

# DUKE CANCER CENTER

EXPANSION

Durham, NC



## TECHNICAL REPORT III

Mechanical Systems Existing  
Conditions Evaluation

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**Table of Contents**

Executive Summary.....2

Existing Mechanical System Description.....3

    Mechanical Design Objectives .....3

    Energy Sources.....3

    Design Conditions .....3

    Design Ventilation Requirements .....4

    Design Load Estimates .....4

    Design Energy Usage Estimate.....6

    Mechanical Equipment Summary.....7

    Mechanical System Cost .....9

    Mechanical Space Requirements.....10

System Operations and Schematics.....11

    Air-side Operations .....11

    Water-side Operations.....12

LEED Analysis .....16

    Energy and Atmosphere .....16

    Indoor Environmental Quality .....18

Mechanical System Evaluation .....21

References .....22

Appendix A- Refrigerant Calculations .....23

Appendix B- CO2 Sensors.....24

## Executive Summary

The Duke Cancer Center expansion is a state-of-the-art facility designed to better serve the Triangle population and the growing need for specialty cancer services and programs at Duke. Primary medical spaces include 123 clinical rooms, 73 infusion stations, radiation oncology, radiology services and a mammography suite (*Note: The Mammography Suite is not included in the original design scope of TK&A and will be considered future tenant fit-out for the purposes of this report*). The treatment and laboratory areas raise a concern for indoor air quality with the potential exposure of bio hazards to the rest of the building. The center will also feature a cancer patient shop, an outdoor garden terrace with an infusion area for patients, a retail pharmacy, a patient resource center, a café, and a quiet room to improve the patient and family experience and promote a healing environment.

The mechanical system serving the building consists of three air handling units. AHU-2 is a one hundred percent outdoor air unit that matches with an exhaust unit serving the large waiting areas and triage rooms. An energy recovery wheel is utilized between the dedicated outdoor air unit and the exhaust to recover any heat from the exhausted spaces. There are multiple exhaust fans located on the roof dedicated to serving a pharmacy, laboratory spaces and kitchen exhaust. The Cancer Center is served with high pressure steam, chilled water, and electricity from a campus utility plant. The high pressure steam is converted to medium and low pressure steam to serve domestic hot water heaters, sterilizers, autoclaves, and other process equipment. The low pressure steam is also used via heat exchangers to produce hot water for space heating. The chilled water is also circulated through the building to provide cooling in addition to being delivered to two plate and frame heat exchangers to provide cooling to required medical equipment like linear accelerators and MRI's.

The mechanical system's first cost account for about 17% of the total project budget at approximately \$37.4 million. The annual operating costs for the Duke Cancer Center based on actual utility rates from the campus plant yield an annual cost of approximately \$150,000.

DCC is pursuing a Silver Certification from the Leadership in Energy and Environmental Design® (LEED) rating system developed by the U.S. Green Building Council (USGBC). An analysis of the LEED progress made by the project team was done based on the submitted documentation to the USGBC. The sections included were Energy and Atmosphere and Indoor Environmental Quality because of their direct impact on the mechanical system design.

In order to determine alternative designs that can be implemented in the Duke Cancer Center mechanical system, an overall analysis was done of the current constructed design. An evaluation of the construction and energy costs, mechanical space requirements, indoor air quality and system control will help to provide baselines for improvement in future proposals of change.

## Existing Mechanical System Description

### Mechanical Design Objectives

The Duke Cancer Center Expansion is a healthcare facility that is a part of Duke University’s medical campus in Durham, North Carolina. The expansion consists of a variety of medical spaces to provide specialty cancer treatment to patients, office space for the doctors, nurses and support staff and several retail areas including a café for patients and their visitors. A variable air volume system was chosen for the building to accommodate the fluctuations in occupancy and equipment use throughout the day.

The addition utilizes (3) air-handling units one of which is a dedicated outdoor air system (DOAS). The DOAS unit uses a heat recovery wheel with a matching exhaust unit to provide a balance to the high energy consumption which results from conditioning one hundred percent outdoor air year round.

### Energy Sources

The Cancer Center is served with high pressure steam and chilled water from the Duke Campus utility plants. Duke University uses two campus steam plants (East and West) to provide high-pressure steam to the entire University, Hospital and Medical Center via coal, natural gas and fuel oil. While the West Campus Steam plant used to be the primary plant, the recently renovated East Plant has taken its place with LEED gold status. The West plant continues to be used as a peak shaving plant to meet higher demands during the winter season. The East Campus plant includes 15 natural gas boilers that use propane as a backup. In the spring of 2011, Duke eliminated the use of coal on campus as part of their Climate Action Plan to become carbon neutral by 2024.

The Central Chilled Water System as Duke University consists of two central plants with 28,000 ton cooling capacity. The system provides chilled water for process equipment cooling and building air conditioning to support about 70 buildings on campus.

The expansion receives its electrical service from the Duke Utility & Engineering Services high Voltage Shop which supplies high voltage power at 12kV and 4kV.

The purchased rates from the Duke utility plants are summarized in *Table 1* below.

**Table 1-DCC Purchased Utility Rates**

<b>Source</b>	<b>Rate</b>
<b>Electricity</b>	\$0.06 per kWh
<b>Chilled Water</b>	\$0.14 per Ton-Hour
<b>Steam</b>	\$11.63 per MBTU

### Design Conditions

The weather data from the ASHRAE Handbook of Fundamentals for Raleigh, North Carolina was used for this analysis because of its similarities with Durham, North Carolina which is around 25 miles northwest. *Table 2* below provides a summary of the heating and cooling weather design conditions along with the

design indoor temperatures based on the design documents provided by the mechanical engineer Bard, Rao + Athanas Consulting Engineers (BR+A).

Table 2- Design Air Conditions for DCC

Space Type	Summer Season (0.4%)			Winter Season (99.6%)		
	Indoor Design (°F)	Outdoor DB (°F)	Outdoor WB (°F)	Indoor Design (°F)	Outdoor DB (°F)	Outdoor WB (°F)
Typical	75	93.7	72.4	70	16.3	-
Office	78	93.7	72.4	72	16.3	-
Food Services	80	93.7	72.4	75	16.3	-

## Design Ventilation Requirements

The ventilation requirements for the Duke Cancer Center meet the minimum requirements of ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality. A majority of the spaces are designed to meet the criteria specified in ASHRAE 170 Table 7-1, Ventilation of Health Care Facilities. Standard 170 specifies minimum air change rates for typical healthcare spaces that exceed that of the normal space types defined in Standard 62.1. AHU-2 is a one hundred percent outdoor air unit that matches with an exhaust unit (EAHU-1) to serve the large waiting areas and triage rooms which will have the cooling load exceeded by ventilation.

In Technical Report I, an analysis of ASHRAE 62.1 was conducted. The results of the analysis compared to the design outdoor air intake are shown below in *Table 3*.

Table 3- Outdoor Air Ventilation Rate Summary

Unit	Location	Design CFM	Design Min. OA CFM	ASHRAE 62.1 Min. OA CFM
AHU-1	Penthouse	120,000	24,000	8,733
AHU-2	Penthouse	120,000	120,000	22,884
AHU-3	00 Mech Rm.	70,000	14,000	6,870

## Design Load Estimates

To evaluate the cooling and heating loads on the Duke Cancer Center, Trane TRACE 700 was used in the Technical II Report Analysis. Using actual design values when specified in the design documents for room geometries and building operating characteristics, the results of the constructed model from Trane TRACE™ were then compared with the design of the implemented system provided by the mechanical engineer.

The results of the comparison between the constructed model and the implemented design are shown below in *Table 4*. The results were also compared against an analysis performed by a third party consultant, Air Water Energy Engineers, Inc. (AWE) using VisualDOE 4.1 energy models for the proposed design of the Duke Cancer Center and an ASHRAE Standard 90.1 baseline building. Those results can also be seen below in *Table 5*.

Table 4- Calculated Load vs. Design Load Summary

		Service Area	Cooling SF/ton	Heating BTUh/SF	Total Supply CFM/SF	Ventilation Supply CFM/SF
<b>Calculated</b>	AHU-1	84221	317.47	27.8	0.99	0.38
	AHU-2	63443	190.53	47.11	0.98	0.86
	AHU-3	70065	221.73	35.84	1.03	0.62
	TOTAL	217729	729.73	110.75	3.00	1.86
<b>Designed</b>	AHU-1	68569	137.51	70.95	1.26	1.26
	AHU-2	55337	150.93	62.17	1.08	1.08
	AHU-3	97858	244.22	64.65	1.50	1.13
	TOTAL	221764	532.7	197.77	3.84	3.47
<b>% Difference</b>		<b>1%</b>	<b>-16%</b>	<b>28%</b>	<b>12%</b>	<b>30%</b>

Table 5- Calculated vs. AWE Analysis Peak Loads

	Calculated	AWE Energy Analysis	% Δ
<b>Heating Peak (kBtu/h)</b>	7,753	13,413	27%
<b>Cooling Peak (kBtu/h)</b>	10,784	5,788	30%

## Design Energy Usage Estimate

The Trane TRACE model used above to calculate peak loads was also utilized in a full year energy analysis of the Cancer Center. Assumptions regarding occupancy, lighting, equipment use and operation schedule were all made using various design documents provided by the mechanical engineer, BR+A. More detail on the assumptions used in the energy analysis can be seen in Technical Report II. The results of the Trane TRACE energy analysis are summarized below in *Figure 1*.

The heating and cooling for the expansion are supplied from a campus steam plant and chilled water plant. The electricity supplied to the building is also supplied from a central campus utility source. The major energy consumers in the Cancer Center are the electrical loads accounting for more than half of total energy use. This is a result of the large equipment loads placed on the building from the different treatment and research spaces in the building. The large receptacle load is also attributed to the administration aspect of the facility from the numerous amounts of nurse workstations and other support staff areas.

The heating is 29% of the total energy consumption which is unusual for a building located in such mild climates as Durham, North Carolina. This may be attributed to the fact that since there is a large air change requirement for healthcare facilities and the design includes more efficient lighting and building envelope, the design would require more heat than the baseline. The baseline building would use more cooling due to a greater light load and radiation from worse performing glass. When operating under the conditions of an improved lighting and envelope selected by the design team, but the same equipment load, the terminal unit would require more reheat to keep the same temperature conditions as the baseline.

Figure 1- DCC Modeled Energy Consumption

### Energy Consumption

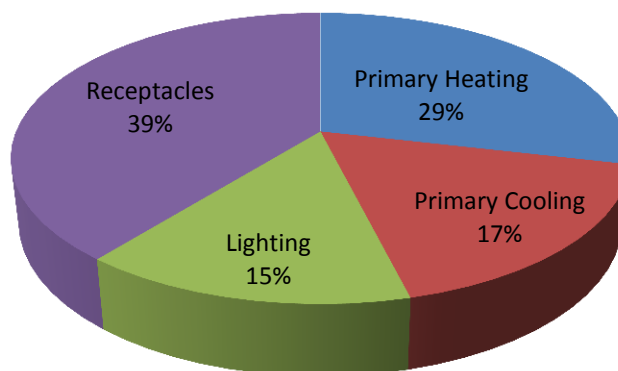


Table 6- Calculated vs. AWE Analysis Total Energy Consumption

A comparison of the Trane TRACE model with the outcome of the AWE Energy Analysis also resulted in some large differences in energy usage which can be seen below in *Table 7*. While different assumption

were made during the two constructed analyses, the percent difference between the two results raises some questions of the loads on the building in particular with relation to heating.

Table 7- Calculated vs. AWE Analysis Total Energy Consumption

Fuel Type	Energy Use per year (kWh)		
	Calculated	AWE Analysis	% Difference
Electricity	10,301	5,359	32%
District Steam	5,094	49,772	81%
District Chilled Water	3,266	9,248	48%

## Mechanical Equipment Summary

The mechanical systems serving the Duke Cancer Center are separated between a large mechanical room in the basement (Level 00) and the mechanical penthouse. The high pressure steam from the campus plant enters the basement mechanical room it encounters a pressure reducing station before being distributed to the rest of the building through a set of risers. The shell and tube heat exchangers use the low pressure steam that has been reduced by the pressure reducing stations from the high pressure steam delivered to the building to heat water that is then supplied to hot water coils in the air-handling system for pre-heat and reheat. The characteristics shown below in *Table 8* for HEX-1 are typical for all four shell and tube heat exchangers.

Table 8- DCC Heat Exchangers (Shell & Tube)

Component	Location	Service	Water Side (Tube)		Steam Side (Shell)
			EWT (°F)	LWT (°F)	#'s per Hour
HEX-1	Level 00 MER	Pre-heat & re-heat	140	180	8,750

The leaving hot water from the shell and tube heat exchangers is then distributed to each air handling unit via a designated pump for each AHU on the supply side and then circulated through the loop to the return via four other pumps. Each pump utilizes a variable frequency drive to turn down the flow of pump to meet the load requirements of the system. Characteristics of the pumps used in hot water distribution throughout the building can be seen below in *Table 9*.

Table 9- DCC Hot Water Pump Schedule

Unit Number	Unit Location	Service	Capacity (GPM)	Head (ft H <sub>2</sub> O)	Motor Size (MHP)
HWP-1	Level 00 MER	AHU Preheat & Building Re-heat	420	60	10
HWP-2	Level 00 MER	AHU Preheat & Building Re-heat	420	60	10



## DUKE CANCER CENTER EXPANSION

<b>HWP-3</b>	Level 00 MER	AHU Preheat & Building Re-heat	420	60	10
<b>HWP-4</b>	Level 00 MER	AHU Preheat & Building Re-heat	420	60	10
<b>HWP-5</b>	Level 00 MER	AHU-1 Pre-heat Coil	295	25	5
<b>HWP-6</b>	Level 00 MER	AHU-2 Pre-heat Coil	340	25	5
<b>HWP-7</b>	Level 00 MER	AHU-3 Pre-heat Coil	215	25	3

The chilled water is also delivered to the basement from the campus plant where it is distributed to the three air-handling units and the two plate and frame heat exchangers. The plate and frame heat exchangers seen below in *Table 10*, use the incoming campus chilled water to cool processed chilled water from the air-handling units to service the cooling needs for medical equipment like the MRI's and linear accelerators.

Table 10- DCC Heat Exchangers (Plate &amp; Frame)

Unit Number	Location	Service	Campus Chilled Water		Process Chilled Water	
			EWT (°F)	LWT (°F)	EWT (°F)	LWT (°F)
<b>HEX-5</b>	Penthouse	MRI Process Chilled Water Loop	40	58	57/63	46/42
<b>HEX-6</b>	Penthouse	Linear Accelerators Process Chilled Water Loop	40	58	82	60

The mechanical penthouse houses two of the three air-handling units, one of the two being the one hundred percent outdoor air unit with the exhaust unit stacked on top. AHU-3 has the smallest capacity of the three and is located in the mechanical room on Level 00. In addition to normal operating conditions, AHU-3 is designed to handle the make-up supply of the atrium in a smoke exhaust situation. AHU-1 and 3 each have a corresponding return air unit as well as economizers to maximize outdoor air intake in appropriate conditions. A summary of the air-handling units serving the Cancer Center can be found below in *Table 11*.

Table 11- DCC Air-Handling Units

Unit Number	Service	Location	CFM	Minimum Outside Air CFM
<b>AHU-1</b>	Cancer Center	Penthouse	120,000	24,000
<b>AHU-2</b>	Cancer Center	Penthouse	120,000	120,000
<b>AHU-3</b>	Cancer Center/Atrium Smoke Make-up	00 Mech. Room	70,000	14,000
<b>AHU-4</b>	Cancer Center	00 Mech. Room	7,000	0
<b>EAHU-1</b>	Cancer Center	Stacked on AHU-2	110,000	-

*\*Note AHU-4 supplies the large existing electrical room in the Morris Building and is not included in the scope of this report*

The ten main exhaust fans that serve the labs, general exhaust and atrium smoke control system are also located in the mechanical penthouse. The exhaust fans all pull the contaminated air in certain spaces and

the dangerous fumes from biosafety cabinets up through the building to release well above the roof in a plume into the atmosphere. Details on the fans found in the Cancer Center can be seen below in *Table 12*.

Table 12- DCC Fan Schedule

Unit Number	Unit Location	Service	Nominal CFM	S.P. (in H <sub>2</sub> O)	Motor Size (MHP)
RF-1	Penthouse	RAU-1	60,000	3.5	60
RF-2	Penthouse	RAU-1	60,000	3.5	60
RF-3	Level 00	RAU-2	20,000	3.25	20
RF-4	Level 00	RAU-2	20,000	3.25	20
EX-1	Penthouse	EAHU-1	55,000	5.3	75
EX-2	Penthouse	EAHU-1	55,000	5.3	75
EX-3	Penthouse	North Lab Exhaust	5,000	3.5	5
EX-4	Penthouse	North Lab Exhaust	5,000	3.5	5
EX-5	Penthouse	South General Exhaust	15,000	4	20
EX-6	Penthouse	South General Exhaust	15,000	4	20
EX-7	Penthouse	Smoke Exhaust	60,000	2.5	100
EX-8	Penthouse	Smoke Exhaust	60,000	2.5	100
EX-9	Morris Building	Level 0 Ventilation	5,000	0.5	1.5
EX-10	Reception Building	Kitchen Exhaust	3,500	4	5
EX-11	Reception Building	Kitchen Exhaust	3,500	4	5
EX-12	Reception Building	Kitchen Exhaust	3,500	4	5
EX-13	Penthouse	Infusion Pharmacy	5,000	3.5	5
EX-14	Penthouse	Infusion Pharmacy	5,000	3.5	5

## Mechanical System Cost

An exact first cost analysis of the mechanical system is unavailable due to sensitivity of the project at owner's request. A basic breakdown for the major building systems however is shown below in *Table 13*. This shows the mechanical system accounting for around 17% of the project budget which is about \$37.4 million or \$140.89 per square foot.

Table 13-DDC Cost by Building System

Building System	Percentage of Building Cost
Structural	10%
Doors & Windows	9%
Finishes	9%
Roofing/Fire-Moisture Protection	2%

**DUKE CANCER CENTER EXPANSION**

Casework	4%
Elevators	5%
Fire Suppression	1%
Plumbing	6%
<b>HVAC</b>	<b>17%</b>
Electrical	15%
Other	22%

Predicted operating costs for the building based on actual utility rates mentioned earlier were calculated using the energy consumption from the Trane TRACE model created for Technical Report II. It can be concluded that Duke Cancer Center Expansion would expect to spend around \$150,000 each year on utilities which is about \$0.69 per square foot. A cost breakdown can be seen below in *Table 14*.

Table 14- DCC Energy Costs

	<b>Total Building Energy</b>	<b>Cost Rate (\$/kBtu)</b>	<b>Cost per year \$</b>	<b>Cost per SF \$</b>
<b>Electricity</b>	2,991,349	0.01758	52,602.85	0.24
<b>Chilled Water</b>	3,266,201	0.01167	38,105.68	0.18
<b>Steam</b>	5,097,214	0.01163	59,280.60	0.27
<b>TOTAL</b>			149,989.13	0.69

## Mechanical Space Requirements

While mechanical systems are necessary in the successful operation of any building, the amount and size of the equipment required often occupy a sizeable portion of a building's usable floor space. Summarized below in Table is a breakdown of the area used by mechanical systems including equipment rooms and shaft spaces. The total mechanical space occupies about 9.1% of the building area. This does not include plumbing chases that occupy shaft space throughout the building or electrical rooms that occupy each floor with transformers and telecommunication equipment which would make the amount of lost usable space more accurate.

Table 15- Lost Usable Space

<b>Level</b>	<b>Area</b>
<b>00</b>	7,038
<b>0</b>	96
<b>1</b>	226
<b>2</b>	103
<b>3</b>	85

<b>4</b>	100
<b>5</b>	85
<b>Penthouse</b>	12,452
<b>TOTAL</b>	20,185

## System Operations and Schematics

The Duke Cancer Center Expansion is controlled by a Building Automation System (BAS) that ties into the existing campus system with all new equipment controlled by the Direct Digital Control (DDC). It is important that all sequencing of the controls is working properly to ensure the correct pressurization of certain critical medical spaces in the building and the proper ventilation required. The steam/hot water and chilled water systems are also in need of constant monitoring and control not only to provide adequate heating and cooling for the spaces of the building, but also to provide process water to equipment that is vital to the successful operation of the cancer facility.

### Air-side Operations

#### *Air-Handling Units 1 & 3*

AHU-1 and AHU-3 are both variable air volume systems which serve terminal units with reheat coils. They are both equipped with dual variable frequency drives for the supply fans. The BAS starts and stops the AHU supply fans and return fans based on occupancy of the building and the manual override of an operator command or smoke control modes.

Both air-handling units are equipped with economizers that modulate outdoor air dampers according to outside temperature. The BAS monitors outdoor airflow so that the enthalpy economizer sequence will maximize the dampers when the return air enthalpy is higher than the outside air enthalpy.

#### *Air-Handling Unit 2*

AHU-2 is a one hundred percent outdoor air unit, variable air volume system with a heat recovery wheel. The heat wheel will operate in the exhaust unit with the outside air temperature is below an adjustable set point of 45°F and above an adjustable set point of 80°F as long as AHU-2 is operating.

#### *Atrium Smoke Control System*

Two exhaust fans sized at 60,000 CFM are used to exhaust the 5-story Atrium in a smoke situation. Make-up air is supplied to the Atrium via louvers and dampered outside air along with make-up air from AHU-3.

#### *Variable Air Volume Terminal Units*

The variable air volume (VAV) terminal units are each equipped with a room temperature sensor with set point control that adjusts the air damper and reheat coil based on design space conditions. The room controls are capable of being adjusted from the sensor as well as a separate communication interface through the BAS. The heating coils are constant volume and provide supplementary heating if the supply temperature is inadequate.

## Water-side Operations

### *Steam/Heating System*

The heating system for the Duke Cancer Center Expansion consists of six steam pressure reducing valve stations that convert the high pressure steam delivered at 125 psi from the campus utility plant to medium and low pressure steam at about 60 psi and 10 psi, respectively. The medium pressure steam is used to serve domestic water heaters, sterilizers, autoclaves, clean steam generators and other medium pressure process requirements. All of the steam condensate generated by the high and medium pressure steam systems is flashed prior to leaving the building through the pressure powered condensate pump. The pressure powered condensate pump is equipped with a heat recovery heat exchanger with bypass that is used to preheat the domestic hot water system. The low pressure steam is delivered to the humidifiers in the built-up air handling units as well as the unit heaters.

The low pressure steam is also delivered to four shell and tube heat exchangers with steam in the shell and water in the tubes. The heat exchangers are sized to handle an entering temperature of 180°F and a discharge temperature of 140°F. The hot water is then distributed throughout the building to serve the preheat coils to the air handling units preheat and reheat systems. *Figure 2* and *Figure 3* show the steam and the hot water flow schematic to the loads including the pumps associated with the distribution throughout the building.

### *Chilled Water System*

The chilled water for the Cancer Center is delivered from and returned to the University campus plant. The chilled water enters at the basement mechanical room and is distributed to the cooling coils of the three air-handling units and the plate and frame heat exchangers. There is no new pump associated with the normal chilled water flow located in the addition of DCC. There are two plate and frame heat exchangers with single-pass construction that are used to provide cooling to the MRI's and Linear Accelerators. There are two air-cooled chillers on the roof connected to emergency power to back the secondary process chilled water. *Figure 4* shows a chilled water flow schematic of the Duke Cancer Center.

Figure 2- DCC Steam Flow Schematic

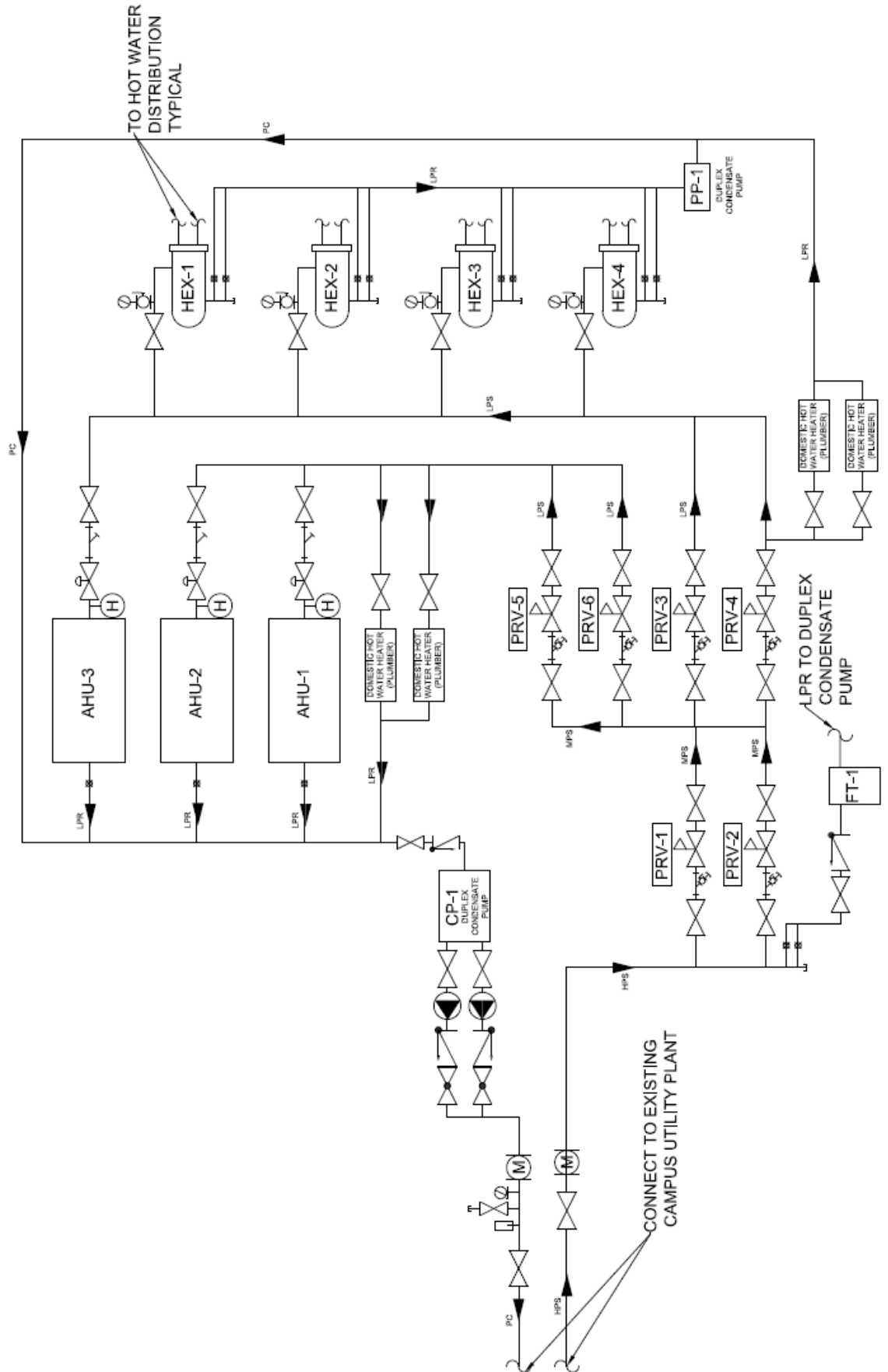


Figure 3- DCC Hot Water Flow Schematic

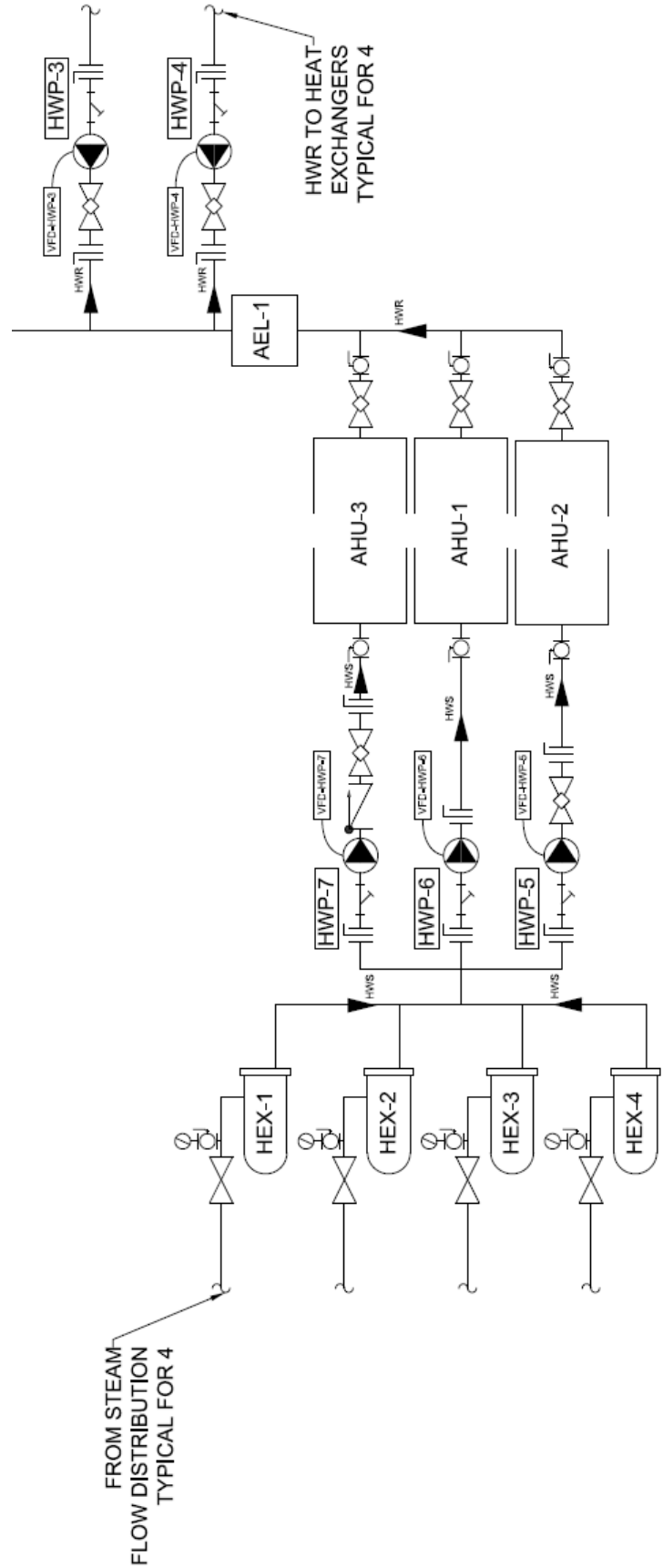
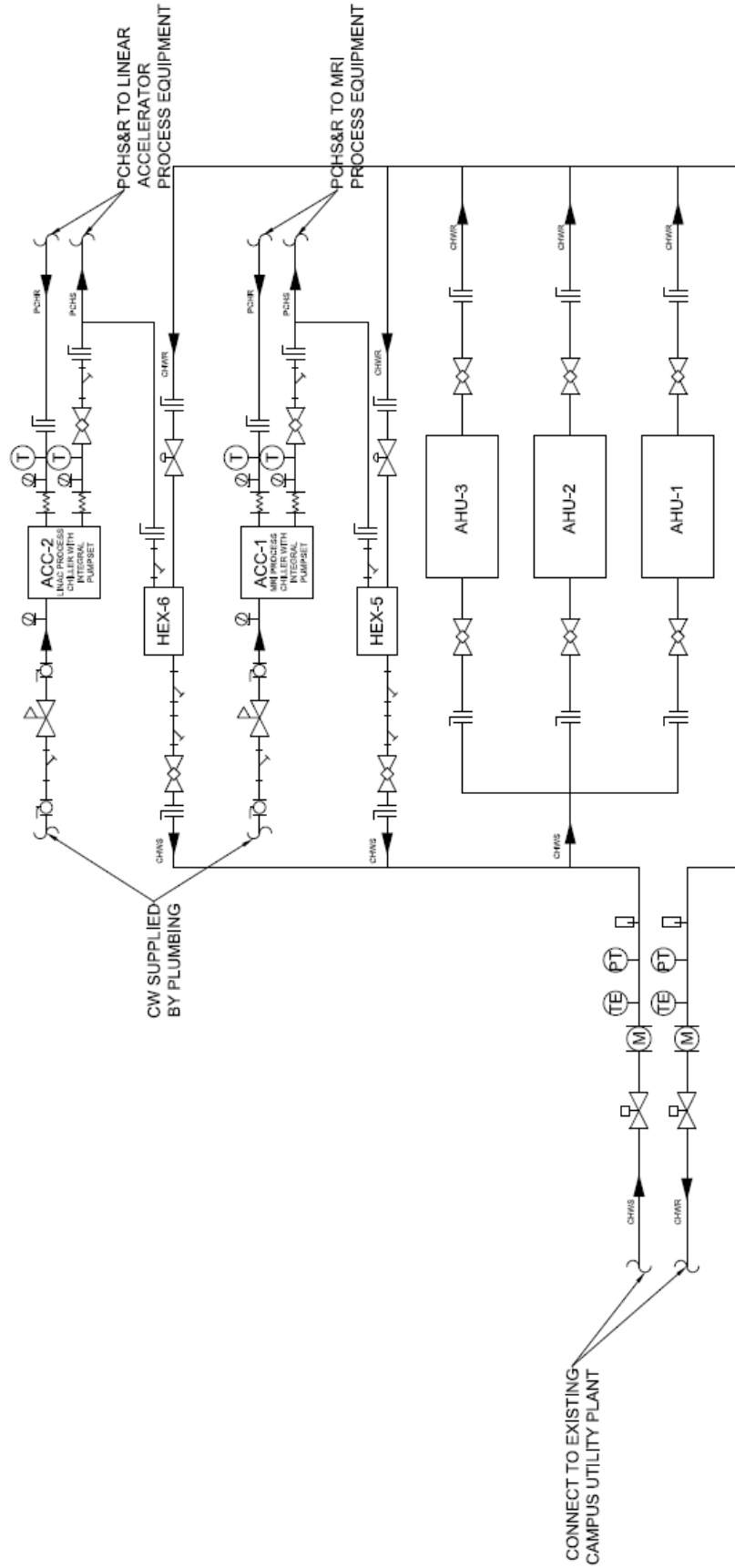


Figure 4- DCC Chilled Water Flow Schematic





## LEED Analysis

Duke University has made a commitment that all new construction and major renovations will achieve Leadership in Energy and Environmental Design (LEED) Certification standards with a goal of LEED Silver. The East Campus Steam Plant facility that services the DCC is currently certified as Gold with the West Campus Steam Plant registered to target Gold and Chilled Water Plant to target Silver.

The Duke Cancer Center Expansion is targeting LEED Silver. The design team and owner are aiming to achieve 42 credits with 11 points of those foreseen as maybe achieving. The two LEED criteria that were evaluated in depth because of their direct effect on the mechanical design were Energy and Atmosphere and Indoor Environmental Quality. An explanation of the documentation provided to achieve the credits in these two categories is shown below.

### Energy and Atmosphere

#### *Prerequisite 1 | Fundamental Commissioning of the Building Energy System*

The intent of this first prerequisite is to involve a commissioning team in the design and construction process to confirm that the energy systems designed for the Duke Cancer Center are installed, calibrated and perform according to the project requirements, basis of design (BOD), and construction documents. In order to achieve this credit, a commissioning team has been specified to participate in the construction process. The mechanical engineer provided a BOD that is specified to be regularly updated to be issued with the commissioning of the building. Project closeout is contingent upon the successful completion of all commissioning procedures and documentation.

#### *Prerequisite 2 | Minimum Energy Performance*

The minimum energy performance prerequisite is used to establish the minimum level of energy efficiency for the Cancer Center in compliance with both the mandatory provisions and the performance requirements of ASHRAE/IESNA Standard 90.1-2004. To fulfill this requirement, a third party consultant, Air Water Energy Engineers, Inc. (AWE) was hired by Tsoi/Kobus & Associates Architects to perform a Whole Building Energy Simulation of the proposed design compared to a baseline model based on Standard 90.1-2004. The overall energy cost of the proposed Cancer Center design is projected to be 16.3% lower than the overall energy cost of the baseline model.

#### *Prerequisite 3 | Fundamental Refrigerant Management*

The purpose of the 3<sup>rd</sup> prerequisite is to reduce ozone depletion by requiring either zero use of chlorofluorocarbon-based refrigerants in new base building HVAC & refrigerant systems or a phase out plan for any existing CFC-based equipment. The Duke Cancer Center Expansion utilizes non-CFC-based refrigerants like R-410a, R-404a, and R-407c in the equipment and therefore complies with this prerequisite.

#### *Credit 1 | Optimize Energy Performance (2 points)*

The amount of points earned from this credit coincides with the percent increase of energy performance beyond the minimum required by Prerequisite 2. The project team achieved this credit using option 1, Whole Building Energy Simulation, with a default process energy cost of 25% of the total energy cost for the baseline building. AWE Engineers used VisualDOE 4.1 energy models to project a savings of \$199,701

in annual operating energy costs for the proposed design of the Cancer Center which correlates with the previously mentioned reduction of 16.3% in energy costs from the baseline building. This percentage meets the 14% threshold for energy savings for new buildings resulting in 2 credits towards LEED certification.

*Credit 2 | On-site Renewable Energy (0 points)*

Credit 2 for Energy and Atmosphere is intended to reduce fossil fuel energy use by encouraging the use of new technologies to produce on-site renewable energy self-supply. Because the Duke Cancer Center receives steam and chilled water from a campus utility plant, it does not directly produce any on-site combustion. While the utility plant does utilize fossil fuel combustion to service campus buildings, this credit was not attempted by the project team for the Cancer Center. The campus plant does have future plans to attempt climate neutral status, however the projected reduction in fossil fuel use over the next twenty years would not immediately impact this credit.

*Credit 3 | Enhanced Commissioning (1 point)*

The purpose of Credit 3 is to place an emphasis on commissioning by beginning it early on in the design and continuing with additional activities after systems performance verification is finished. DCC has contracted a third party commissioning agent, Horizon Engineering Associates, LLP (HEA) under an enhanced contract to fulfill both the commissioning prerequisite and enhanced credit. Documentation and testing of all mechanical systems as well as training of all owner operation and maintenance personnel are specified by the project team in compliance with this credit.

*Credit 4 | Enhanced Refrigerant Management (1 point)*

Credit 4 is intended to reduce the ozone depletion by complying with either option 1; do not use refrigerants or option 2; select refrigerants that minimize/eliminate ozone depletion and global warming. Option 2 is earned if:

$$\Sigma [(LCGWP + LCODP \times 10^5) \times Q_{unit}] / Q_{total} \leq 100$$

Where,

LCGWP= Life cycle direct global warming potential [lb. CO<sub>2</sub>/ton-yr.]

LCODP= Life cycle ozone depletion potential [lb. CFC-11/ton-yr.]

Q<sub>unit</sub>= Cooling capacity of an individual HVAC or refrigeration unit [tons]

Q<sub>total</sub>= Total cooling capacity of all HVAC or refrigeration

Table 16 below shows that this requirement is met with further calculation documentation provided in Appendix A. The Cancer Center complies with this requirement.

Table 16- DCC Refrigerant Impact Calculations

HVAC & Refrigeration Equipment Type	Quantity	Q (tons)	Refrigerant	Refrigerant Impact per ton	Refrigerant Impact Total
AHU-4	1	20	R-410a	78.1	1,562
ACC-1	1	60	R-404a	370.3	22,218
ACC-2	1	22	R-404a	698.9	15,376

<b>EMRU-1</b>	1	10	R-410a	120.0	1,200
<b>HP-1</b>	1	4	R-410a	47.3	189
<b>CAC-1</b>	3	9	R-407c	27.7	249
<b>Food Service</b>	1	1	R-404a	572.0	572
<b>Food Service</b>	1	1	R-404a	1,872.0	936
<b>Chiller Plant #1</b>	1	10,500	R-123	92.4	970,200
<b>Chiller Plant #2</b>	1	17,400	R-123	81.5	1,418,100
<b>TOTAL</b>		28,027		<b>86.73</b>	2,430,602

#### *Credit 5 | Measurement & Verification (1 point)*

Credit 5 aims to provide ongoing accountability of building energy consumption over time by implementing a Measurement and Verification (M&V) Plan consistent with Option D: Calibrated Simulation, or Option B: Energy Conservation Measure Isolation. The commissioning team, HEA has developed a plan for Duke Cancer Center based on Option D due to the larger number of energy conservation measures at the whole-building level that shall span from March 2012 to March 2013. Their services will include the necessary requirements to satisfy this credit.

#### *Credit 6 | Green Power (pending 1 point)*

The last credit of energy and atmosphere encourages the development and use of grid-source, renewable energy technologies on a net zero pollution basis by providing at least 35% of the building's electricity from renewable sources. This credit is pending on Duke University Medical Center Engineering and Operation for documentation. Since the Cancer Center is served by campus utility plants, this credit relies on campus initiatives toward green power. At the moment, the Facilities Management at Duke plans to achieve climate neutrality by 2024 and has eliminated coal use on campus in May 2011.

## Indoor Environmental Quality

#### *Prerequisite 1 | Minimum IAQ Performance*

Prerequisite 1 of Indoor Environmental Quality is intended to enhance indoor air quality performance in buildings by requiring that Duke Cancer Center meets the minimum requirements of Sections 4 through 7 of ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality. DCC is mechanically ventilated with all air handling systems exceeding the minimum ventilation rates outlined in Section 6.2 of the Standard and therefore meets this prerequisite.

#### *Prerequisite 2 | Environmental Tobacco Smoke (ETS)*

This prerequisite aims to minimize the building occupants, indoor surfaces, and ventilation air systems to Environmental Tobacco Smoke by requiring 1 of 2 options: prohibit smoking in the building altogether or prohibit smoking in the building except in designated smoking areas. The Duke Cancer Center is a nonsmoking facility and specifies any designated smoking areas to be located at least 25 feet from its entries and outdoor air intakes and therefore complies with this prerequisite.

#### *Credit 1 | Outdoor Air Delivery Monitoring (1 point)*

Credit 1 is given to projects that monitor and provide feedback on ventilation system performance to ensure the systems are operating as they are designed. The Cancer Center's outdoor air delivery plan consists of wall-mounted CO2 sensors in densely occupied areas as well as outdoor air flow measuring

stations at each air handling unit. The CO<sub>2</sub> sensors are controlled so that if the maximum space set point is exceeded by more than 10%. The flow measuring stations are also controlled to maintain the minimum design flow rates and will alarm if the air flow falls below the design by more than 10%. Therefore, DDC meets the criteria for this credit.

*Credit 2 | Increased Ventilation (0 points)*

Credit 2 is intended to improve indoor air quality by providing additional outdoor air ventilation at least 30% greater than the minimum requirements specified in ASHRAE Standard 62.1-2004. While the Duke Cancer Center exceeds minimum air change rates specified in Section 6.2 of the Standard to meet healthcare facility requirements and utilizes a 100% outdoor air system to serve some of the spaces, this credit was not attempted by the design team.

*Credit 3.1 | Construction IAQ Management Plan, During Construction (1 point)*

The purpose of Credit 3.1 is to reduce the indoor air quality problems that result from the construction process by developing and implementing an IAQ management plan for the construction and pre-occupancy phase of the building. The construction manager of the Cancer Center, BE&K has the responsibility of carrying out the IAQ management plan for the project to meet the requirements for this credit. Additionally, the construction documents specify that all ductwork shall be designed and constructed in accordance with the Sheet Metal & Air Conditioning Contractor's National Association (SMACNA) which also meets this requirement.

*Credit 3.2 | Construction IAQ Management Plan, Before Occupancy (1 point)*

Credit 3.2 is used in conjunction with Credit 3.1 to reduce indoor air quality problems during construction and pre-occupancy by aiming to purge the building of harmful contaminants prior to tenant use.

*Credit 4.1 | Low-Emitting Materials, Adhesives & Sealants (1 point)*

The next four credits are aimed at reducing the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants by complying with specified volatile organic compound (VOC) content limit. Credit 4.1 targets contaminants in adhesives and sealants used in the building. The Duke Cancer Center Expansion stipulates adhesives and sealants in the finishes section of the specifications to comply with these limits to earn this credit.

*Credit 4.2 | Low-Emitting Materials, Paints & Coatings (1 point)*

Credit 4.2 targets contaminants in paints and coatings used in the building. The Duke Cancer Center Expansion stipulates paints and coatings in the finishes section of the specifications to comply with the VOC limits to earn this credit.

*Credit 4.3 | Low-Emitting Materials, Carpet Systems (1 point)*

Credit 4.1 targets contaminants in carpet systems used in the building. The Duke Cancer Center Expansion stipulates carpet systems in the finishes section of the specifications to comply with the VOC limits to earn this credit.

*Credit 4.4 | Low-Emitting Materials, Composite Wood & Agrifiber Products*

Credit 4.1 targets contaminants in composite wood and agrifiber products used in the building. The Duke Cancer Center Expansion stipulates composite wood and agrifiber products in the wood and plastics and finishes sections of the specifications to contain no added urea-formaldehyde resins to earn this credit.

*Credit 5 | Indoor Chemical & Pollutant Source Control*

The intent of Credit 5 is to minimize exposure of building occupants to potentially hazardous particulates and chemical pollutants. The requirements include employing permanent entryway systems to capture dirt and particulates entering the building at entryways connected directly to outdoors, exhausting and negatively pressurizing spaces that utilize hazardous gases or chemicals, and filtering return and outside air with a Minimum Efficiency Reporting Value (MERV) of 13 or better.

The Cancer Center complies with this credit by providing entryway vestibules with walk-off mats to be maintained weekly. Spaces with hazardous gases and chemicals are directly exhausted and negatively pressurized with partitions that go to the underside of the slab and are sealed at that location. DCC is also mechanically ventilated with all air-handling units supplied with MERV 15 filters in order to earn this credit.

*Credit 6.1 | Controllability of Systems, Lighting (1 point)*

Credit 6.1 aims to promote the productivity, comfort and well-being of building occupants by requiring individual lighting controls for a minimum of 90% of the building occupants to be able to adjust according to task and preferences along with control systems for multi-occupant spaces.

The Duke Cancer Center Expansion addresses these requirements by providing 100% of individual workstations with lighting controls and also providing lighting controllability for all shared multi-occupant spaces to accommodate group needs. The breakdown of the control systems provided for each space in the Cancer Center can be seen in Appendix B.

*Credit 6.2 | Controllability of Systems, Thermal Comfort (0 points)*

Controllability of systems is also assessed in Credit 6.2 which requires that the building have individual comfort controls for a minimum of 50% of the building occupants and comfort controls for all shared multi-occupant spaces to allow for preferential adjustments. This credit was not attempted by the design team for the Duke Cancer Center.

*Credit 7.1 | Thermal Comfort, Design (1 point)*

The purpose of Credit 7.1 is to provide a comfortable thermal environment by meeting the requirement of ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy. The design team has designed to the requirements of Standard 55 with the psychrometric conditions summarized below in Table 1 and will earn one point.

Table 17- Duke Cancer Center Psychrometric Conditions

Psychrometric Condition	DB Temperature (°F)	WB Temperature (°F)	Humidity (gr/lb)
<b>Outdoor Design Conditions</b>	100	78	110
<b>Discharge Air</b>	49.1	49	52
<b>Occupied Spaces</b>	70-75	57.2-62.5	54.2-55

*Credit 7.2 | Thermal Comfort, Verification (1 point)*

Credit 7.2 reinforces the design requirements by providing an assessment of building thermal comfort over time from surveying tenants within six to 18 months of occupancy. The survey will determine the

overall satisfaction with thermal performance and allow for a corrective plan to be developed if more than 20% of occupants are dissatisfied. The owner, Duke Medicine plans to conduct the survey after construction to earn this credit.

*Credit 8.1 | Daylight & Views, Daylight 75% of Spaces (0 points)*

Credit 8.1 contributes to indoor environmental quality through the introduction of daylight and views to the regularly occupied area of the buildings. The credit can be earned by demonstrating that the building has a minimum of 75% glazing in regularly occupied spaces through one of three options: a calculation, a computer simulation process or a measurement of 25 footcandles from daylight illumination. The design team for Duke Cancer Center did not attempt this credit.

*Credit 8.2 | Daylight & Views, Views for 90% of Space (0 points)*

Similar to the previous credit, Credit 8.2 provides an additional credit for going beyond the 75% daylight requirement to achieve a direct line of sight to the outdoor environment via vision glazing to provide views to 90% of the regularly occupied areas. This credit was also not attempted by the Cancer Center design team.

## Mechanical System Evaluation

The mechanical system designed for the Duke Cancer Center Expansion is effective in meeting ASHRAE Standard 62.1-2007 and 90.1-2007 requirements as well as making reductions in energy usage and ozone depletion to potentially acquire LEED status. The first cost of the mechanical system is approximately \$37.4 million, about 17% of the total budget which is typical for healthcare projects. While it may be difficult to reduce first costs based on equipment selection and quantity since there is a stringent ventilation requirement for healthcare facilities, there may be more potential savings in the actual operating costs of the building than the upfront construction costs.

The operating annual costs of \$150,000 were calculated in an earlier report using Trane TRACE. This value needs to be investigated further with dramatic differences seen in energy usage between the calculated Trane TRACE model and the third party consultant Energy Analysis. There is potential for redesign with respect to heating because both analyses (Trane TRACE and AWE) result in a large annual heating load of the Cancer Center.

While the design team for Duke Cancer Center has taken many initiatives toward LEED accreditation with respect to the mechanical system, there is still potential for improvement beyond the criteria of LEED. Other rating systems such as ASHRAE's bEQ may be investigated to explore other alternatives of energy savings and building improvements.

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### Appendix A- Refrigerant Calculations

HVAC & Refrigeration Equipment Type	Quantity	Q (tons)	Refrigerant	GWPr	ODPr	Rc (#/ton)	Life (yrs)	Lr (%)	Mr (%)	LCGWP	LCODP x 10 <sup>^5</sup>	Refrigerant Impact per ton	Refrigerant Impact Total
AHU-4	1	20	R-410a	1890	0	1.55	15	2	10	78.1	0	78.1	1,562
ACC-1	1	60	R-404a	3900	0	3.9	23	2	10	370.3	0	370.3	22,218
ACC-2	1	22	R-404a	3900	0	7.36	23	2	10	698.9	0	698.9	15,376
EMRU-1	1	10	R-410a	1890	0	2.38	15	2	10	120	0	120.0	1,200
HP-1	1	4	R-410a	1890	0	0.94	15	2	10	47.3	0	47.3	189
CAC-1	3	9	R-407c	1700	0	0.61	15	2	10	27.7	0	27.7	249
Food Service	1	1	R-404a	3900	0	5.5	15	2	10	572	0	572.0	572
Food Service	1	1	R-404a	3900	0	18	15	2	10	1,872	0	1,872.0	936
Chiller Plant #1	1	10,500	R-123	76	0.02	1.83	23	2	10	3.4	89.1	92.4	970,200
Chiller Plant #2	1	17,400	R-123	76	0.02	1.61	23	2	10	3	78.5	81.5	1,418,100
TOTALS		28,027										86.73	2,430,602



## Appendix B- CO2 Sensors

### Duke Cancer Center

CO2 Sensors for EQ credit 1

Room #	Room Name	# of Seats	Floor Area (sq ft)	People/1000 sq ft	Currently Has CO2 Sensor?
SB44	Physician Workroom	7	280	25	Yes
0008	Staff Lounge	8	190	42	Yes
0019	Conference Room	16	540	30	Yes
0036	Skills Lab	6	205	29	Yes
1021	Conference Room	16	515	31	Yes
1023	Staff Lounge	8	150	53	Yes
1099	Staff Lounge	8	210	38	Yes
2011	Staff Lounge	20	390	51	Yes
2018	Physician Workroom	5	145	34	Yes
2074	Conference Room	16	500	32	Yes
3004	Physician Workroom	7	262	27	Yes
3005	Physician Workroom	7	262	27	Yes
3008	Physician Workroom	7	262	27	Yes
3009	Physician Workroom	7	262	27	Yes
3012	Staff Lounge	12	260	46	Yes
3016	Physician Workroom	6	236	25	Yes
3126	Staff Lounge	10	285	35	Yes
3130	Conference Room	16	530	30	Yes
3088	Physician Workroom	6	195	31	Yes
3099	Physician Workroom	6	235	26	Yes
4089	Staff Lounge	12	270	44	Yes
5004	Physician Workroom	7	255	27	Yes
5005	Physician Workroom	7	255	27	Yes
5008	Physician Workroom	7	255	27	Yes
5009	Physician Workroom	7	255	27	Yes
5012	Staff Lounge	12	260	46	Yes
5016	Physician Workroom	6	238	25	Yes
5070	Physician Workroom	6	228	26	Yes