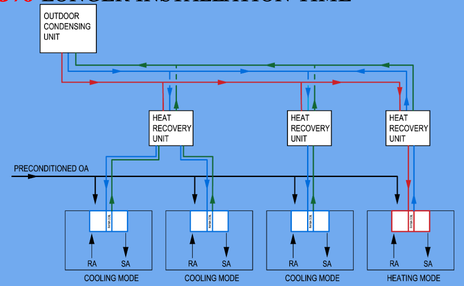
## VARIABLE REFRIGERANT FLOW

SAVES **60%** IN ELECTRICAL ENERGY CONSUMPTION

CONSUMES **72%** LESS NATURAL GAS

PAYBACK PERIOD OF **8.72** YEARS

TAKES **16%** LONGER INSTALLATION TIME



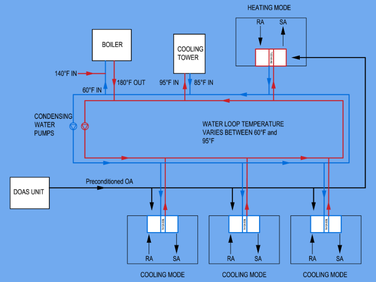

## WATER SOURCE HEAT PUMP

SAVES **31%** IN ELECTRICAL ENERGY CONSUMPTION

CONSUMES **51%** LESS NATURAL GAS

PAYBACK PERIOD OF **2.96** YEARS

TAKES **8%** LONGER INSTALLATION TIME



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# ACKNOWLEDGEMENTS


| | |
|---|---|
| MICHAEL MORDER | MECHANICAL DESIGN ENGINEER, SOUTHLAND INDUSTRIES |
| ASHLEY HAYES | PROJECT MANAGER, SOUTHLAND INDUSTRIES |
| SHAWN MANLEY | SENIOR MECHANICAL ENGINEER, SOUTHLAND INDUSTRIES |
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# QUESTIONS?

## CARL R. DARNALL ARMY MEDICAL CENTER REPLACEMENT