Technical Assignment 3

Mechanical Systems Existing Conditions Evaluation

Des Places Residence Hall

Duquesne University

Pittsburgh, PA

DUQUESNE UNIVERSITY

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November 29, 2010

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Executive Summary

Technical Report Three provides a summary of the intent, function and design of the mechanical systems in Des Places Residence Hall. Des Places is a new mixed use dormitory building that has modern student living space, offices and conference space. The building is located on the campus of Duquesne University in Pittsburgh, Pennsylvania.

Des Places receives chilled water and steam from two central plants on campus. The steam is converted to hot water, which is then used as the primary heating source for the building. Fan coil units condition the majority of the rooms and an energy recovery unit in the penthouse provides ventilation for the entire building and conditions the IDF rooms. The hot and chilled water is pumped throughout the building in a variable primary flow arrangement and all of the water pumps are equipped with variable frequency drives.

The total cost of the mechanical system is estimated at $2,827,770 and comprises only 10.2% of the projects total budget. This is significantly lower than the typical cost of a mechanical system for a building, which usually falls in the range of 15%-20% of the total budget. The building meets the ventilation requirements of ASHRAE Standard 62.1 and has a low annual operating cost of $95,663, which is equivalent to $0.73 a square foot.

Des Places is striving to earn a minimum of LEED Certification upon its completion. A LEED analysis was performed in this report, using the rating scale found in LEED version three. Only the credits in the Energy and Atmosphere and Indoor Environmental Quality sections were analyzed for compliance, because these two areas of the standard have special relevance to the mechanical system of a building. Des Places is predicted to earn 26 of the possible 50 credits in these two sections.

An overall evaluation was performed for this report, which includes analysis of the mechanical system construction cost, maintainability, operating cost, space requirements, equipment and overall organization. After completing a detailed study, it was concluded that the engineers designed an appropriate system that will be able to adequately meet the requirements of the project.

Mechanical System Summary

Introduction

Des Places Residence Hall is a 13 story, 131,000 square foot mixed use dormitory building for Duquesne University in Pittsburgh, Pennsylvania. The building primarily consists of student living space, with offices on the first and second floor, conference space on the twelfth floor and mechanical space on the first floor and thirteenth floor penthouse. The total estimated budget for the project is $27,535,000. Des Places was designed to provide comfortable and modern living space to its student occupants while at the same time minimizing its energy use. The building was designed to achieve a minimum of LEED certification upon its completion and it will achieve this through the implementation of efficient mechanical and electrical systems, energy saving controls, high efficiency lighting fixtures and sustainable construction practices.

Design Objectives and Requirements

There were several objectives that drove the design of the mechanical system for Des Places. Duquesne University wanted a system that could provide fast responding individual control for all of the occupied spaces in the building and the system had to meet the prescribed standards given by the 2009 edition of the National Mechanical Code and the National Plumbing Code. Des Places was designed in accordance with ASHRAE Standards 62.1 and 90.1 as well, and therefore the building is designed to meet all of the energy, ventilation, temperature and humidity requirements prescribed in these documents. The University also required that the building achieve a minimum of LEED certification upon its completion. After considering several alternatives, the mechanical engineers decided to use individual fan coil units to condition each room, and a dedicated OA air handling unit to deliver the required amount of ventilation to each space.

Site and Budget

The site of Des Places is located on Duquesne University's campus in Pittsburgh, Pennsylvania. There is an existing dormitory building on the site that will need to be demolished before the construction of Des Places can begin. The site is along the eastern edge of Duquesne's campus with a busy urban street that acts as the dividing line between campus property and a residential area. Because of the urban environment surrounding Duquesne, the building was designed with security in mind. Certain precautions were made to ensure the safety of students living in the building, such as a limited amount of entrances, card access and security cameras. The building will get its steam for heating and chilled water for cooling from central plants that service all of the buildings on campus. The site is immediately adjacent to an athletic field to the west, academic buildings to the north and a smaller street that runs through campus on the south. An improvement to the existing landscaping and exterior lighting around Des Places is included in the scope of the project. The total budget for the project was set at approximately $30,000,000. The estimated cost for the construction and design of Des Places was $27,535,000, so the building should be within budget with some extra money for various improvements, if the construction process goes according to plan. Des Places has been designed to be as energy efficient as possible while staying within the budget. Although it will still be able to achieve a LEED certification, improvements to the buildings overall efficiency could be made if more money was available.

Initial Cost of System

The cost for the entire mechanical system of Des Places was estimated by Regency Construction Services to be $2,827,770 which is equivalent to $21.52 per square foot of floor area. The plumbing system was estimated to be $2,067,912 which comes out to approximately $15.74 per square foot. The mechanical system will account for about 10.2% of the buildings total cost and the plumbing will take up about 7.5% of the overall cost.

Lost Space

The lost space due to the mechanical and electrical systems is summarized in table 1 below. The mechanical system accounts for the large majority of the total square footage values given in the table. The electrical rooms, IDF rooms, mechanical rooms and the space taken up by the vertical duct risers were all accounted for in the square footage calculations. The mechanical and electrical space accounts for approximately 6.8% of the total square footage of Des Places.

Lost Space due to Mech/Elec Systems	
Floor	**Area (SF)**
1	3,216
2	239
11-3	2,511
12	279
Penthouse	2,706
TOTAL	8,951

Table 1: *Lost space due to mechanical and electrical systems in building*

Energy Sources

Des Places will receive steam and chilled water from central plants on campus. These two utilities are connected to the building through underground piping that enters the mechanical room on the first floor through penetrations in the foundation wall. The main electrical feed is provided through an existing Duquesne Light manhole on the site. A 23 KV cable delivers power to a pad mount transformer, which brings the power supply down to a 277/480 V, three phase, four wire cable. The average utility costs for Des Places were given to CJL Engineering by Duquesne University and are given in the table below.

Utility Costs	
Energy Type	**Cost**
Electricity	0.087 ($/KWh)
Natural Gas	1.282 ($/therm)

Table 2: *Duquesne University utility costs*

Design Air Conditions

Des Places is located within the city limits of Pittsburgh, PA so the outdoor design conditions for Pittsburgh were used for the buildings energy model. This data was attained from ASHRAE Fundamentals 2005 and is given in Table 3.

Outdoor Air Design Conditions				
Summer Conditions		Winter Conditions	Clearness Number	Ground Reflectance
Dry Bulb	Wet Bulb	Dry Bulb		
86 F	71 F	5 F	0.97	0.2

Table 3: *Outdoor air design conditions used for Trace model*

The indoor design conditions for Des Places were obtained from the mechanical designer, CJL Engineering. These figures are shown in Table 4 below.

Indoor Design Conditions	
Cooling Dry Bulb Setpoint	75 F
Cooling Dry Bulb Driftpoint	78 F
Heating Dry Bulb Setpoint	72 F
Heating Dry Bulb Driftpoint	64 F
Relative Humidity	50%

Table 4: *Indoor air design conditions used for Trace model*

Mechanical Equipment Summaries

All of the rooms in Des Places except for the data rooms, electrical rooms and the conference room on the 12th floor will be fully conditioned by individual four-pipe fan coil units. There are 257 FCUs throughout the building that range in size from 300 CFM to 1200 CFM. All of these units are connected to separate hot water and chilled water pipes and are equipped with thermostats so that occupants can have direct control of the temperature in each space. They are also equipped with motion sensors so that they can change from occupied to unoccupied mode and automatically shut themselves off when the room is empty. Duquesne University required that Whalen fan coil units be used for Des Places, because they have had them installed in other buildings and have found that they are especially reliable and easy to maintain. This has caused many of the units to be oversized, because the heating and cooling capability of the smallest FCU that Whalen produces (FC-A in the schedule) is much larger than the demands of many spaces in the building. The fan coil unit schedule is given in Table 5 below.

Fan Coil Unit Schedule													
				Hot Water Coil				Chilled Water Coil					
								EAT				Total	Sensible
Mark	CFM	Motor HP	Max Amp	EA DB	EWT	LWT	Total MBH	DB	WB	EWT	LWT	MBH	MBH
FC-A	300	0.025	0.75	70	140	120	12	78	65	45	57	11.5	8.1
FC-B	400	0.03	0.9	70	140	120	17	78	65	45	57	13.5	9.5
FC-C	600	0.05	1.2	70	140	120	24	78	65	45	57	20.1	13.6
FC-D	800	0.08	1.5	70	140	120	27	78	65	45	57	28.2	21.8
FC-E	1200	0.16	2.3	70	140	120	34	78	65	45	57	34.6	27.3

Table 5: *Fan coil unit schedule*

The 12th floor conference space required the highest quality interior finishes in the building and the sound produced by the mechanical equipment serving the space had to be kept to a minimum. Because of these two factors, the architects decided that the Whalen fan coil units could not be used to condition this space. Instead two blower coils were placed above the ceiling to deliver conditioned air through diffusers. The technical information for these blower coils is given in the table below.

Blower Coil Schedule					
		Motor	Cooling Coil		Heating Coil
Mark	Airflow (cfm)	HP	MBH Total	MBH Sensible	MBH Total
BC-1	1600	1	60.3	44	58.9
BC-2	800	3/4	30.1	22	31.1

Table 6: *Blower coil schedule*

A one-hundred percent outdoor air, energy recovery unit provides all of the required ventilation needed for the building, in accordance with ASHRAE Standard 62.1. The ERU also exhausts all of the public and private bathrooms in the building and conditions the electrical rooms and data rooms. ERU-1 uses a desiccant energy wheel to transfer latent and sensible heat between the incoming outdoor air stream and the outgoing exhaust air from the bathrooms and data rooms. After passing through the energy wheel, the outdoor air goes through a preheat coil for freeze protection and then a cooling coil. After this stage of conditioning the air is split into two separate ducts. One duct sends air at 52 ^{o}F to the data rooms and the other duct has a reheat coil that brings the air back to a neutral temperature where it is delivered to all of the other rooms in the building for ventilation purposes. The fans in both the exhaust plenum and outdoor air plenum are equipped with variable frequency drives to reduce the energy consumption of the unit. Information for ERU-1 is given below.

Energy Recovery Unit Schedule											
						CHW Cooling Coil					
	Supply Air		Exhaust Air			EAT		LAT		HW Reheat Coil	
Mark	Airflow (cfm)	Motor HP	Airflow (CFM)	Motor HP	Net Efficiency	DB	WB	DB	WB	EAT DB	LAT DB
ERU-1	20,600	10	13,375	10	66.3	68.9	62.3	52	52	54	70

Table 7: *Energy Recovery Unit Schedule*

The laundry dryers and rooms that contain potentially harmful or odorous air were given their own dedicated exhaust systems. The air from these rooms and machines will be sent directly outside of the building by separate exhaust fans in accordance with ASHRAE Standard 62.1. Technical Report 1 gives a more detailed analysis of the buildings compliance with this standard. The exhaust fan schedule is shown in Table 8 below.

Exhaust Fan Schedule			
Mark	Serves	Airflow (cfm)	Motor HP
EF-1	Trash and Recycling	400	1/8
EF-2	Trash Chute	800	1/4
EF-3	Generator Room	150	1/4
EF-4	Dryer Vent Riser	6000	3

Table 8: *Exhaust fan schedule*

The large amount of air exhausted from the building by these four fans explains the difference between the exhaust air cfm and outdoor air cfm in ERU-1. When the exhaust air leaving through the energy recovery unit is combined with the exhaust air leaving through the four fans shown above the total cfm is roughly equivalent to the supply air cfm in ERU-1.

The heating source for Des Places comes from Duquesne University's central steam plant. Immediately after the main steam line enters Des Places it is converted into hot water by two steam to hot water convertors. The schedule for these two heat exchangers is shown below.

Steam to Hot Water Converter Schedule									
	Tube	Diameter	Fouling		Shell Operating	Tubes			
Mark	Length (in)	(in)	Factor	Lbs/Hr.	Pressure (psig)	Flow (GPM)	EWT	LWT	Passes
C-1	41	10	0.00086	2400	5	195	120	140	2
C-2	41	10	0.00086	2400	5	195	120	140	2

Table 9: *Steam to hot water converter schedule*

The pumps in Des Places are a major component of the buildings mechanical system. All of the pumps in the building are connected to a variable frequency drive with the exception of the condensate pump. A variable primary flow arrangement is used for the hot water, chilled water and domestic water. The schedule for all of the pumps in Des Places is shown in table 9.

Pump Schedule							
Mark	Pump Duty	Type	Flow (GPM)	Head (ft)	Motor HP	Motor RPM	Impeller Size (in)
P-1	Chilled Water	Base Mounted	480	71	5	1760	8.5
P-2	Chilled Water	Base Mounted	480	71	5	1760	8.5
P-3	Hot Water	Base Mounted	180	71	5	1760	8.5
P-4	Hot Water	Base Mounted	180	71	5	1760	8.5
P-5	Chilled Water Booster	Base Mounted	120	60	5	1750	8
P-6	Domestic Hot/Chilled Water Booster	Base Mounted	175	60	5	1750	8.5
P-7	Hot Water Booster	Base Mounted	175	60	5	1750	8.5
P-8	Condensate Pump	Base Mounted	12	30 PSIG	0.75	3000	--

Table 10: *Pump schedule*

Operating History of System

Des Places Residence Hall is currently under construction and therefore there is no operating data for the designed mechanical system.

Ventilation Requirements

In order to verify that the buildings air handling system provided adequate ventilation to its occupants, a ventilation rate calculation had to be performed in accordance with one of the suggested methods outlined in ASHRAE 62.1. ERU-1 is a 100% outdoor air unit that provides fresh air to all of the required zones in the building. The amount of outdoor air entering the building from ERU-1 has to be compared to the total outdoor air needed in order to see if the building has enough ventilation. The Ventilation Rate Procedure was chosen over the IAQ Procedure because the building does not utilize controls that remove air contaminants.

The table below shows the total outdoor air required by floor and the design outdoor air delivered to each floor by the supply registers and diffusers. The value for $\sum V_{oz}$ was found by summing the V_{oz} calculated for each room. The values in the column entitled "Design OA" is the sum of the design outdoor air delivered to each room by all of the supply registers and diffusers on each floor.

OA Requirements By Floor

Floor	∑Voz	Vot	Design OA
1	769 cfm	769 cfm	1425 cfm
2	868 cfm	868 cfm	1615 cfm
3	897 cfm	897 cfm	1265 cfm
4	897 cfm	897 cfm	1265 cfm
5	897 cfm	897 cfm	1265 cfm
6	897 cfm	897 cfm	1265 cfm
7	897 cfm	897 cfm	1265 cfm
8	897 cfm	897 cfm	1265 cfm
9	897 cfm	897 cfm	1265 cfm
10	897 cfm	897 cfm	1265 cfm
11	897 cfm	897 cfm	1265 cfm
12	1145 cfm	1145 cfm	1470 cfm
Total:	10855 cfm	10855 cfm	15895 cfm

Table 11: *Total outdoor air required and delivered to each floor*

The next table is a summary of the building's compliance with the ASHRAE ventilation guidelines, given in section 6.2.

Compliance Summary				
AHU	**Calculated Outdoor Air**	**Design OA Flow Into Rooms**	**Design OA Flow From Schedule**	**ASHRAE 62.1 Compliance**
ERU-1	10855 cfm	15895 cfm	20600 cfm	YES

Table 12: *ASHRAE 62.1, Section 6 Compliance Summary for ERU-1*

The Energy Recovery Unit in the penthouse is the only system that delivers outdoor air to the building, so it was therefore the only piece of equipment that was examined for ventilation compliance. According to the schedule on drawing H0.1, ERU-1 can supply a maximum of 20,600 CFM of outside air. This is almost double the required amount for the building, as calculated in accordance with the procedures given in Section 6.2. It is also 4,705 cfm more than the total design outdoor airflow into all of the spaces from the supply diffusers. Therefore it can be concluded that ERU-1 safely meets the ventilation requirements of ASHRAE Standard 62.1.

Design Heating and Cooling Loads

Trane Trace 700 was used to model the energy consumption of Des Places Residence Hall. This program provides an in depth analysis of a buildings energy consumption, design loads and performance and is relatively user friendly. A combination of individual room and block loading was used to model this building. All of the information necessary to create this model was found in the drawings and specifications for Des Places.

The table below summarizes the total cooling load, heating load and supply airflow for the entire building and compares it to the heating capability, cooling capability, and total supply airflow of all the fan coil units in the building. This table also compares the total ventilation airflow calculated in Trace to the amount of outdoor air coming from the energy recovery unit.

Comparisons by System								
	Cooling		**Heating**		**Supply Airflow**		**Ventilation Airflow**	
	Design (MBh)	**Modeled (MBh)**	**Design (MBh)**	**Modeled (MBh)**	**Design (CFM)**	**Modeled (CFM)**	**Design (CFM)**	**Modeled (CFM)**
Fan Coil Units	2,421	1,452	3,624	1,200	92,100	51,266	20,600	17,667

Table 13: *Design vs. modeled load comparison by system*

Table 12 shows that the designed heating and cooling capability of the fan coil units in Des Places far outweighs the total designed heating and cooling loads. This large discrepancy gives the appearance of either a poor energy model or some significant errors made during the design process. However there is a justification for the fan coil units being so oversized in comparison to the loads. According to Tony Valenza, a mechanical engineer for CJL Engineering who worked on the Des Places project, Duquesne University specifically required the use of Whalen fan coil units to heat and cool the building. The owner wanted fan coil units in each room, so that the students could have personalized control of the temperature in the space they were occupying. Furthermore they specifically required Whalen units, because they had used them in other buildings and found that they were very reliable. The smallest fan coil unit that Whalen makes has a heating coil capacity of 12 MBh and a cooling coil capacity of 8.1 MBh. The vast majority of rooms in Des Places have calculated heating and cooling loads that are far less than these values, so all of these rooms have oversized equipment.

Another reason for the discrepancy between the design load and the modeled load for the building was the fact that the templates made for all of the rooms in the Trace model used internal loads that described typical usage for that type of space. In the actual design of the building the engineers were more cautious and designed for a worst case scenario so that the heating and cooling loads in each space would not exceed the capability of the fan coil unit. This resulted in the use of fan coil units that were slightly oversized even in rooms that had heating and cooling loads that surpassed the capability of the smallest available Whalen FCU.

Annual Energy Use

The annual energy consumption for Des Places was calculated using the Trace model created for the building. Utility rates for chilled water, hot water and electricity were provided by CJL Engineering. The energy model created by the engineers that worked on Des Places could not be attained. Therefore their energy model could not be compared to the one created for this report.

The annual energy consumption for the entire building is broken down into major categories in Table 13. The boilers that power the heating system use gas and the chillers that are used for the cooling system were assumed to be electric. All of the major mechanical and electrical systems are powered by electricity except for the primary heating.

Annual Energy Consumption		
System	Electrical Consumption (kWh)	Gas Consumption (kBTU)
Primary Heating	--	1,397,382
Heating Accessories	13,770	--
Primary Cooling	387,640	--
Cooling Accessories	3,854	--
Pumps	24,152	--
Supply Fans	201,090	--
Lighting	263,162	--

Table 14: *Annual energy consumption by system*

All of the primary systems in Des Places that require some form of energy are shown in relationship to one another in Figure 1. The entities that were measured in kWh were converted to kBTU, so that all of the systems could be accurately compared. The figure below shows that the primary heating and cooling take up the majority of energy being used in the building. The lighting and supply fans used in the mechanical system take up most of the remaining energy, while the other entities use a negligible amount. This finding makes sense for Des Places for several reasons. The lighting should not take up that much of the total energy load, because a variety of efficient fixtures such as LED and High Output T5 lamps were used throughout the building. The fans should not have a very high load, because there are very few that require more than 2 hp to operate, and the ones that do utilize VFDs so that they run more efficiently. The cooling and heating will use most of the energy in the building because the oversized fan coil units in the bedrooms and living rooms will not be running near their ideal efficiencies when they are not operating near full load.

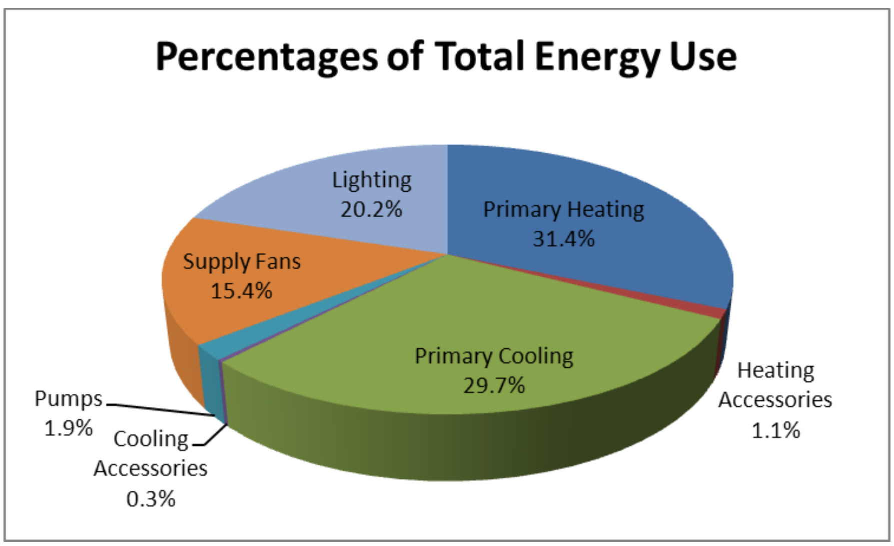

Figure 1: *Pie chart showing percentages of total energy use*

System Operation and Schematics

The waterside and airside system schematics are shown in Appendix B of this report. The waterside section has a schematic for the steam, hot water and chilled water systems and the airside section has one drawing, showing how the energy recovery unit in the mechanical penthouse distributes air throughout the building. A legend for the water side systems (shown below) explains what all of the abbreviations and symbols mean in Figures 3 through 5.

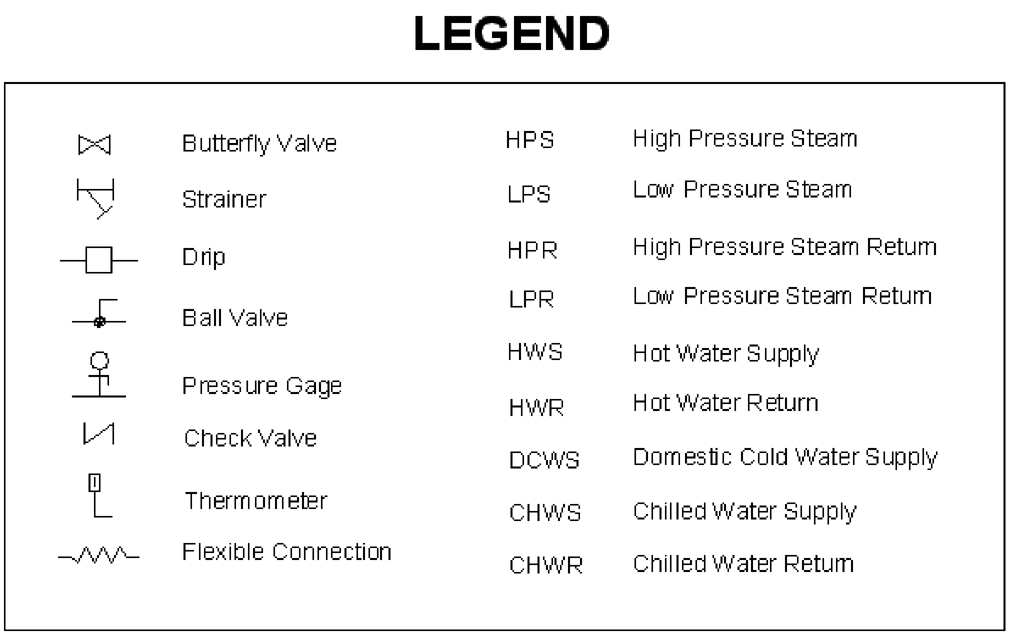

Figure 2: *Legend for water side system schematics*

Water Side

Steam

High pressure steam enters the building from the central steam plant through a foundation wall on the first floor in a 4” pipe at a pressure of 50 lbs and a velocity of 6,000 fpm. Immediately after the high pressure steam enters Des Places it goes through a pressure reducing valve station that brings the steam to a more manageable pressure. The pressure reducing valve is connected to a flash tank that takes care of any flashing steam and turns it into condensate. Some of the low pressure steam then branches off to the domestic water heater that services the entire building. After running through a temperature control valve station, the remaining low pressure steam enters two identical steam to hot water converters that act as heat exchangers between the steam and the return hot water for the building. These two converters are arranged in parallel and feed the hot water system that is responsible for heating the entire building. After making two passes through the converters the hot water temperature rises from 120 ^{o}F to 140^{o}F. The two heat exchangers turn all of the remaining steam into condensate. A condensate pump then pushes all of the condensate produced by the flash tank, domestic water heater, and heat exchangers out of the building and back into the district steam loop where it is brought back to Duquesne's central plant.

Hot Water

The supply hot water for the building starts at the two steam to hot water converters at 140^{o}F. Before the water reaches any of the pumps it passes through an air separator that removes any air bubbles from the water. This is done to avoid cavitation in the pumps, which leads to inefficiency and damage to the equipment. A portion of the hot water supply branches off to serve all of the unit heaters in the building and the two heating coils in the energy recovery unit. The water in this branch is circulated by a single 5 HP, base mounted pump. This pump is equipped with a variable frequency drive that matches the load demand. The remaining majority of the hot water is delivered to the fan coil units on each floor of the building by two variable frequency pumps arranged in parallel. These two pumps are identical and work together as one package so that they are operating at the most efficient combination possible that will still meet the required load. A small amount of hot water is diverted from the fan coil loop in the first floor mechanical room, so that chemicals can be fed into the water and then recirculated into the loop through the return water. The chemicals injected into the hot water return keep the water from fouling and protect the pipes from corrosion. The pumps are arranged in a variable primary flow arrangement, so there are no secondary pumps in the building. After the hot water meets the load it is returned back to the two heat exchangers at 120 ^{o}F where it is heated back up again to 140 ^{o}F.

Chilled Water

The chilled water loop for the building is structured in an almost identical arrangement as the hot water loop. The chilled water enters the building in the first floor mechanical room straight from Duquesne's central plant instead of from heat exchangers like the hot water. The chilled water comes in at 45 ^{o}F and is returned to the district cooling loop at 57 ^{o}F after running through the various loads in the building. Because the chilled water is not recirculated in the system like the hot water, chemical treatment is not necessary. The chilled water is broken into two loops. The smaller loop serves the cooling coil in ERU-1 and is circulated by a single pump, and the larger loop serves all of the buildings fan coil units and is circulated by two identical pumps arranged in parallel.

Air Side

The airside system for this building is limited to the large energy recovery unit in the penthouse and the associated ducts and diffusers that provide ventilation to the entire building and condition the IDF rooms. This unit is also responsible for exhausting all of the lavatories in the building as well. The ERU uses 100% outdoor air and exhausts all of its return air directly outside of the building. The unit is able to recover some of the latent and sensible heat from the exhaust air stream with a dessicant wheel. In the supply air plenum, the incoming air passes through a preheat coil for freeze protection and then a cooling coil. From there the energy recovery unit becomes a split system. A small amount of air is sent to the IDF rooms conditioned at 52 ^{o}F and the remaining air splits off into another duct to bring outdoor air at a neutral temperature into all of the rooms in the building that require ventilation. This air supply is braught back up to a neutral temperature by a second reheat coil in the ventilation air plenum. This coil brings the air from 52 ^{o}F to 70 ^{o}F. The supply air flow and the exhaust air flow are both pushed through the system by 10 HP fans in the energy recovery unit. These fans are run by variable frequency drives that use pressure sensors to determine their operating speed.

3.0 LEED Analysis

The standard for Leadership in Energy and Environmental Design (LEED) was created by the United States Green Build Council (USGBC) to encourage building owners and designers to adopt energy efficient and environmentally friendly construction practices. The 2009 LEED standard has two sections that are particularly influenced by the mechanical design of a building. These two sections are titled Energy and Atmosphere (EA) and Indoor Environmental Quality (IEQ). These sections are the only ones addressed in this report, because of their significant relevance to the mechanical system of a building. The Des Places project has to achieve a minimum of LEED certification, so the engineers at CJL tried to attain as many points as possible within the EA and IEQ sections. For the Energy and Atmosphere section, the design team anticipates that Des Places will receive 13 of the possible 35 points and for the Indoor Environmental Quality section it is anticipated that the building will receive 13 of the possible 15 points. An explanation for all of the points that this project will be able to attain within these two sections is given below.

Energy and Atmosphere

EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems - YES

Intent: To verify that the project's energy-related systems are installed, and calibrated to perform according to the owner's project requirements, basis of design and construction documents.

Des Places: A commissioning authority with the proper amount of documented experience will review and oversee the completion of commissioning activities and report their findings and recommendations directly to the owner.

EA Prerequisite 2: Minimum Energy Performance - YES

Intent: To establish the minimum level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use.

Des Places: Technical Report 1 shows that the buildings mechanical system fully complies with ASHRAE Standard 90.1-2007. In an energy model comparison performed by CJL Engineering the designed mechanical system is more than 10% efficient than the baseline building.

EA Prerequisite 3: Fundamental Refrigerant Management - YES

Intent: To reduce stratospheric ozone depletion.

Des Places: No cholorofluorocarbon (CFC) based refrigerants will be used in any of the HVAC equipment in this building.

EA Credit 1: Optimize Energy Performance – 6 POINTS

Intent: To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.

Des Places: The energy model for the designed mechanical system shows a 22% improvement in energy usage over the baseline building. The baseline building energy model was created in accordance with Appendix G of ASHRAE Standard 90.1-2007.

EA Credit 2: On-site Renewable Energy – 1 POINT

Intent: To encourage and recognize increasing levels of on-site renewable energy self-supply to reduce environmental and economic impacts associated with fossil fuel energy use.

Des Places: The only renewable energy source that Des Places uses is an array of electric solar panels on the rooftop. This array is comprised of three rows of eleven 318 Watt, DC power photovoltaic panels. The amount of electricity that these PVs produce is equivalent to approximately 1% of the buildings total energy consumption.

EA Credit 3: Enhanced Commissioning – 2 POINTS

Intent: To begin the commissioning process early in the design process and execute additional activities after systems performance verification is completed.

Des Places: A contract will be in place prior to any new construction with an experienced commissioning authority to lead and oversee all commissioning activities. This commissioning agent is entirely independent from the construction company and all of the design firms working on this project and will report their findings directly to the owner, Duquesne University.

EA Credit 4: Enhanced Refrigerant Management – 2 POINTS

Intent: To reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to climate change.

Des Places: Des Places receives its chilled water from a central plant on campus and therefore does not require any refrigerants to be used within the building.

EA Credit 6: Green Power – 2 POINTS

Intent: To encourage the development and use of grid-source, renewable energy technologies on a net zero pollution basis.

Des Places: Duquesne University is already purchasing at least 35% of the electricity needed for the campus from renewable sources. Because Des Places is a building on Duquesne's campus, it satisfies the requirements for this credit.

Indoor Environmental Quality

IEQ Prerequisite 1: Minimum IAQ Performance – YES

Intent: To establish minimum indoor air quality (IAQ) performance to enhance indoor air quality in buildings, thus contributing to the comfort and well-being of the occupants.

Des Places: Sections 4 through 7 of ASHRAE Standard 62.1-2007 were met by this building, as outlined in Technical Report 1. Mechanical ventilation was used for the entire building in accordance with the ventilation rate procedure given in Standard 62.1.

IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control – YES

Intent: To prevent or minimize exposure of building occupants, indoor surfaces and ventilation air distribution systems to environmental tobacco smoke (ETS).

Des Places: Smoking is prohibited in the building itself or within 25 feet of entries, outdoor air intakes and operable windows.

IEQ Credit 1: Outdoor Air Delivery Method – 1 POINT

Intent: To provide capacity for ventilation system monitoring to help promote occupant comfort and well-being.

Des Places: The supply diffusers going to all of the spaces in the building that are connected to ERU-1 are set at a constant cfm. Therefore they will consistently bring the right amount of outdoor air into each room. The energy recovery unit is equipped with flow meters to monitor the amount of outdoor air coming into the unit and CO_2 sensors will be placed in all densely occupied spaces.

IEQ Credit 2: Increased Ventilation – 1 POINT

Intent: To provide additional outdoor air ventilation to improve indoor air quality (IAQ) and promote occupant comfort, well-being and productivity.

Des Places: The outdoor air quantity delivered to all of the spaces in the building that require ventilation has been increased to 30% more than the minimum required rates given in ASHRAE 62.1-2007.

IEQ Credit 3.1: Construction IAQ Management Plan, During Construction – 1 POINT

Intent: To reduce indoor air quality (IAQ) problems resulting from construction or renovation and promote the comfort and well-being of construction workers and building occupants.

Des Places: An IAQ management plan has been developed by Duquesne University and the general contractor that should successfully create a construction environment that exceeds the control measures outlined by the Sheet Metal and Air Conditioning National Contractors Association in their IAQ Guidelines for Occupied Buildings Under Construction. Absorptive materials on site will also be protected from moisture damage.

IEQ Credit 3.2: Construction IAQ Management Plan, Before Occupancy – 1 POINT

Intent: To reduce indoor air quality (IAQ) problems resulting from construction or renovation and promote the comfort and well-being of construction workers and building occupants.

Des Places: IAQ testing will be performed after construction ends in accordance with Option 2 of this credit, as outlined in LEED 3.0. If the air in the building has contaminant concentrations higher than what is allowed by Credit 3.2, then a building flush-out will be performed.

IEQ Credits 4.1 – 4.4: Low-Emitting Materials – 4 POINTS

Intent: To reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

Des Places: No adhesives, sealants, paints, coatings or carpets used in the construction of Des Places will exceed the volatile organic compound (VOC) content amounts as stated in Credits 4.1-4.3 of LEED 3.0. Any composite wood or agrifiber products used in the interior of the building will not contain urea-formaldehyde resins.

IEQ Credit 6.2: Controllability of Systems, Thermal Comfort – 1 POINT

Intent: To provide a high level of thermal comfort system control1 by individual occupants or groups in multi-occupant spaces (e.g., classrooms or conference areas) and promote their productivity, comfort and well-being.

Des Places: Individual comfort control is available to 100% of the buildings occupants, through the fan coil units in each room. Each fan coil unit can be controlled by the occupants of each room with a thermostat. Windows in the bedrooms and living rooms are operable as well.

IEQ Credit 7.1: Thermal Comfort, Design – 1 POINT

Intent: To provide a comfortable thermal environment that promotes occupant productivity and well-being.

Des Places: All of the heating, ventilating and air conditioning systems and the building envelope were designed to satisfy the requirements of ASHRAE Standard 55-2004.

IEQ Credit 7.2: Thermal Comfort, Verification – 1 POINT

Intent: To provide for the assessment of building occupant thermal comfort over time.

Des Places: This credit is contingent upon receiving Credit 7.1, so it is assumed for this report that the previous credit will be met. A monitoring system will be put in place in Des Places after its construction to make sure that the building continues to meet the requirements of ASHRAE 55-2004.

Overall System Evaluation

The mechanical system for Des Places is designed to be both simple and energy efficient at the same time. The combination of the fan coil units for conditioning and the energy recovery unit for ventilation make the overall system easy to maintain, while still achieving the goals set forth by the owner. Various technologies and controls were added to this building at a reasonable cost to reduce its energy use and earn Des Places at least a LEED certification.

The estimated construction cost of the mechanical system is $2,827,770 which comes out to $21.52 a square foot. The mechanical system will take up 10.2% of the buildings total cost, which is relatively inexpensive. The mechanical and electrical systems take up 8,951 ft^2 in Des Places, which is only 6.8% of the buildings total square footage. The minimal space requirement is primarily because all of the conditioning is done with fan coil units, which reduces the duct sizes needed for the energy recovery unit. There is also less mechanical equipment in the building than usual because Des Places receives district heating and cooling from two central plants off site.

The energy use for the building is dominated by primary heating and cooling. Each entity uses roughly the same amount of energy and each one accounts for about 30% of the buildings total usage. The predicted annual operating cost for Des Places is $95,663 which comes out to only $0.73 a square foot. Not only is the operating cost very low for this building, but the maintenance costs should be kept to a minimum as well, because the system is relatively simple and the maintenance staff have a good amount of experience with the Whalen fan coil units used in Des Places.

The mechanical system that was designed for Des Places succeeds in meeting the goals and requirements set forth by the owner, Duquesne University. The building meets all of the ventilation requirements set forth in ASHRAE Standard 62.1 and the energy standards in ASHRAE 90.1. Des Places should easily earn a LEED certification and has the potential to become a LEED Silver building upon its completion. The mechanical system accomplishes all of this with a relatively low first cost and easy maintainability into the future.

Appendix A

List of Tables and Figures

Figures

Tables

Appendix B

System Schematics

Water Side Systems

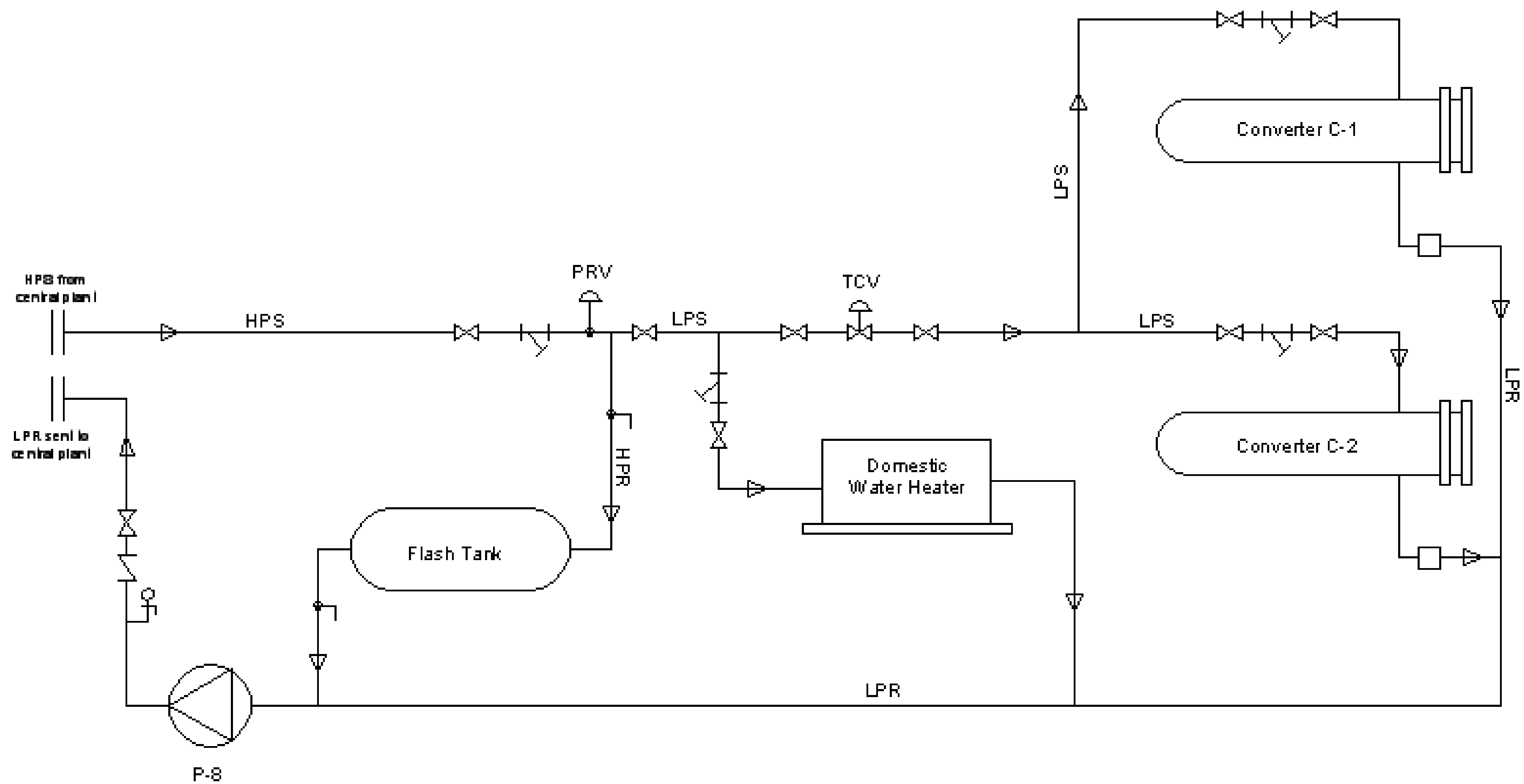

Figure 3: *Steam system schematic*

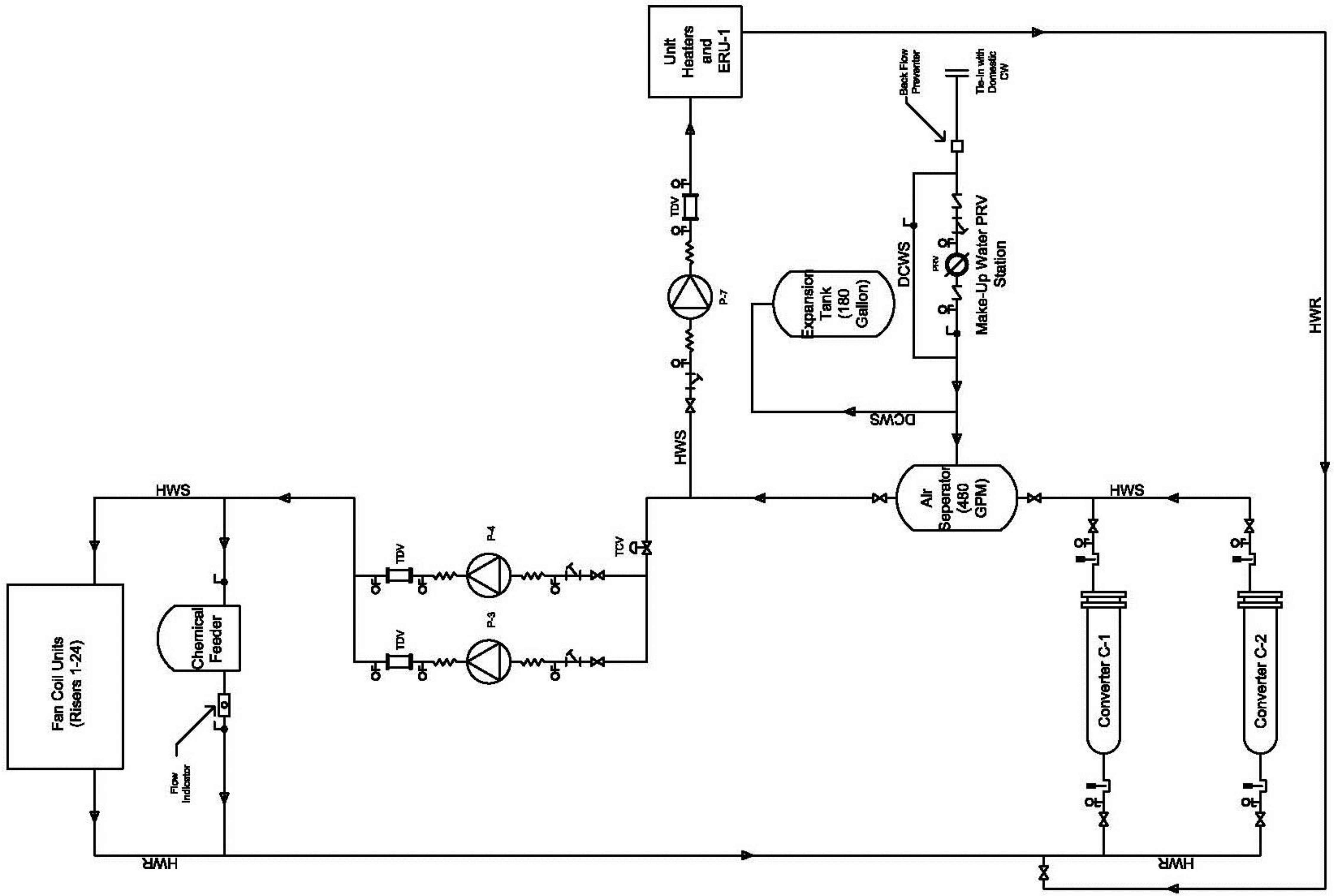

Figure 4: *Hot water system schematic*

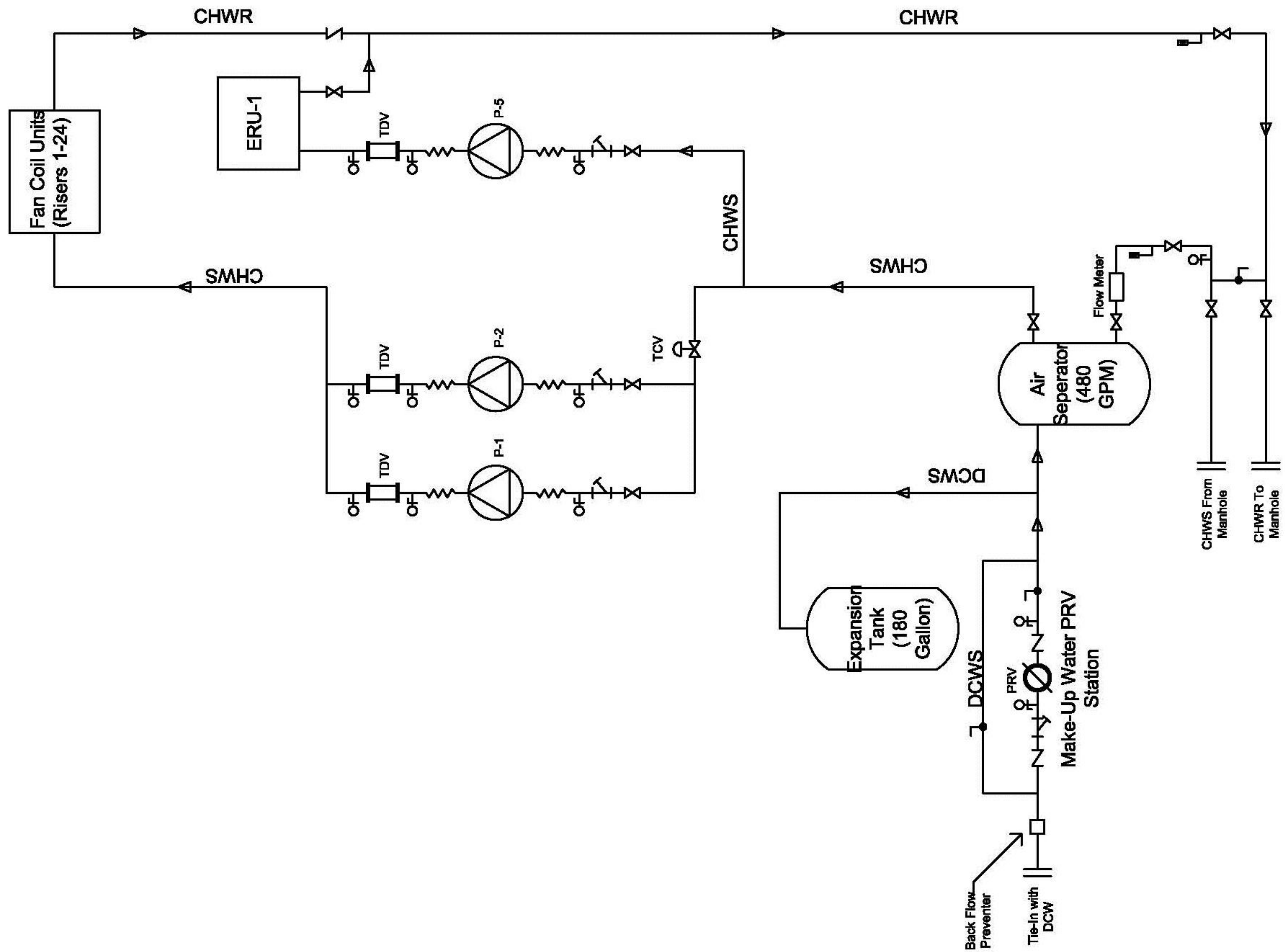

Figure 5: *Chilled water system schematic*

Air Side System

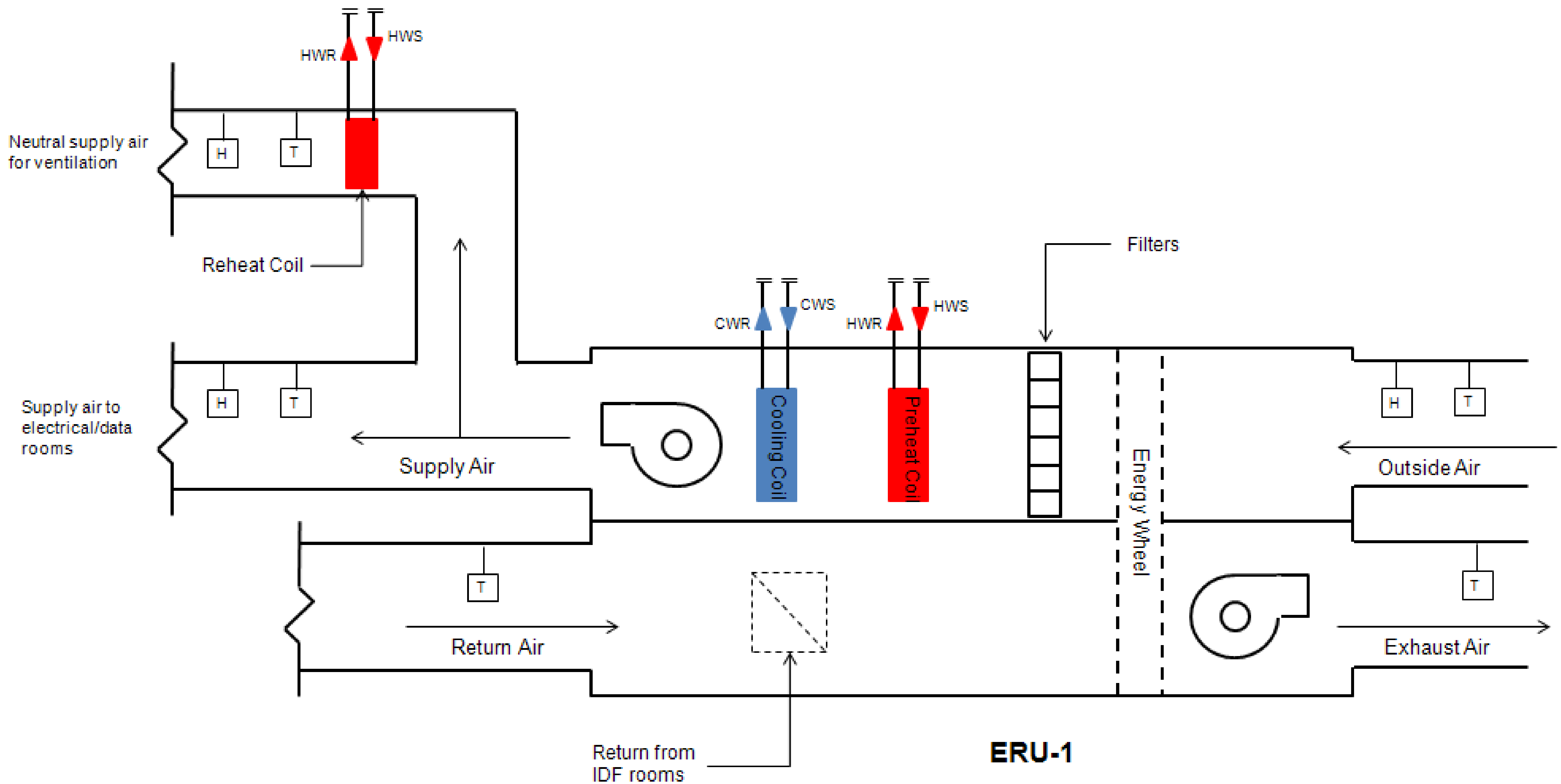

Figure 6: *Air side system schematic*