McCarran International Airport
Terminal 3
Las Vegas, NV

Technical Assignment 3

Mechanical System Existing Conditions Evaluation

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Prepared By:
Jason A. Witterman
Mechanical Option

Faculty Advisor:
Dr. William Bahnfleth, Ph.D., P.E.

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Executive Summary

This report is an evaluation of the existing mechanical system for Terminal 3 at McCarran International Airport in Las Vegas, NV. It includes design conditions, ventilation requirements, design loads and energy analysis as included in previous technical assignments. In addition, this report also includes a summary of design considerations, a summary of equipment, a description of how the system operates, and a critique of the system.

As demonstrated in Technical Assignment 1, Terminal 3 is mostly compliant with ASHRAE Standard 62.1-2007. A breakdown of the design outdoor airflows for each air handling unit is included in the body of this report. Design loads and energy analysis were discussed in Technical Assignment 2, and are included here for reference. Trane TRACE was used to perform the load estimations as well as the energy analysis. The data included in this report was provided by the mechanical design engineer, and represents the estimates used to design Terminal 3. A new analysis could not be performed due to various limitations. The calculated total block cooling load for Terminal 3 is 9,600 tons; and the total block heating load is 76,166,959 Btu/h. An annual cost analysis is included in the body of this report, but should be considered inconclusive as the model was intended only for system sizing and was never intended for energy analysis.

The Department of Aviation had several requests related to the design of Terminal 3. In general, it was requested that the design of the new central plant be as similar as possible to the existing central to simplify maintenance and operation. The most basic request of the owner was to ensure an efficient system capable of meeting peak demand loads. The comfort and satisfaction of passengers within Terminal 3 is considered the primary goal related to the design of the mechanical systems.

The chilled water system is a variable primary flow configuration with a peak cooling capacity of 11,000 tons being provided by five 2,200 ton centrifugal chillers. The condensing water system demand is met by five field erected concrete cooling towers. Two plate and frame heat exchangers are also provided for chilled water return pre-cooling and waterside free cooling. The heating hot water system is a primary / secondary system with a peak output capacity of 105, 840, 000 Btu/h being provided by six 21,000 MBH boilers. A total of 88 air handling units are included at Terminal 3, with an additional three units serving the central plant. These units are either Variable Air Volume (VAV), Single Zone Variable Air Volume (SZ VAV), or Constant Volume (CV). Many of the air handling units are equipped with variable frequency drives.

The existing mechanical system design of Terminal 3 seems to be appropriate for such a facility, with a high amount of consideration given to thermal comfort and indoor air quality. While the system appears to be adequately sized to meet the expected swings in occupant density, one must consider if the issues of energy consumption have been fully analyzed. The use of alternative technologies may help to reduce annual energy costs, and should be given further consideration.

Design Objectives and Considerations

The construction and engineering department of McCarran International Airport was fairly specific in terms of the requirements they had for the mechanical systems of Terminal 3. Since Terminal 3 will be supported by a new central utility plant, many of these requests were specific to this plant. In general, it was requested that the new central plant be designed in such a manner that it would be as similar as possible to the already existing central plant. One of the main reasons for this request is the intent to switch personnel between the plants. That is, if the plants are similar in nature, the operations and maintenance staff will be better equipped to perform necessary tasks in either plant.

The pumps for the existing central plant are horizontal split case pumps. Since the maintenance staff for McCarran performs their own maintenance on theses pumps, the same type of pump was used in the new plant. Again, this basis of design allows for a more effective maintenance schedule without the need for training on the new pumps. Similarly, the intent was to maintain the same manufacturer for other major pieces of equipment. In the case of the chillers, York equipment is used in the existing plant and is also used as the basis of design for the new plant. Consideration was given to other major chiller manufacturers, though they were eliminated for various reasons. Carrier does not currently offer chillers capable of effectively handling such large loads, and therefore are not typically used for large plants. Additionally, the owner requested the use of R-134a refrigerant. As a result, Trane was also eliminated as they currently use R-123. The boilers in the existing central plant are flex water tube boilers manufactured by Bryan. However, Bryan was not the basis of design for the new central plant as they claim to be unable to maintain the new lower emissions requirements on large boilers. As a result, the boilers in the new plant are designed around Unilux. Both plants also utilize field erected concrete cooling towers that will be discussed in further detail later in this report.

Another design objective was to design an energy efficient mechanical system. Part of this involved using efficient chillers and boilers. In addition, nearly all air handling units include variable frequency drives (VFD's) to reduce fan energy. VFD's are also included on pumps where appropriate. The effective reduction of outdoor air quantities when possible was another major objective in the design process. This is accomplished through the use of carbon dioxide and carbon monoxide sensors throughout the building.

The owner also had several other miscellaneous requests that were incorporated into the mechanical system design. One example of this was the request that energy recovery devices be omitted from the air handling units due to past problems. The owner also made a request for all air handling units to have filter racks capable of accepting carbon filters in the future. In the end, perhaps the most important criteria specified by Clark County Department of Aviation is an efficient system capable of meeting peak demand loads. Given that Las Vegas is a frequent tourist destination, passenger satisfaction is especially important. It is imperative to remember that McCarran International Airport often creates a first impression for those visiting Las Vegas. The local economy is greatly impacted by these visitors, so it is necessary to maintain passenger comfort and satisfaction at all times.

Outdoor and Indoor Design Conditions

Both outdoor and indoor design conditions are important for properly estimating design loads within Terminal 3. Table 1 summarizes the outdoor design conditions listed in the ASHRAE Handbook of Fundamentals, as well as those values used by the mechanical design engineer for Terminal 3.

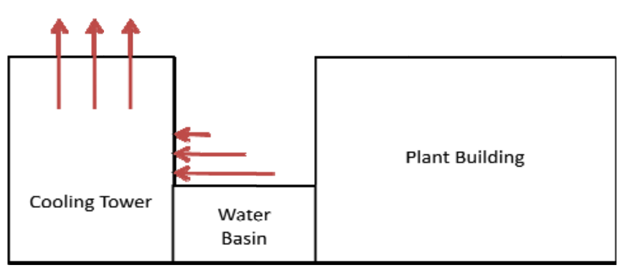
Table 1 – Design Outdoor Air Conditions

Annual Cooling Design Conditions					
ASHRAE 2005, 0.4%			Actual Design Values		
Cooling DB	MCWB	Evaporation WB	Cooling DB	MCWB	Evaporation WB
108.4 °F	66.9 °F	71.4 °F	115 °F	74 °F	77 °F
Annual Heating Design Conditions					
ASHRAE 2005, 99.6%			Actual Design Values		
Heating DB			Heating DB		
28.9 °F			27 °F		

Table 1 indicates that the actual design values for cooling vary somewhat significantly from those suggested by ASHRAE. The mechanical design engineer stated that the owner specifically requested the use of higher ambient conditions than those listed in ASHRAE. This was done for a couple of reasons. The first reason is a result of site factors at McCarran International Airport. The site itself is comprised of several buildings that can be considered relatively small compared to the size of the overall site. The remaining portions of the site consist mostly of runways and aprons that are paved with 18" thick concrete. This incredibly large area of concrete creates a heat island at the airport. As a result, the local outdoor conditions on the airport site are actually higher than the surrounding areas. A second reason for the use of higher design cooling values is the fact that Terminal 3 is subject to high occupant density values. This is especially true in the event of delayed flights. Flight delays are a possibility at any airport, and often result in overcrowded hold rooms at airline gates. The increase in cooling dry bulb temperature and mean coincident wet bulb temperature help to compensate for both of these issues, and are likely considered good design practice for a facility of this nature.

Table 1 also shows an increase in evaporation wet bulb temperature. This value is used for the design of the cooling towers, and has been increased due to the layout of the cooling towers themselves. Each cooling tower has only one air inlet, and they are located adjacent to the cooling tower basin.

Figure 1 – Illustration of Airflow Through Cooling Tower



As Figure 1 illustrates, this basin is located between the cooling tower stack and the central plant itself. Essentially this area is an approximately 20’-0” wide separation between the two building components. The inlet is also located approximately 24’-0” from the top of the structure. That being said, the air entering the cooling tower must pass over the basin and is subject to higher humidity levels. Furthermore, the large air quantities that pass through the cooling tower have the potential for entrainment back to the fan inlet.

Indoor design conditions are listed in Table 2 as provided by the design engineer. Again, these conditions are also taken into account during the load estimation process to accurately size the equipment.

Table 2 – Design Indoor Air Conditions

Summer Design Conditions	
DB Temperature	Relative Humidity
75 °F	50% or less
Winter Design Conditions	
DB Temperature	Relative Humidity
72 °F	50% or less

There is one exception to the design indoor air conditions listed in Table 2, in that during the summer season the baggage handling areas are designed to be maintained at 80 °F. This is an attempt to conserve the energy required to cool this space, which is often open to ambient outdoor conditions due to the nature of the space.

Design Ventilation Requirements

An analysis of the ventilation requirements for Terminal 3 was performed in Technical Assignment 1 – ASHRAE Standard 62.1 Ventilation Compliance Summary. The results of this analysis are included in this report for reference and are summarized in Table 3. This table lists the nominal outside air (ΣV_{oz}) and required outdoor airflow (V_{ot}) for each air handling unit, as well as for the entire building. In addition, this table includes the values for the design outdoor airflow (V_{oa}) as determined from the air handling unit schedule found in the construction documents for Terminal 3. If the design outdoor airflow is higher than the required outdoor airflow (V_{ot}), then the system is compliant with ASHRAE Standard 62.1-2007 Section 6.

Overall, most of the systems comply with ASHRAE Standard 62.1-2007 Section 6. The only exceptions to this are the electrical substation rooms. These rooms were likely designed under the reasonable assumption that they would normally be unoccupied spaces. As a result, the air handling units were selected as 100% recirculated air to handle the space thermal loads only. Since the required outdoor air quantities for these spaces are relatively low, the non-compliance could likely be remedied through the use of transfer air from adjacent spaces.

Several spaces throughout the building also have design outdoor airflows that are relatively high compared to the outdoor air intake flow required. While this would typically indicate that the system is over designed and may be wasting energy, all of these systems include either carbon monoxide or carbon dioxide monitoring. As a result, the outdoor air intake flow required may be reset as design conditions change. This is permitted in accordance with ASHRAE Standard 62.1-2007. In the event of an extremely high occupant density in these areas, the system will still be able to meet the high ventilation requirement. It is also important to consider that Terminal 3 may undergo many tenant improvement projects throughout the building life. In preparation for this, it is important to size the system for adequate future outdoor airflow.

Table 3 – Summary of Ventilation Requirements

Air Handling Unit No.	$\Sigma V_{oz,}$ Nominal Outdoor Airflow Required (cfm)	$V_{ot,}$ Outdoor Air Intake Flow Required (cfm)	$V_{oa,}$ Design Outdoor Airflow (cfm)	Complies with ASHRAE Standard 62.1-2007 Section 6
AH-1	7,677	15,822	16,000	Yes
AH-2	2,025	2,372	5,000	Yes
AH-3	31,287	31,287	32,000	Yes
AH-4	27,927	27,927	28,000	Yes
AH-5	12,501	13,790	16,000	Yes
AH-6	1,647	1,647	7,500	Yes
AH-7	23,252	23,252	30,000	Yes
AH-8	10,213	10,405	175,000	Yes
AH-9	2,048	2,048	95,000	Yes
AH-10	22,010	22,010	26,000	Yes
AH-11	1,887	4,162	5,000	Yes
AH-12	11,522	14,216	17,000	Yes
AH-13	9,496	10,189	16,000	Yes
AH-14	1,123	1,123	6,000	Yes
AH-15	3,107	3,153	14,500	Yes
AH-16	1,811	1,811	6,000	Yes
AH-17	7,746	17,334	19,500	Yes
AH-18	33,743	33,743	40,000	Yes
AH-19	13,668	14,398	20,000	Yes
AH-20	1,565	1,565	5,000	Yes
AH-21	7,012	7,526	15,000	Yes
AH-22	22,365	22,365	23,000	Yes
AH-23	18,237	18,237	21,000	Yes
AH-24	2,711	2,711	12,500	Yes
AH-25	9,302	9,338	10,000	Yes
AH-26	12,934	16,547	26,000	Yes
AH-27	14,487	14,487	19,000	Yes
AH-28	1,692	1,692	6,000	Yes
AH-29	2,620	2,664	12,500	Yes
AH-30	9,244	17,451	18,000	Yes
AH-31	11,850	14,611	20,000	Yes
AH-32	1,542	1,542	6,000	Yes
AH-33	25,709	25,709	28,500	Yes
AH-34	2,298	2,298	11,000	Yes
AH-35	10,627	14,603	16,500	Yes
AH-36	32,294	32,294	33,500	Yes

Air Handling Unit No.	$\Sigma V_{oz,}$ Nominal Outdoor Airflow Required (cfm)	$V_{ot,}$ Outdoor Air Intake Flow Required (cfm)	$V_{oa,}$ Design Outdoor Airflow (cfm)	Complies with ASHRAE Standard 62.1-2007 Section 6
AH-37	3,841	6,431	12,000	Yes
AH-38	24,294	24,294	26,500	Yes
AH-39	13,820	17,464	25,000	Yes
AH-40	2,818	4,777	7,000	Yes
AH-41	3,712	10,320	13,000	Yes
AH-42	2,778	4,494	14,000	Yes
AH-43	6,134	18,490	21,000	Yes
AH-44	2,021	2,021	11,000	Yes
AH-45	6,391	11,180	23,000	Yes
AH-46	13,451	24,988	30,000	Yes
AH-47	6,760	17,311	22,000	Yes
AH-48	2,360	2,360	12,000	Yes
AH-49a	1,473	1,473	7,500	Yes
AH-49b	1,516	1,516	7,500	Yes
AH-50a	5,021	7,850	10,000	Yes
AH-50b	5,790	8,781	10,000	Yes
AH-51a	9,625	9,852	16,000	Yes
AH-51b	9,269	10,578	19,500	Yes
AH-52	9,785	18,741	27,000	Yes
AH-53	1,722	1,722	10,000	Yes
AH-54	6,289	19,180	26,000	Yes
AH-55	2,341	2,341	12,500	Yes
AH-56	13,325	19,814	27,000	Yes
AH-57	6,314	8,855	20,000	Yes
AH-58	1,612	1,612	10,000	Yes
AH-59	5,169	7,523	23,000	Yes
AH-60	4,495	11,939	22,000	Yes
AH-61	2,832	3,232	6,000	Yes
AH-62	43	43	0	No
AH-63	43	43	0	No
AH-64	95	95	0	No
AH-65	106	106	0	No
AH-66	49	49	0	No
AH-67	49	49	0	No
AH-68	55	55	0	No
AH-69	55	55	0	No
AH-70	64	64	0	No

Air Handling Unit No.	ΣV_{oz}, Nominal Outdoor Airflow Required (cfm)	V_{ot}, Outdoor Air Intake Flow Required (cfm)	V_{oa}, Design Outdoor Airflow (cfm)	Complies with ASHRAE Standard 62.1-2007 Section 6
AH-71	64	64	0	No
AH-72	77	77	0	No
AH-73	93	93	0	No
AH-74	93	93	0	No
AH-75	124	124	0	No
AH-76	54	54	0	No
AH-77	54	54	0	No
AH-78	103	103	0	No
AH-79	103	103	0	No
AH-80	111	111	0	No
AH-81	66	66	0	No
AH-82	66	66	0	No
AH-83	66	66	0	No
AH-84	32	32	0	No
AH-85	32	32	0	No
CUP AH-1	3,398	3,398	3,500	Yes
CUP AH-2	3,398	3,398	3,500	Yes
CUP AH-3	775	880	5,000	Yes
Building Total	**595,405**	**744,841**	**1,340,500**	--

Design Heating and Cooling Loads

The data contained in this section of the report is a summary of the analysis performed for Technical Assignment 2 – Building and Plant Energy Analysis Report. As a reminder, this summary represents the analysis performed by the mechanical consultant for Terminal 3. Due to software limitations and lack of feasibility, a new load estimate could not be performed for comparison in Technical Assignment 2. Unfortunately, this issue has not yet been resolved and a new load estimate has still not been performed. Again, it is still anticipated that a new load simulation model will be performed in the future for further use in the overall thesis project.

Load estimates for Terminal 3 were determined through the use of TRACE 700 by Trane. This software takes into account the actual design occupancy values, lighting and equipment electrical loads, and outdoor air ventilation rates. Furthermore, TRACE uses design indoor and outdoor conditions to appropriately model the building based on the climate. These conditions are included in Table 1 under the section Outdoor and Indoor Design Conditions.

Table 4 compares the results of the load simulation to the actual building design loads. Please note that this table does not include data for the following systems: air handling units serving substations, evaporative coolers serving the central plant boiler rooms, and fan coil units used throughout the project. Overall, the design loads seem to be reasonably close to the estimated loads. However, there are several systems that appear to be overdesigned. It is important to recall, however, that the air handling units are equipped with variable frequency drives to help reduce energy usage when not operating at peak load conditions. When comparing the estimate to the actual design, one must also take into account the potential for simple modeling differences. Small changes have been likely made in the design documents without being modified in the load simulation. The intention is for these changes to be incorporated into an updated load simulation for future analysis.

Table 4 also provides the airflow rates for outdoor air used for ventilation purposes. This is similar to the data provided in Table 3, which can be found in the previous section. It is important to distinguish the differences in data included in these two tables. Table 3 provides required outdoor air intake flow as calculated by ASHRAE Standard 62.1-2007. It also includes the total design outdoor air flows for each air handling unit. Table 4, on the other hand, provides an estimate of the required outdoor air intake flow in terms of cfm per square foot. Additionally, it provides the design outdoor air flows in terms of cfm per square foot. As previously stated, Terminal 3 is equipped with demand controlled ventilation, so differences in estimated and actual design outdoor air flows are likely not a major concern.

Table 4 – Comparison of Cooling Loads

Air Handling Unit No.	SF / ton		Total Supply Air [cfm/ SF]		Ventilation Outdoor Air [cfm/ SF]	
	Estimated	As Designed	Estimated	As Designed	Estimated	As Designed
AH-1	251.29	242.16	0.92	1.15	0.39	0.46
AH-2	467.47	302.39	0.68	1.06	0.12	0.27
AH-3	99.65	128.16	1.58	1.73	1.50	1.53
AH-4	101.15	124.74	1.50	1.88	1.50	1.50
AH-5	212.46	241.37	1.01	1.16	0.49	0.46
AH-6	160.45	160.67	1.82	2.00	0.50	0.50
AH-7	94.07	96.58	2.01	2.32	1.50	1.93
AH-8	217.66	242.34	0.96	1.07	0.50	0.48
AH-9	217.82	184.67	1.11	1.60	0.50	0.51
AH-10	92.45	100.33	1.98	2.39	1.50	1.77
AH-11	167.19	183.88	2.24	1.91	0.23	0.32
AH-12	229.44	306.35	0.96	1.08	0.45	0.46
AH-13	211.65	237.69	1.06	1.18	0.46	0.47
AH-14	111.38	81.03	3.36	4.27	0.05	0.64
AH-15	225.30	222.27	0.99	1.24	0.50	0.51
AH-16	128.74	130.72	2.93	2.65	0.03	0.40
AH-17	169.54	207.08	1.37	1.25	0.57	0.61
AH-18	646.22	210.78	0.53	0.87	0.08	0.87
AH-19	239.24	225.34	0.98	1.08	0.51	0.54
AH-20	262.85	230.53	1.25	1.30	0.38	0.43
AH-21	193.73	198.27	1.01	1.42	0.57	0.53
AH-22	103.81	132.53	1.50	1.68	1.50	1.54
AH-23	109.10	109.53	1.50	2.06	1.50	1.73
AH-24	218.52	197.61	1.10	1.42	0.50	0.51
AH-25	92.53	88.45	3.61	3.68	0.63	0.92
AH-26	165.42	187.93	1.12	1.22	0.82	0.80
AH-27	95.93	64.69	1.91	2.07	1.50	1.97
AH-28	127.97	122.10	2.94	2.84	0.04	0.43
AH-29	211.23	191.83	1.18	1.47	0.50	0.52
AH-30	222.30	259.50	0.96	1.01	0.44	0.46
AH-31	203.23	250.50	1.06	1.03	0.50	0.52
AH-32	116.97	111.27	3.22	3.12	0.04	0.47
AH-33	80.46	111.47	2.94	2.10	1.50	1.66
AH-34	198.98	176.29	1.51	1.68	0.50	0.53
AH-35	188.50	193.58	1.14	1.34	0.61	0.63
AH-36	96.25	120.11	1.76	1.86	1.50	1.56

Air Handling Unit No.	SF / ton		Total Supply Air [cfm/ SF]		Ventilation Outdoor Air [cfm/ SF]	
	Estimated	As Designed	Estimated	As Designed	Estimated	As Designed
AH-37	308.71	257.46	0.83	1.15	0.30	0.35
AH-38	81.48	106.90	2.73	2.22	1.50	1.64
AH-39	196.12	212.24	0.97	1.09	0.67	0.68
AH-40	379.00	334.12	0.73	0.91	0.22	0.59
AH-41	131.31	131.07	1.67	1.99	0.78	0.86
AH-42	241.28	167.77	0.98	1.64	0.36	0.65
AH-43	157.32	179.74	1.49	1.78	0.56	0.39
AH-44	127.18	119.29	2.46	2.73	0.50	0.60
AH-45	167.34	173.43	1.28	1.49	0.54	0.69
AH-46	143.55	161.09	1.36	1.42	0.84	0.85
AH-47	155.49	155.55	1.51	1.67	0.56	0.74
AH-48	128.87	124.66	2.47	2.57	0.50	0.56
AH-49a	155.79	160.77	1.82	1.87	0.50	0.56
AH-49b	157.17	165.33	1.80	1.82	0.50	0.55
AH-50a	161.21	123.99	1.78	2.39	0.44	0.80
AH-50b	159.98	119.37	1.79	2.48	0.45	0.83
AH-51a	111.77	97.34	1.79	2.33	1.05	1.49
AH-51b	108.76	98.24	1.77	2.07	1.15	1.35
AH-52	172.54	181.84	1.31	1.43	0.55	0.70
AH-53	156.35	126.98	1.81	2.56	0.50	0.64
AH-54	148.31	148.72	1.29	1.64	0.70	0.85
AH-55	129.34	123.84	2.45	2.59	0.50	0.59
AH-56	134.83	149.58	1.42	1.54	0.92	0.92
AH-57	170.53	173.62	1.27	1.49	0.53	0.75
AH-58	159.80	118.84	2.25	2.74	0.50	0.68
AH-59	157.72	156.11	1.23	1.57	0.65	0.90
AH-60	162.63	123.26	1.61	1.99	0.59	1.10
AH-61	332.16	313.50	0.82	1.02	0.19	0.25
CUP AH-1	114.37	105.72	3.08	2.97	0.52	0.52
CUP AH-2	114.37	105.72	3.08	2.97	0.52	0.52
CUP AH-3	170.15	86.16	1.66	2.50	0.36	1.14

The new central plant is being designed to serve both Terminal 3 and Satellite D. In order to provide a clearer understanding of the central plant, the loads for both facilities will be explained in this section. The calculated block cooling load for Terminal 3 and related projects is 9,600 tons. These related projects include a combination Automated Transportation System (ATS) and pedestrian tunnel connecting Terminal 3 and Satellite D, Terminal 3 ATS Station, Satellite D ATS Station, and Satellite D Ramp Tower. This new central plant will also have the capability of serving Satellite D. It is included here as a separate load due to the fact that it can be served by either the new or the existing central plant. The estimated block load for this building is 2,400 tons. The sum of these two block cooling loads is 12,000 tons. A solar diversity factor has already been included in this value to account for the fact that all exposures of the building can not peak at the same time. In addition, a 90% diversity factor is taken on the 12,000 tons block load. Such a factor accounts for load diversities throughout the buildings, and is considered to be normal for central plants of this size. The resulting diversified cooling load to be served by the central plant is 10,800 tons.

The block heating loads for the various buildings are separated in the same manner as the block cooling loads. The calculated block heating load for Terminal 3 and related projects is 76,166,959 Btu/h. The total estimated block heating load for Satellite D is 33,280,000 Btu/h. The sum of these two block heating loads is 109,446,959 Btu/h. Again, a 90% diversity factor is taken on this value to account for load diversities throughout the various buildings. The resulting diversified heating load to be served by the central plant is 98,502,263 Btu/h.

Summary of Waterside Equipment

The following is a description of the waterside equipment included in the design of the new central plant at McCarran International Airport. A more in-depth explanation of the system operation will be included later in this report. This equipment has been sized to satisfy the load requirements listed in the previous section of this report. Schedules of this equipment can be found in Appendix A.

A peak cooling capacity of 11,000 tons will be provided by a variable primary flow chilled water system. This peak capacity is supplied by five 2,200 ton centrifugal chillers. An additional 2,200 ton centrifugal chiller will be provided as standby for a total of six chillers. Three variable flow chilled water pumps are provided to serve the cooling load, with an additional chilled water pump provided as standby. This results in a total of four chilled water pumps. As mentioned earlier, these pumps are horizontal split case to maintain consistency with the existing central plant. The pumping arrangement is such that the chilled water pumps are decoupled from the chillers. Any chilled water pump or group of chilled water pumps can operate with any chiller or group of chillers.

The condensing water system for the central plant will consist of field erected concrete cooling towers. There will be a total of six cells corresponding to the six chillers. Again, five of the cooling towers are provided to serve the cooling load, and one additional cell is provided as standby. The condenser water system is a constant flow system, with five condenser water pumps serving the condenser water load. An additional condenser water pump is provided as standby for a total of six condenser water pumps. Similar to the chilled water pumps and chillers, the condenser water pumps are decoupled from the cooling towers. This will allow for any one condenser water pump or group of condenser water pumps to operate with any one cooling tower or collection of cooling towers. Variable Frequency Drives (VFD's) will be included on the cooling tower fan motors to maintain appropriate condenser water temperatures.

A total of two plate and frame heat exchanges are provided for chilled water return pre-cooling and waterside free cooling. These operating modes are explained in further detail later in this report in the System Schematics and Sequence of Operation section. Since the chilled water return pre-cooling mode will require the use of condenser water at two separate temperatures, the basin is divided by two sluice gates. When closed, these gates create two separate water basins served by different cooling towers.

A peak heating capacity of 105,840,000 Btu/h will be provided by a primary / secondary heating hot water system. This peak capacity is supplied by six 21,000 MBH flexible water tube boilers. The total input capacity of these boilers is 126,000 MBH, and the boilers have an efficiency rating of 84%. The resulting output capacity is therefore 105,840,000 Btu/h. An additional 21,000 MBH input boiler will be provided as standby for a total of seven boilers. The primary heating hot water loop includes six constant flow hot water primary pumps to serve the heating load. An additional hot water primary pump is provided as standby. The secondary heating hot water loop includes three variable flow hot water secondary pumps to serve the heating load. Again, an additional hot water secondary pump is provided as standby. Both primary and secondary hot water pumps will be horizontal split case piped with common headers to allow the operation of any pump with any boiler.

Summary of Airside Equipment

Terminal 3 is served by 88 air handling units, with an additional three units serving the central plant. All of these air handling units are summarized in Table A6, found in Appendix A. This table shows that with the exception of the baggage handling areas, electrical substations, and chiller rooms; all of the spaces have a carbon dioxide monitoring system. Similarly, the air handling units serving the baggage handling areas include a carbon monoxide monitoring system due to the operation of combustion engine driven baggage tugs. Each of these sensors allows for demand controlled ventilation in accordance with ASHRAE Standard 62.1-2007 Section 6.2.7. Almost all air handling units include variable speed drives as well. The exceptions to this are the units serving the electrical substations (AH-62 through AH-85), and those serving the chiller rooms at the central plant (CUP AH-1, CUP AH-2).

The terminal concourses and baggage handling / screening areas are served by a total of 26 Single Zone Variable Air Volume (SZ VAV) units. As mentioned above, these air handling units are equipped with VFD's to allow for a reduction in airflow during periods of reduced occupancy. A total of 37 VAV air handling units are used to serve baggage claim, airline operations, TSA screening, ticketing, and other public areas. The electrical substations are all served by Constant Volume (CV) air handling units. There are a total of 24 CV AHU's to serve the various substations. At the owner's request, IDF / Telecom and other computer rooms are cooled by floor mounted chilled water equipment.

All outside air systems are designed in accordance with ASHRAE Standard 62.1-1999. This air will be filtered through MERV 7 pleated pre-filters, and MERV 13 bag type final filters. The air handling units have also been provided with empty filter sections to allow for the addition of activated carbon / media filters, as well as MERV 7 after filters if desired in the future. This has been the case with other air systems recently designed at McCarran International Airport.

Toilet, concession, and general exhaust will be routed to roof mounted centrifugal exhaust fans. These fans are located a minimum of 20 feet from any outside air intake, and arranged to avoid contamination of outside air intakes. The louvers for the exhaust and relief air are located on the airside potion of the terminal. The outdoor air intakes, however, are located on the landside portion of the terminal to avoid contamination from exhaust air and the operation of jet engines on the airside portion.

Energy Rates and Annual Consumption

Similar to the Design Heating and Cooling Loads section, this portion of the report is also a summary of the analysis performed for Technical Assignment 2 – Building and Plant Energy Analysis Report. Unfortunately, actual energy consumption and operating cost data is not available since Terminal 3 is not yet in operation. As a result, the analysis contained in this report is a result of the load and energy simulation performed in Trane TRACE. As a reminder, this model is the original simulation performed by the mechanical consultant for Terminal 3. A new simulation could not be created for use in this report due to software issues. It is expected that a new simulation will be performed in the future for continued use throughout the thesis project.

It is crucial to note that the mechanical design engineer for Terminal 3 has indicated the load simulation was performed strictly for use in the sizing of mechanical equipment and systems. It was never intended to be used for energy consumption analysis, and must be analyzed with caution. Therefore, please note that the values contained in this section correlate to a maximum operating profile. In other words, this analysis does not take into account a change in load profiles based on varying occupancy levels and equipment use. These details are likely to be taken into account in the new load simulation.

While this energy analysis does not contain actual load schedules, it does take into account the actual utility rates for the building. These rates are shown in Table 5.

Table 5 – Utility Rates

Natural Gas (Southwest Gas Schedule SG-5L)			
Period	Service Charge per Month	Consumption Charge per Therm	Demand Charge per kW
All Periods	$150.00	$1.03450	$0.00
Electric (Nevada Power Schedule LGS-3)			
Period	Service Charge per Month	Consumption Charge per kW	Demand Charge per kW
Summer On-Peak	$254.60	$0.10758	$9.17
Summer Mid-Peak		$0.09410	$0.68
Summer Off-Peak		$0.06987	$0.00
All Other Periods		$0.07163	$0.50

The results of the analysis are summarized in Table 6 – Annual Energy Consumption Summary, and Table 7 – Annual Energy Cost Breakdown. Table 6 shows results in a form that also includes the percentage of total energy consumed by various building equipment. The analysis reports do not display the total energy cost of these individual pieces of equipment; however, the cost has been broken down by utility type. Table 7 shows the total yearly annual cost for the electrical and natural gas consumption of the building. This table also shows the annual cost per square foot of building area for the same utility services.

Table 6 – Annual Energy Consumption Summary

Component	Electrical Consumption (kWh)	Gas Consumption (kBtu)	Total Building Energy (kBtu/yr)	% of Total Building Energy
Primary Heating Boilers and Accessories	188,340	14,666,311	15,309,115	3.5%
Primary Cooling Chillers and Accessories	14,050,719	-	47,955,104	10.9%
Cooling Tower Fans and Pumps	6,593,685	-	22,504,246	5.1%
Supply Air Fans	26,498,022	-	90,437,749	20.5%
Auxiliary Pumps	3,770,557	-	12,868,911	2.9%
Lighting	35,212,764	-	120,181,164	27.2%
Electrical Equipment	38,692,356	-	132,057,011	29.9%
Total	**125,006,443**	**14,666,311**	**441,313,300**	**100.0%**

Table 7 – Annual Energy Cost Breakdown

Utility	Annual Cost [$/yr]	Annual Cost per Square Foot [$/(SF*yr)]
Electricity	$11,586,792	$6.18
Natural Gas	$147,350	$0.08
Total	**$11,734,142**	**$6.26**

Once again, it is important to remember that this analysis is greatly simplified, and far overestimated. Even small changes in the occupancy and equipment use schedules can have major impacts on the overall analysis. It is even believed that the results presented in this section may be incorrect by a full order of magnitude. Obviously, the results listed in this section should not be considered conclusive until a more accurate analysis can be performed.

System Schematics and Sequence of Operation

Chilled Water and Condenser Water System

All chillers, cooling towers, and heat exchangers have associated isolation valves. When a given chiller or cooling tower is energized, the respective isolation valve shall be open. In contrast, when a given chiller or cooling tower is de-energized, the respective isolation valve shall be closed. Similarly, when a heat exchanger is to be in operation, the associated isolation valve shall open. When a heat exchanger is no longer in operation, the isolation valve shall be closed. The plant itself is also provided with valves to isolate it from the remainder of the system. These valves are pneumatic, and controlled locally within the plant. The Building Management System (BMS) is alarmed in the event the plant isolation valves are closed.

The chilled water system is designed with three potential operating modes. These operating modes are controlled by several operating mode system valves as shown in Figure 2 – Chilled Water Schematic, and Figure 3 – Condenser Water Schematic. Table 8 indicates the position of these system valves for the various operating modes.

Mechanical Refrigeration

In this mode, the chillers are operated as required to maintain the plant leaving water temperature setpoint of 42°F. Chilled water pumps are also operated as required to satisfy the chilled water demand. In addition, the cooling towers are staged as required to satisfy the condenser water demand of the chillers. The condenser water supply setpoint is set to 85°F.

Chilled Water Return Pre-Cooling

In this operating mode, chilled water return water (CHR) passes through one or both of the heat exchangers (HX-1, HX-2) prior to entering the chillers. Operation in this mode requires that the sluice gates (SG-1, SG-2) be closed to separate the cooling tower basin into two basins. One portion of the basin makes condenser water for the chillers at a condenser water supply temperature of 52°F, while the other portion makes water as cold as ambient conditions will allow for use in the heat exchangers. The desired condenser water supply temperature for use in the heat exchangers is 38°F. The chillers are utilized in this mode to provide the remaining cooling required on the chilled water that is not performed in the heat exchangers. The portion of the system making condenser water for the chillers includes cooling towers CT-3, CT-4, CT-5, and CT-6; as well as condenser water pumps P-7, P-8, P-9, and P-10. The portion of the system providing colder condenser water for the heat exchangers is served by cooling towers CT-1, and CT-2; as well as condenser water pump P-5, and P-6. No chillers are utilized by this side of the system. Any chiller and any chilled water pump are permitted to operate in this mode.

When seasonal weather permits this mode of operation to be successful, the sluice gates will be manually closed. The condenser water pump headers are also separated, but through automatic control. The condenser water system is now divided into a hot system for use by the chillers, and a cold system for use by the heat exchangers. When the outside air wet bulb temperature falls to 10°F below the chilled water return temperature, the BMS shall index the system to operate in the chilled water return pre-cooling mode. At this time, the isolation valves on both the chilled water and condenser water sides of the heat exchangers are opened. The BMS shall then position system valves as indicated in Table 8. When the cold system condenser water temperature is 2°F less than the chilled water return temperature for duration of five continuous minutes, the BMS places the chilled water system into mechanical refrigeration mode. Once the system valves are positioned to allow for full chilled water return flow to the chillers, the BMS shall close all isolation valves on the heat exchanger.

Waterside Free Cooling

In this mode, all chillers are de-energized. The cooling towers operate in sequence to make water for the heat exchangers that will maintain the plant leaving water temperature setpoint. The condenser water supply setpoint is set to 38°F. Chilled water pumps are again staged as necessary to satisfy the chilled water demand of the system.

Operation in this mode is set when the outside air wet bulb temperature falls to 38°F. At this time, the BMS shall stage off any chillers that are in operation and open the isolation valves on both the chilled water and condenser water sides of the heat exchanger. The BMS shall then position system valves as indicated in Table 8. If the chilled water supply temperature rises to 49°F for five minutes, the BMS shall place the chilled water system into the chilled water pre-cooling mode.

Table 8 – Chilled Water and Condenser Water System Control Valve Matrix

Operation Mode	V-1	V-2	V-3	V-4	V-5	V-6
Mechanical Refrigeration	Open	Closed	Closed	Closed	Open	Open
Chilled Water Return Pre-Cooling	Closed	Open	Closed	Closed	Closed	Closed
Waterside Free Cooling	Closed	Closed	Open	Closed	Open	Open

Figure 2 - Chilled Water Flow Diagram

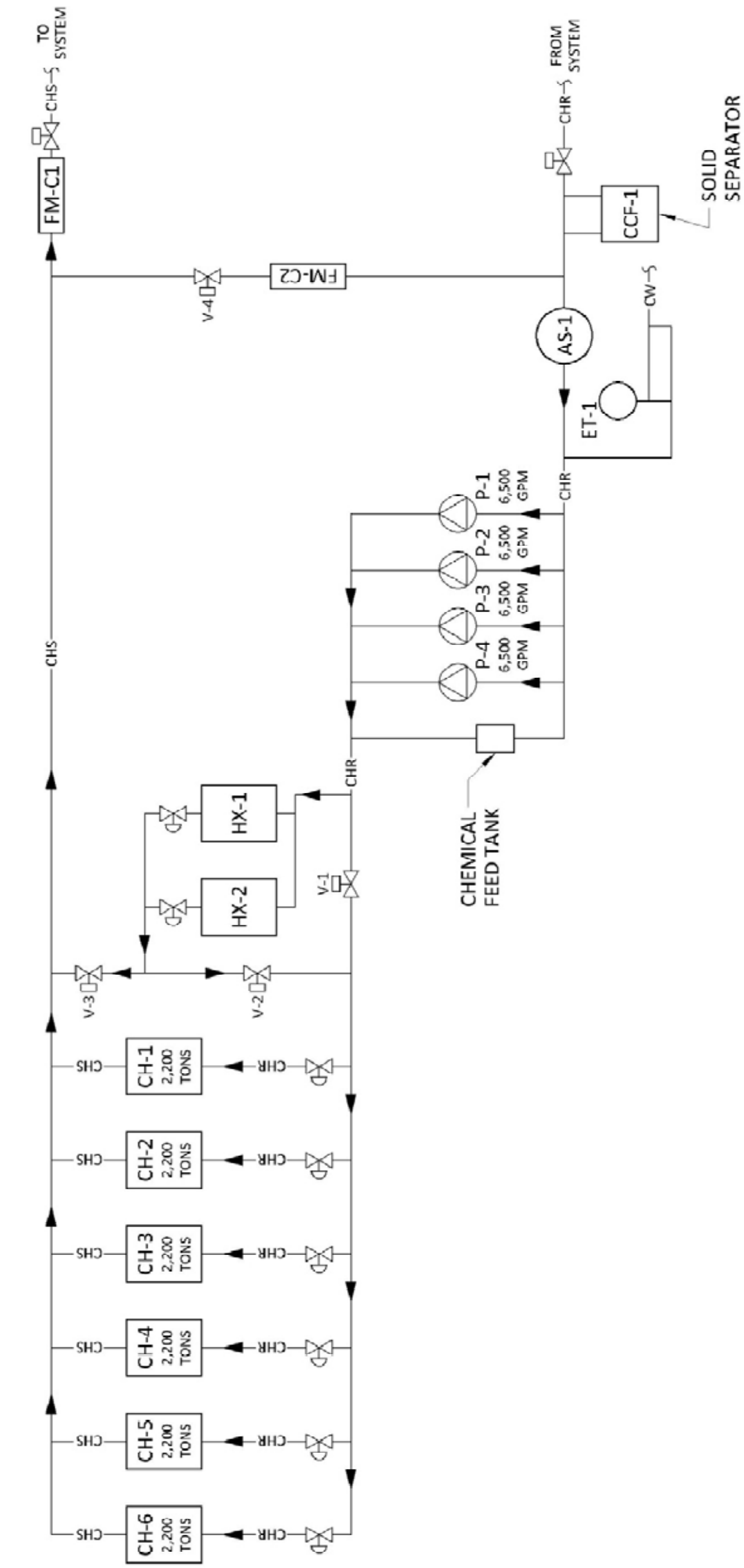
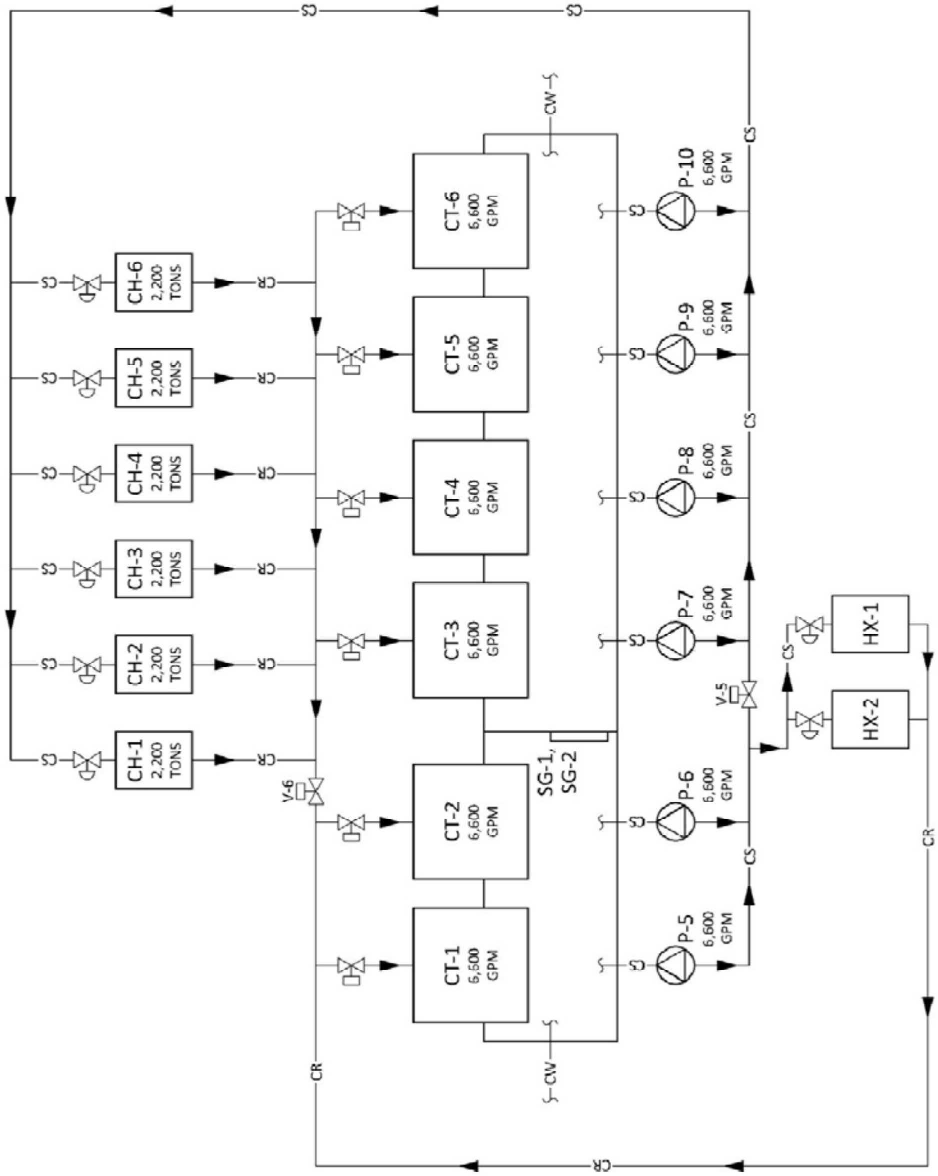


Figure 3 - Condenser Water Flow Diagram



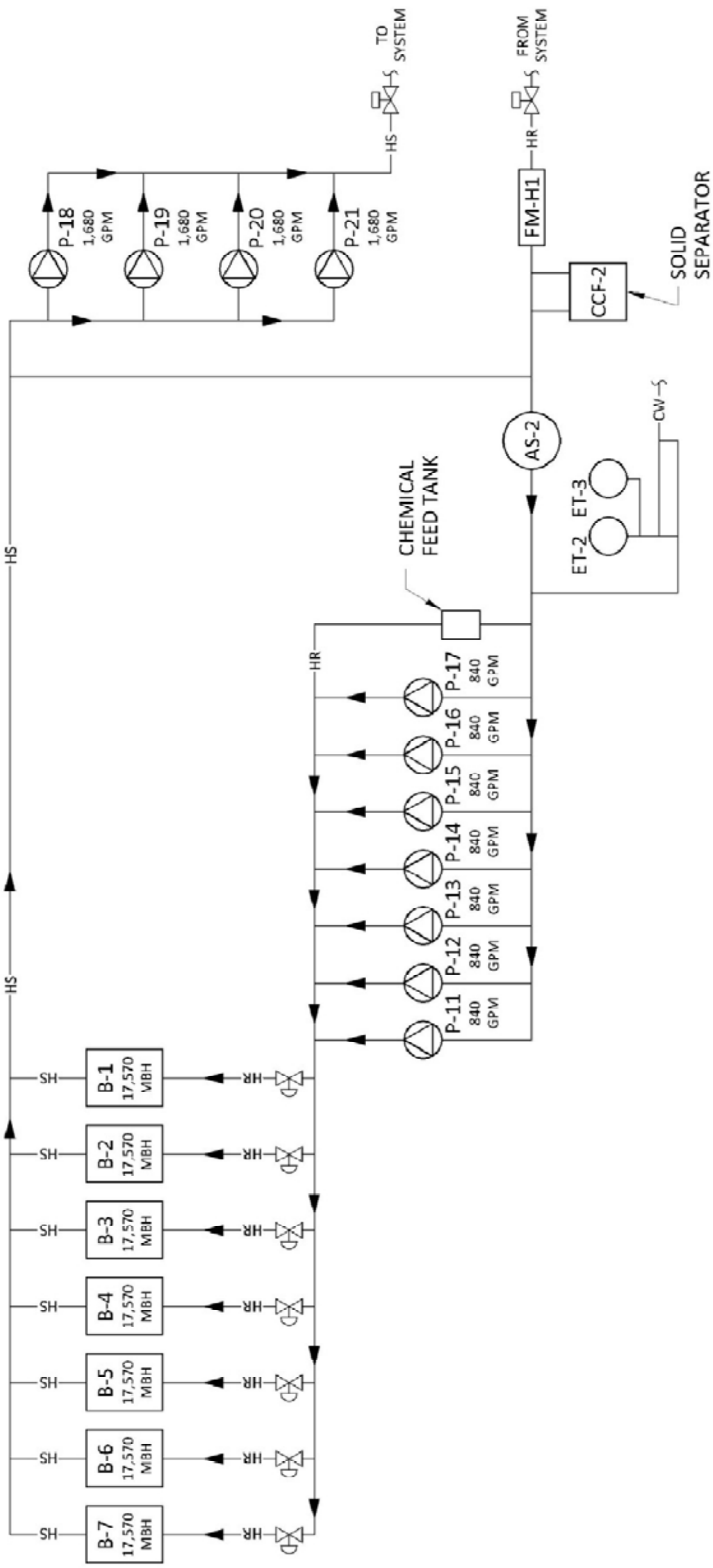


Figure 4 - Heating Hot Water Flow Diagram

Heating Hot Water System

Figure 4 shows the flow diagram for the heating hot water system. Similar to the chilled water system, the equipment on the heating hot water system also has associated isolation valves. When a boiler is energized, the associated isolation valve shall be open. When a boiler is de-energized, the respective isolation valve shall then be closed. The heating hot water system also has plant isolation valves that allow the plant to be isolated from the remainder of the system. These valves are pneumatic, and controlled locally within the plant. A closed plant isolation valve is set to alarm the BMS.

The heating hot water supply temperature setpoint is 200°F. The building heating load demand is determined through the measurement of heating hot water flow rate, as well as supply and return temperatures of the heating hot water. These flow meters are identified on the heating hot water system schematic.

Prior to the heating hot water system being enabled, all equipment isolation valves are closed, all boilers, primary and secondary heating hot water pumps, and direct / indirect evaporative combustion units are off. Once the system is enabled, the BMS enables the direct / indirect evaporative coolers to provide conditioned and filtered make-up air to the boiler room. The VFD's on these evaporative coolers will be controlled by the BMS to provide the required quantity of combustion air based on the number of boilers to be operating. Once this is achieved, the BMS opens the lead boilers heating hot water isolation valve and the lead heating hot water primary pump. Next, the lead heating hot water secondary pump will be energized. The lead boiler will then be enabled to operate based on the factory controller for control of burner operation and firing.

The following process is then executed to stage additional boilers on as required. If the boilers in operation have been on for 20 minutes and the heating hot water supply temperature is 5°F or less below the setpoint for five continuous minutes, then additional boilers shall be staged on. The first step in this process is to open the next-in-line lag boiler isolation valve. Once the valve is proved open, the next-in-line lag heating hot water primary pump is enabled. The next-in-line boiler is then allowed to operate according to its own factory controller.

If the system heating load decreases below the capacity of an online boiler for five continuous minutes, then the following sequence is executed by the BMS. First, the boiler with the highest Total Accumulated Run Time (TART) is disabled. After a two minute time delay, the boiler's associated heating hot water isolation valve will be closed. This delay is included to reduce the stored heat in the boiler.

The secondary heating hot water pumps are varied as required to maintain specified differential pressure on the system. These differential pressure sensors are located in several locations throughout the distribution system, though not shown on the heating hot water system schematic. The BMS monitors these readings, and they are all used to set the plant differential pressure transmitter. This differential pressure transmitter is used to stay below the system high limit. The BMS also allows the lead pump VFD to ramp up or down as required to match the differential pressure setpoint. Lag pumps are then ramped up or down as follows. If the differential pressure drops below setpoint for five minutes, the BMS enables the next-in-line lag pump VFD to ramp up and match the VFD output of the lead pump for two minutes. The BMS ramps all pump VFD's in unison to maintain the differential pressure setpoint. If the differential pressure rises above setpoint for five minutes, the BMS ramps down the lag pump VFD over a 2 minute time period and then disables the VFD. The lead pump VFD, as well as any lag pump VFD's still operating, is then ramped up if necessary to maintain the heating hot water differential pressure setpoint.

Satellite D Tertiary Booster Pumps

Heating hot water and chilled water booster pumps are included to serve Satellite D. These pumps are energized by the BMS only when the facility is being served by the new central plant. Interlocks are provided to prevent the operation of these pumps when the existing Satellite D pumps are already running. Two-position automatic control valves are used to isolate these pumps from the new central plant. The valves require the BMS operator to either open or close them depending on which plant is providing chilled water and heating hot water to Satellite D. These pumps are also controlled to maintain the system differential pressure setpoint. This operation and sequencing is done in the same manner as the existing pumps.

Variable Air Volume (VAV) Air Handling Units

VAV AHU's are energized and de-energized by the BMS, with the supply and return fans starting and stopping in unison. The fans are equipped with VFD's and a speed ramp-up and ramp-down routine to allow for soft start and stop of the fans. These VFD's are controlled by a duct mounted static pressure sensor located ¾ of the way down the most hydraulically remote duct run. This sensor modulates the supply fan VFD to maintain an adjustable static pressure setpoint, with the return fan modulating in unison. If after five minutes of operation, the static pressure reading is less than 0.3 inches of water column, the reading will be considered and error, an alarm will be sent, and the fan speed will be set to 50% of design maximum.

When an air handling unit is de-energized, the outside air and relief air dampers will be closed while the return air and mixed air dampers will be open. Once the unit is energized, the outside air damper modulates to the design cfm setpoint. Outside air, return air, relief air, and mixed air dampers will then modulate as required based on carbon dioxide monitoring and economizer operation. This carbon dioxide monitoring system will modulate the outside air damper position based on carbon dioxide levels in the space. Return air and relief air dampers are then modulated accordingly to ensure that space concentrations do not reach 800 ppm. This carbon dioxide monitoring system is capable of overriding the economizer operation.

The economizer operation modulates the outside air damper position to maintain space temperature setpoint before the cooling coil is operated. If the outside air temperature is less than the return air temperature, the economizer operation will be enabled and will modulate all dampers as required to maintain space temperature setpoint. If the outside air temperature is greater than the return air temperature, or if the outside air temperature is less than 40°F, then the outside air damper will modulate to its minimum position of 30% design outdoor air flow.

Chilled water and heating hot water valves are two-way modulating valves used to maintain unit discharge temperature setpoint as scheduled. An interlock is included to prevent the operation of both coils at the same time. When the unit is off, the valves are in the closed position. Similarly, loss of power to the unit will modulate both valves to the closed position. The discharge temperature sensor serves as the low temperature controller, and alarms the BMS if the supply air temperature falls below 40°F. In multi-zone systems, the discharge air temperature will be reset by the zone requiring the most cooling. Once the coolest zone temperature drops from setpoint to 2°F below setpoint, the discharge air temperature is reset upwards from 55°F to 65°F.

Cooling Only VAV Terminal Boxes

Pressure independent VAV boxes are energized and de-energized by the BMS. The space temperature sensor modulates the VAV box damper to maintain space temperature setpoint. The box minimum damper position is 30% of the maximum indicated supply airflow.

Cooling and Heating VAV Terminal Boxes

These are also pressure independent VAV boxes that are energized and de-energized by the BMS. The space temperature sensor modulates both the VAV box damper and the two-way modulating heating hot water control valve to maintain the space temperature setpoint. The box minimum damper position is now 50% of the maximum indicated supply airflow. If space temperature drops below setpoint, the box damper begins to close and continues to close until reaching the minimum damper position. The heating hot water control valve remains closed. If the space temperature continues to drop from setpoint, the heating hot water control valve modulates open to maintain space temperature setpoint. A few of the terminal boxes are programmed as constant air volume. In these instances, the space temperature setpoint is maintained solely through modulation of the heating hot water control valve. In either instance, a loss of power causes the heating hot water control valve to fail to the closed position.

Constant Volume (CV) Air Handling Units

These CV AHU's are energized and de-energized through the BMS. During an occupied period, the supply fan runs continuously, and the chilled water and heating hot water control valves modulate to maintain the space temperature setpoint. When the unit is in unoccupied mode, the fans are de-energized, and the control valves are closed. Upon loss of power, the chilled water control valve fails to the open position. This ensures necessary cooling is provided for the equipment located in rooms served by these units.

Direct / Indirect Evaporative Coolers

These units are also energized and de-energized through the BMS. The supply fan on these units is controlled to maintain sufficient combustion air for the boilers at the central plant. When the boilers are in operation, the fan speed is modulated only during the staging on or off of boilers. The fan speed is not modulated for space temperature control when the boilers are in operation. When the unit is energized, the outside air damper is open. If the unit is de-energized, the outside air damper is closed.

The two stages of cooling are enabled based on the space temperature relative to the setpoint. The first stage is the operation of the indirect evaporative cooling section, and the second stage is the use of the direct evaporative cooling section. The cooling sections are de-energized when the outside air temperature is below 60°F. Water sumps are automatically drained when the outside air temperature falls below 50°F. In heating mode, the two-way modulating heating hot water valve is used to maintain unit discharge temperature setpoint. An interlock is provided to ensure that the cooling and heating modes can not be operated at the same time. When the unit is off, the heating hot water valve is closed. Similarly, a loss of power to the unit will cause the valve to fail to the closed position.

These units are interlocked with the boilers and heating hot water system. Interlocks are provided to control VFD's on supply fans to ensure sufficient combustion air to the boilers based on boiler staging. The BMS energizes the direct / indirect evaporative coolers, or increases VFD setpoint if units are already operating, prior to staging on another boiler. The BMS does not step down the fan speed until after a boiler has been staged off and the shutdown cycle of the boiler has been completed.

Exhaust Fans

Toilet exhaust and break room exhaust fans are energized and de-energized by the BMS. During an occupied period, the associated two-position damper is open and the fan runs continuously. During unoccupied periods, the damper is closed and the fan is off.

Refrigerant leak monitoring exhaust fans in the central plant are provided for the refrigerant storage room, as well as the chiller room and pump gallery. These fans operate continuously to provide pressure differential from adjacent spaces as required by code.

System Critique

Overall, the mechanical system design of Terminal 3 seems appropriate for such a facility. As stated earlier, occupant comfort and satisfaction were major considerations taken into account in the design. Of particular interest is the use of higher outdoor air conditions than those listed in ASHRAE. This consideration will help to ensure that the peak building load can be met, even during periods of high occupancy. Unfortunately, this also has a negative impact on cost since the capacity of the equipment is increased to meet this higher load. Again, given the use of the facility, most would consider this trade-off to be worth the increased cost.

In addition to a high level of thermal comfort, Terminal 3 seems to also be carefully designed from an indoor air quality perspective. Confirmation of this was made in Technical Assignment 1 – ASHRAE Standard 62.1-2007 Ventilation Compliance Summary. This report indicated that all air handling units, except those serving the electrical substations, provided necessary outdoor airflow rates in accordance with ASHRAE Standard 62.1-2007. Furthermore, all of the air handling units serving occupied areas are equipped with either carbon dioxide or carbon monoxide sensors. These sensors ensure that the proper quantity of outdoor airflow is being provided, and allow for a reduction in outside airflow when the occupant density is not at a maximum level. While this seems to be a concept that is capable of reducing energy costs related to higher outdoor air fractions, there are also potential issues associated with it. Pollutants in a building can be a result of more than just the occupants of the building. They can be a result of the materials in the building itself. That being said, consideration must be given as to whether or not demand controlled ventilation is properly utilized in Terminal 3.

The mechanical system design also seems to take into account the owner's request related to ease of maintenance. While there is some variation between the existing and the new central plants, they are mostly similar. This certainly helps to make the maintenance process easier as the operations and maintenance staff has experience with similar equipment. While the use of innovative technologies may have certain benefits, they are often unfamiliar to the operations and maintenance staff. This creates the potential for incorrect operation and maintenance, so such technologies must be carefully considered before being implemented into a design. In the case of Terminal 3, some consideration was given to alternative technologies, but the Department of Aviation was not interested in incorporating them.

The central plant is also well designed for a plant of such a size. The use of a variable primary flow chilled water system will likely allow for savings in plant energy, as well as pump energy. Given the size of the plant, these savings can potentially become quite large. In contrast, the operation of a variable primary flow chilled water system is considered to be more complicated than operation of a primary / secondary chilled water system. However, this is assumed to not be an issue since the existing central plant at McCarran International Airport also uses a variable primary flow chilled water system, and has been operated without major issues. Additionally, the chilled water pre-cooling and waterside free cooling modes of the chilled water system help to create a more flexible and efficient system than one consisting solely of mechanical refrigeration.

It is also worthwhile to note that mechanical system equipment is quite efficient as demonstrated in Technical Assignment 2 – Building and Plant Energy Analysis Report. This report shows that equipment meets the minimum efficiency requirements listed in ASHRAE Standard 90.1-2004. Furthermore, variable frequency drives are used where appropriate to ensure efficient operation of fans and pumps throughout the terminal and associated central plant. These VFD's have an increased first cost, but will likely provide significant savings in annual operating cost.

In conclusion, the existing mechanical system for Terminal 3 seems to be well suited for the building and the owner. However, energy consumption is still a concern that could be potentially reduced with alternative systems. There are significant operating costs associated with a plant of this size, so investigation into reducing these costs through a more efficient system would have obvious advantages. From an airside standpoint, the use of under floor air distribution may help to create an even more enjoyable indoor environment for areas of high occupant density. This type of design would also help to reduce energy consumption in these spaces. Other alternatives to the demand controlled ventilation system should also be considered to determine the best technology for providing a healthy indoor environment.

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Appendix A – Equipment Schedules

The following tables provide information for equipment referenced in the Summary of Waterside Equipment and Summary of Airside Equipment sections. A further description of this equipment can be found in these sections.

Table A1 – Centrifugal Chiller Schedule

Item	Refrigerant	Capacity	Chilled Water				Condenser Water			kW/Ton at Design	NPLV
			EWT	LWT	Design Flow	Max / Min Flow	EWT	LWT	Design Flow		
CH-1, 2, 3, 4, 5, 6	R-134a	2,200 Tons	58 °F	42 °F	3,300 gpm	4,500 / 2,500 gpm	85 °F	95 °F	6,600 gpm	0.574	0.482

Table A2 – Cooling Tower Schedule

Item	Type	EWT	LWT	Flow	Ambient Wet Bulb	Fan Type	Fan HP
CT-1, 2, 3, 4, 5, 6	Induced Draft Cross Flow	95 °F	85 °F	6,600 gpm	77 °F	Variable Speed Propeller	75

Table A3 – Heat Exchanger Schedule

Item	Type	System Side				Condenser Water			
		EWT	LWT	Flow	Fluid	EWT	LWT	Flow	Fluid
HX-1, 2	Plate and Frame	57 °F	49 °F	6,600 gpm	Water	47 °F	55 °F	6,600 gpm	Water

Table A4 – Heating Hot Water Boiler Schedule

Item	Fuel	Input	Efficiency	Output	Flow	HWS Temp.	Working Pressure
B-1, 2, 3, 4, 5, 6, 7	Natural Gas	20,670 MBH	84%	17,570 MBH	840 gpm	200 °F	160 psig

Table A5 – Pump Schedule

Item	Service	Type	Fluid, Temp. Range	Flow (gpm)	Flow	Head (ft)	RPM	Min. HP	Efficiency
P-1, 2 , 3, 4	Chilled Water	Horizontal Split Case	Water, 40 °F - 60°F	6,500	Variable	250	1750	500	85%
P-5, 6, 7, 8, 9, 10	Condenser Water	Horizontal Split Case	Water, 50 °F - 100°F	6,600	Constant	100	1200	250	87%
P-11, 12, 13, 14, 15, 16, 17	Heating Hot Water - Primary	Horizontal Split Case	Water, 100 °F - 200°F	840	Constant	50	1750	15	76%
P-18, 19, 20, 21	Heating Hot Water - Secondary	Horizontal Split Case	Water, 100 °F - 200°F	1,680	Variable	170	1750	100	82%

Table A6 – Air Handling Unit Schedule

Air Handling Unit No.	Service	Type	Heating Coil					Cooling Coil							Total Supply Air	Design Outside Air	Carbon Monoxide Sensor	Carbon Dioxide Sensor
			Airside		Waterside			Airside				Waterside						
			EAT [°F]	LAT [°F]	EWT [°F]	LWT [°F]	Flow [gpm]	EAT [°F] DB	EAT [°F] WB	LAT [°F] DB	LAT [°F] WB	EWT [°F]	LWT [°F]	Flow [gpm]				
AH-1	00 Level - Baggage Claim	VAV	51	95	200	150	70	93	67	51.5	51.2	45	63	191	40,000	16,000	--	X
AH-2	01 Level - Building Services / Airline Ops	VAV	59	95	200	150	29	87	65	51.3	51.1	45	63	83	20,000	5,000	--	X
AH-3	01 Level - Inbound / Outbound Baggage	SZ VAV	24	95	200	150	102	112	73	56.1	54.3	45	63	217	36,000	32,000	X	--
AH-4	01 Level - Inbound / Outbound Baggage	SZ VAV	28	95	200	150	94	109	72	56.1	54.2	45	63	199	35,000	28,000	X	--
AH-5	00 Level - Baggage Claim	VAV	51	95	200	150	70	93	67	21.5	51.2	45	63	191	40,000	16,000	--	X
AH-6	00 Level - Landside Concourse	SZ VAV	59	95	200	150	43	87	65	51.4	51.2	45	63	124	30,000	7,500	--	X
AH-7	01 Level - Inbound / Outbound Baggage	SZ VAV	27	95	200	150	99	109	73	56.5	54.8	45	63	214	36,000	30,000	X	--
AH-8	00 Level - Baggage Claim	VAV	49	95	200	150	73	94	68	51.2	51.1	45	63	206	40,000	17,500	--	X
AH-9	00 Level - Landside Concourse	SZ VAV	56	95	200	150	47	90	66	51.3	51.1	45	63	135	30,000	9,500	--	X
AH-10	01 Level - Inbound / Outbound Baggage	SZ VAV	30	95	200	150	91	106	72	56.5	54.8	45	63	195	35,000	26,000	X	--
AH-11	01 Level - Storage / Airline Ops	VAV	63	95	200	150	38	84	64	51.5	51.3	45	63	114	30,000	5,000	--	X
AH-12	00 Level - Baggage Claim	VAV	50	95	200	150	72	94	67	51.3	51	45	63	193	40,000	17,000	--	X
AH-13	00 Level - Baggage Claim	VAV	51	95	200	150	70	93	67	51.5	51.2	45	63	191	40,000	16,000	--	X
AH-14	01 Level - TSA Bag Screening	SZ VAV	64	95	200	150	50	84	64	51.3	51	45	63	154	40,000	6,000	--	X

Air Handling Unit No.	Service	Type	Heating Coil					Cooling Coil							Total Supply Air	Design Outside Air	Carbon Monoxide Sensor	Carbon Dioxide Sensor
			Airside		Waterside			Airside				Waterside						
			EAT [°F]	LAT [°F]	EWT [°F]	LWT [°F]	Flow [gpm]	EAT [°F] DB	EAT [°F] WB	LAT [°F] DB	LAT [°F] WB	EWT [°F]	LWT [°F]	Flow [gpm]				
AH-15	00 Level - Landside Concourse	SZ VAV	51	95	200	150	62	93	67	51.1	50.9	45	63	170	35,000	14,500	--	X
AH-16	01 Level - TSA Bag Screening	SZ VAV	64	95	200	150	50	84	64	51.3	51	45	63	154	40,000	6,000	--	X
AH-17	00 Level - Baggage Claim / Concessions	VAV	47	95	200	150	78	96	68	51.3	50.9	45	63	206	40,000	19,500	--	X
AH-18	0B Level - ATS Maintenance	VAV	27	95	200	150	109	115	74	51.5	51.2	45	63	287	40,000	40,000	--	X
AH-19	00 Level - ATS T3 Station	VAV	46	95	200	150	78	97	68	51.3	50.9	45	63	206	40,000	20,000	--	X
AH-20	00 Level - ATS North Pedestrian Tunnel	SZ VAV	55	95	200	150	24	90	66	51.5	51.2	45	63	67	15,000	5,000	--	X
AH-21	00 Level - TSA Screening, 01 Level Maintenance	VAV	53	95	200	150	68	92	67	51.7	51.4	45	63	190	40,000	15,000	--	X
AH-22	01 Level - Inbound / Outbound Baggage	SZ VAV	23	95	200	150	72	112	73	56.3	54.4	45	63	150	25,000	23,000	X	--
AH-23	01 Level - Inbound / Outbound Baggage	SZ VAV	27	95	200	150	69	110	73	56.6	54.8	45	63	148	25,000	21,000	X	--
AH-24	00 Level - Landside Concourse	SZ VAV	53	95	200	150	58	91	67	51.5	51.4	45	63	166	35,000	12,500	--	X
AH-25	00 Level - TSA Screening	VAV	59	95	200	150	58	87	65	51.6	51.3	45	63	164	40,000	10,000	--	X
AH-26	00 Level - TSA Queue	VAV	38	95	200	150	91	102	70	51.5	51.2	45	63	232	40,000	26,000	--	X
AH-27	01 Level - Maintenance	VAV	23	95	200	150	58	113	73	51.7	51.3	45	63	136	20,000	19,000	X	--
AH-28	01 Level - TSA Bag Screening	SZ VAV	64	95	200	150	50	84	64	51.3	51	45	63	154	40,000	6,000	--	X
AH-29	00 Level - Landside Concourse	SZ VAV	53	95	200	150	58	91	67	51.5	51.4	45	63	166	35,000	12,500	--	X

Air Handling Unit No.	Service	Type	Heating Coil					Cooling Coil							Total Supply Air	Design Outside Air	Carbon Monoxide Sensor	Carbon Dioxide Sensor
			Airside		Waterside			Airside				Waterside						
			EAT [°F]	LAT [°F]	EWT [°F]	LWT [°F]	Flow [gpm]	EAT [°F] DB	EAT [°F] WB	LAT [°F] DB	LAT [°F] WB	EWT [°F]	LWT [°F]	Flow [gpm]				
AH-30	00 Level - Baggage Claim	VAV	49	95	200	150	74	95	68	51.7	51.4	45	63	203	40,000	18,000	--	X
AH-31	00 Level - Baggage Claim	VAV	46	95	200	150	78	97	68	51.3	50.9	45	63	206	40,000	20,000	--	X
AH-32	01 Level - TSA Bag Screening	SZ VAV	64	95	200	150	50	84	64	51.3	51	45	63	154	40,000	6,000	--	X
AH-33	01 Level - Inbound / Outbound Baggage	SZ VAV	28	95	200	150	97	108	72	56	54.3	45	63	205	36,000	28,500	X	--
AH-34	00 Level - Landside Concourse	SZ VAV	56	95	200	150	55	90	66	51.3	51	45	63	158	35,000	11,000	--	X
AH-35	00 Level - Customs and Border Patrol	VAV	48	95	200	150	67	95	68	51.2	51.1	45	63	180	35,000	16,500	--	X
AH-36	01 Level - Inbound / Outbound Baggage	SZ VAV	27	95	200	150	110	110	73	56.4	54.6	45	63	239	40,000	33,500	X	--
AH-37	00 Level - Customs and Border Patrol	VAV	56	95	200	150	62	89	66	51.2	51	45	63	180	40,000	12,000	--	X
AH-38	01 Level - Inbound / Outbound Baggage	SZ VAV	31	95	200	150	93	106	72	56.3	54.6	45	63	202	36,000	26,500	X	--
AH-39	00 Level - Customs and Border Patrol	VAV	40	95	200	150	89	101	70	51.7	51.4	45	63	231	40,000	25,000	--	X
AH-40	01 Level - Airline Operations	VAV	57	95	200	150	38	88	66	51.8	51.5	45	63	110	25,000	7,000	--	X
AH-41	02 Level - Airside Concourse, Gate 14 & Gate 15	VAV	50	95	200	150	55	94	68	51.5	51.4	45	63	153	30,000	13,000	--	X
AH-42	02 Level - DOA Back of House	VAV	51	95	200	150	61	93	67	51.1	50.9	45	63	170	35,000	14,000	--	X
AH-43	02 Level - Airside Concourse, Gate 11 & Gate 12	VAV	48	95	200	150	86	95	68	51	51	45	63	209	45,000	21,000	--	X

Air Handling Unit No.	Service	Type	Heating Coil					Cooling Coil							Total Supply Air	Design Outside Air	Carbon Monoxide Sensor	Carbon Dioxide Sensor
			Airside		Waterside			Airside				Waterside						
			EAT [°F]	LAT [°F]	EWT [°F]	LWT [°F]	Flow [gpm]	EAT [°F] DB	EAT [°F] WB	LAT [°F] DB	LAT [°F] WB	EWT [°F]	LWT [°F]	Flow [gpm]				
AH-44	02 Level - Landside Concourse	SZ VAV	61	95	200	150	69	86	65	51.6	51.3	45	63	205	50,000	11,000	--	X
AH-45	02 Level - Airside Concourse, Gate 10	VAV	48	95	200	150	94	95	68	51.2	51	45	63	258	50,000	23,000	--	X
AH-46	02 Level - Ticketing (West)	VAV	41	95	200	150	108	100	70	51.3	51.1	45	63	291	50,000	30,000	--	X
AH-47	02 Level - Airside Concourse, Gate 8 & Gate 9	VAV	49	95	200	150	92	94	68	51.4	51.2	45	63	256	40,000	22,000	--	X
AH-48	02 Level - Landside Concourse	SZ VAV	61	95	200	150	76	86	65	51.2	51.1	45	63	229	55,000	12,000	--	X
AH-49a	02 Level - Landside Concourse	SZ VAV	56	95	200	150	39	90	66	51.5	51.3	45	63	111	25,000	7,500	--	X
AH-49b	02 Level - Landside Concourse	SZ VAV	56	95	200	150	39	90	66	51.5	51.3	45	63	111	25,000	7,500	--	X
AH-50a	02 Level - Airside Concourse, TSA Screening (West)	VAV	55	95	200	150	48	90	66	51.3	51.1	45	63	135	30,000	10,000	--	X
AH-50b	02 Level - Airside Concourse, TSA Screening (East)	VAV	55	95	200	150	48	90	66	51.3	51.1	45	63	135	30,000	10,000	--	X
AH-51a	02 Level - TSA Queue (West)	VAV	39	95	200	150	56	102	70	51	51	45	63	147	25,000	16,000	--	X
AH-51b	02 Level - TSA Queue (East)	VAV	31	95	200	150	64	107	72	51.2	51	45	63	196	30,000	19,500	--	X
AH-52	02 Level - VIP Lounge, Gate 6 & Gate 7	VAV	47	95	200	150	107	96	68	51.4	51	45	63	283	55,000	27,000	--	X
AH-53	02 Level - Landside Concourse	SZ VAV	59	95	200	150	58	87	65	51.6	51.3	45	63	164	40,000	10,000	--	X

Air Handling Unit No.	Service	Type	Heating Coil					Cooling Coil							Total Supply Air	Design Outside Air	Carbon Monoxide Sensor	Carbon Dioxide Sensor
			Airside		Waterside			Airside				Waterside						
			EAT [°F]	LAT [°F]	EWT [°F]	LWT [°F]	Flow [gpm]	EAT [°F] DB	EAT [°F] WB	LAT [°F] DB	LAT [°F] WB	EWT [°F]	LWT [°F]	Flow [gpm]				
AH-54	02 Level - Airside Concourse, Gate 4 & Gate 5	VAV	45	95	200	150	100	97	69	51.4	51.2	45	63	273	50,000	26,000	--	X
AH-55	02 Level - Landside Concourse	SZ VAV	60	95	200	150	77	86	65	51.2	51.1	45	63	229	55,000	12,500	--	X
AH-56	02 Level - Ticketing (East)	VAV	41	95	200	150	98	100	70	51.4	51.3	45	63	261	45,000	27,000	--	X
AH-57	02 Level - Airside Concourse, Gate 3	VAV	46	95	200	150	78	97	68	51.3	50.9	45	63	206	40,000	20,000	--	X
AH-58	02 Level - Landside Concourse	SZ VAV	59	95	200	150	58	87	65	51.6	51.3	45	63	164	40,000	10,000	--	X
AH-59	02 Level - Airside Concourse, Gate 2	VAV	42	95	200	150	85	99	69	51.5	51.2	45	63	218	40,000	23,000	--	X
AH-60	02 Level - Airside Concourse, Gate 1	VAV	43	95	200	150	83	98	69	51.7	51.4	45	63	217	40,000	22,000	--	X
AH-61	02 Level - Metro Substation	VAV	56	95	200	150	36	87	65	51.4	51.1	45	63	104	25,000	6,000	--	X
AH-62	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-63	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-64	Electrical Substation	CV	--	--	--	--	--	85	63	54.6	51.9	45	63	16	5,000	--	--	--
AH-65	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-66	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-67	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-68	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-69	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-70	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-71	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--

Air Handling Unit No.	Service	Type	Heating Coil					Cooling Coil							Total Supply Air	Design Outside Air	Carbon Monoxide Sensor	Carbon Dioxide Sensor
			Airside		Waterside			Airside				Waterside						
			EAT [°F]	LAT [°F]	EWT [°F]	LWT [°F]	Flow [gpm]	EAT [°F] DB	EAT [°F] WB	LAT [°F] DB	LAT [°F] WB	EWT [°F]	LWT [°F]	Flow [gpm]				
AH-72	Electrical Substation	CV	--	--	--	--	--	85	63	54.6	51.9	45	63	16	5,000	--	--	--
AH-73	Electrical Substation	CV	--	--	--	--	--	85	63	54.6	51.9	45	63	16	5,000	--	--	--
AH-74	Electrical Substation	CV	--	--	--	--	--	85	63	54.6	51.9	45	63	16	5,000	--	--	--
AH-75	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-76	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-77	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-78	Electrical Substation	CV	--	--	--	--	--	85	63	54.6	51.9	45	63	16	5,000	--	--	--
AH-79	Electrical Substation	CV	--	--	--	--	--	85	63	54.6	51.9	45	63	16	5,000	--	--	--
AH-80	Electrical Substation	CV	--	--	--	--	--	85	63	54.6	51.9	45	63	16	5,000	--	--	--
AH-81	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-82	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-83	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-84	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
AH-85	Electrical Substation	CV	--	--	--	--	--	85	63	54.2	51.7	45	63	13	4,000	--	--	--
CUP AH-1	Chiller Room	CV	60	95	200	150	28	85	65.5	52.3	51.6	45	63	85	20,000	3,500	--	--
CUP AH-2	Chiller Room	CV	60	95	200	150	28	85	65.5	52.3	51.6	45	63	85	20,000	3,500	--	--
CUP AH-3	Upper Level Offices	VAV	51.5	95	200	150	20	96.7	67.7	52.1	46.7	45	63	68	11,000	5,000	--	X