Central
Washington
University

CAPITAL PROJECT PROPOSALS 2021-2023

1200 Ton Chiller Addition

Infrastructure – Stand Alone

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CAPITAL PROJECT PROPOSALS 2021-23

1200 Ton Chiller Addition

Infrastructure – Stand Alone

Please direct questions about this proposal to:
Steve DuPont, CWU Director of Government Relations
509-201-0528

August 15, 2020

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Central
Washington
University

CAPITAL PROJECT PROPOSALS 2021-23

1200 Ton Chiller Addition
Infrastructure – Stand Alone

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2020 PROJECT PROPOSAL CHECKLIST

2021-23 Biennium Four-year Higher Education Scoring Process

INSTITUTION	CAMPUS LOCATION
375 - Central Washington University	Ellensburg Washington
PROJECT TITLE	**FPMT UNIQUE FACILITY ID # (OR NA)**
1200 Ton Chiller Addition	NA
PROJECT CATEGORY	**PROJECT SUBCATEGORY**
Infrastructure	Standalone
PROPOSAL IS	
New or Updated Proposal (for scoring)	**Resubmitted Proposal (retain prior score)**
☐ New proposal ☐ Resubmittal to be scored (more than 2 biennia old or significantly changed)	☐ Resubmittal from 2017-19 biennium ☒ Resubmittal from 2019-21 biennium
CONTACT	**PHONE NUMBER**
Steve Dupont	Steve.dupont@cwu.edu / 509-201-0528

PROPOSAL CONTENT

- ☒ Project Proposal Checklist: this form; one for each proposal
- ☒ Project Proposal Form: Specific to category/subcategory (10-page limit)
- ☒ Appendices: templates, forms, exhibits and supporting/supplemental documentation for scoring.

INSTITUTIONAL PRIORITY

- ☒ Institutional Priority Form. Sent separately (not in this packet) to: Darrell Jennings.

Check the corresponding boxes below if the proposed project meets the minimum threshold or if the item listed is provided in the proposal submittal.

MINIMUM THRESHOLDS

- ☒ Project is not an exclusive enterprise function such as a bookstore, dormitory or contract food service.
- ☒ Project meets LEED Silver Standard requirements.
- ☒ Institution has a greenhouse gas emissions reduction policy in place in accordance with RCW 70.235.070 and vehicle emissions reduction policy in place per RCW 47.01.440 or RCW 43.160.020 as applicable.
- ☐ Design proposals: A complete predesign study was submitted to OFM by July 1, 2020.
- ☐ Growth proposals: Based on solid enrollment projections and is more cost-effectively providing enrollment access than alternatives such as university centers and distance learning.
- ☐ Renovation proposals: Project should cost between 60 – 80% of current replacement value and extend the useful life of the facility by at least 25 years.
- ☐ Acquisition proposals: Land acquisition is not related to a current facility funding request.
- ☒ Infrastructure proposals: Project is not a facility repair project.
- ☐ Stand-alone, infrastructure and acquisition proposals: is a single project requesting funds for one biennium.

2020 PROJECT PROPOSAL CHECKLIST

2021-23 Biennium Four-year Higher Education Scoring Process

REQUIRED APPENDICES

☒ Capital Project Report CBS 002

☒ Project cost estimate:

- CBS 003 for projects between $2 million and $5 million
- Excel C-100 for projects greater than $5 million

☐ Degree Totals and Targets template to indicate the number of Bachelors, High Demand and Advanced degrees expected to be awarded in 2021. (Required for Overarching Criteria scoring criteria for Major Growth, Renovation, Replacement and Research proposals).

☐ Availability of Space/Campus Utilization template for the campus where the project is located. (Required for all categories/subcategories except Infrastructure and Acquisition proposals).

☐ Assignable Square Feet template to indicate program-related space allocation. (Required for Growth, Renovation and Replacement proposals, all categories/subcategories).

OPTIONAL APPENDICES

Attach supplemental and supporting project documentation, *limit to materials directly related to and needed for the evaluation criteria*, such as:

☐ Degree and enrollment growth projections

☒ Selected excerpts from institutional plans

☐ Data on instructional and/or research space utilization

☐ Additional documentation for selected cost comparables (acquisition)

☐ Selected materials on facility conditions

☐ Selected materials on code compliance

☐ Tables supporting calculation of program space allocations, weighted average facility age, etc.

☐ Evidence of consistency of proposed research projects with state, regional, or local economic development plans

☐ Evidence of availability of non-state matching funds

☐ Selected documentation of prior facility failures, high cost maintenance, and/or system unreliability for infrastructure projects

☐ Documentation of professional assessment of costs for land acquisition, land cleanup, and infrastructure projects

☒ Selected documentation of engineering studies, site survey and recommendations, or opinion letters for infrastructure and land cleanup projects

☐ Other: Click or tap here to enter text.

I certify that the above checked items indicate either that the proposed project meets the minimum thresholds or the corresponding items have been included in this submittal.

Name: Delano Palmer

Title: Director of Capital Planning & Projects

Signature: Click or tap here to enter text.

Date: 8/14/20 Click or tap here to enter text.

Office of Financial Management

Revised: June 2020

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INSTITUTION	CAMPUS
Central Washington University	Ellensburg
PROJECT TITLE	
1200 Ton Chiller Addition	

SUMMARY NARRATIVE

1. Problem Statement

Central Washington University will not have enough cooling capacity when the Health Sciences building is complete in the fall of 2021Chillers at the physical plant make it possible to cool computer systems and maintain comfortable temperatures in classrooms, labs, and offices. However, with the addition of the Health Sciences Building, all of the six large high-traffic buildings on the same distribution line will not be able to be cooled during hot weather periods. The ability to maintain constant cool temperatures is absolutely critical to ensuring the functionality of sensitive lab instruments and the viability of research—undergraduate and graduate. The Health Sciences programs focus on human body systems, all of which are affected by ambient temperatures. As well, research involves lab samples, including blood, tissue and other biological samples sensitive to temperatures.

The project promotes the reliability and securing of institutional cooling. Currently, mechanical failures during a peak-demand period would require one third of the current cooling capacity (one of three coolers) to be taken offline for repairs. Adding a fourth creates capacity to absorb the cooling load in the event of a system failure.

In 2012, CWU commissioned the Abacus Load Impact Study (Appendix D), which indicated the need for an additional chiller once Discovery Hall ("Science II") and Samuelson Hall became occupied, and before the completion of the new Health Sciences building. Discovery Hall was occupied in 2013 and Samuelson in 2017. CWU has requested state funding for chillers, but, lacking funding, none has been added to the system during that period. Cooling capacity is now being stretched to its maximum and has no redundancy in the case of a failure.

Ellensburg is located directly in the Cascade rain shadow and experiences very hot weather from the spring through fall; outdoor temperatures can exceed 100 degrees from May through September. Unlike the mild weather in Western Washington, air conditioning is a necessity for day-to-day operations.

One chiller is more than 20 years old and nearing the end of its useful life. It experiences mechanical failures more frequently and must be taken offline for costly repairs several times a year. With the chillers running at maximum capacity on an almost continuous basis during summers, the aging of the chillers is being accelerated and breakdowns are increasing. These breakdowns come at a monetary cost for repairs, and disrupt faculty and students when the academic buildings heat to uncomfortable temperatures.

In the 2006 supplemental capital budget, CWU requested funding to replace a chiller that had failed; that request was not funded. Central has requested chiller funding every biennium since 2015-17 as part of a comprehensive Energy Efficiency package of infrastructure upgrades, but the package has never received capital budget funding. Since the chiller component of the package is now urgently needed, CWU is submitting an individual decision package in order to highlight its need.

Project benefits

Full funding of the request will accomplish the following:

- Produce sufficient cooling capacity to meet peak demand at all times.
- Enhance the reliability of the system and reduce the need for costly repairs.
- Establish a more environmentally friendly system that consumes less electricity.
- Create capacity to designate the oldest chiller as a backup so that even if one chiller fails, the system will still have enough capacity to meet peak demand.
- Generate surplus capacity that enables CWU to serve more students.

2. History of the Project or Facility:

CWU requested state funding in the 2006 supplemental capital budget, and in each of the last three consecutive biennia. None of these requests was funded.

Since 2012, several large cooling loads have been added to the campus system including Science II (physics and geology), Samuelson Hall (computer science), portions of Randall and Michaelsen Halls, and Dugmore residence hall, which opened in the fall of 2019. The anticipated demand of the Health Sciences building will be between 3,200 and 3,300 tons, exceeding the capacity of the university’s cool system.

3. University programs addressed or encompassed by the project:

The project supports virtually all university programs and activities, from residential life to academic programs, from administrative operations to recreational activities. None of these entities can function without environmental modification when temperatures rise into the 90s or even beyond 100 degrees. Appropriate cooling also can be essential to the preservation and operations of critical equipment and other resources, including digital technology, archival records, scientific and **artistic display, research, and instructional materials.**

GENERAL CATEGORY SCORING CRITERIA

4. **Significant health, safety, and code issues**

A. Identify whether the project is needed to bring the facility within current life safety (including seismic and ADA), energy, utilities or transportation code requirements.

The addition of the new chiller supplying cooling demands for the new Health Science building fulfills the recommended requirements of the following regulations

Occupation Safety & Health Admin. (OSHA) Section III, Chapter 2, subsection V

Installing a new chiller for Health Science would address OSHA Technical Manual "Recommendations for the Employer," which articulates engineering recommendations for ventilation, operational efficiency, air treatment, and source controls. As noted above, several of the lab conditions with Health Science will have their own specific requirements beyond the conditions identified within subsection V.

Expanding chiller capacity allows CWU to meet OSHA standards that set the range for office temperature controls between 68 to 76 degrees F. This echoes research by ASHRAE, which provides recommendations for thermal comfort in offices and classrooms in ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy. Temperatures substantially above this range can result in decreased productivity, increased absenteeism, and undesirable heat stress on the human body. For life-safety purposes, CWU buildings operate with fresh air rates of 15 to 100 percent, depending upon the use and building occupancy, with labs, art studios, and food services having the most outside air. Additional support documentation in maintaining hospitable learning conditions is identified in OSHA Section III, Chapter 4 regarding heat stress. The addition of the chiller is a direct representation of "Heat-related Illness" by ensuring

- The use of air conditioning
- Increase of general ventilation
- Running local exhaust ventilation where heat is produced.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 55, Section 5, subsection 5.1 – 5.4 & Section 6, subsection 6.1-6.2

Thermal Environmental Conditions for Human Occupancy should allow students or employees wearing a normal amount of clothing to feel neither too cold nor too warm, based on a calculation of acceptable operative temperature ranges in comparison to the mean monthly outdoor air temperature. Failure to secure a new chiller will jeopardize the ability to maintain the facility temperatures within an acceptable range.

ASHRAE Standard 62, Section 5, subsection 5.7 – 5.17

Adding a chiller enables CWU to meet this standard, which relates to the ventilation, humidity control, and removal of air contaminants. These are especially critical to the care of temperature-sensitive controls of various labs spaces, and to prevent overheating.

Food & Drug Admin. (FDA), Section 6-202.12 Heating, Ventilating, Air Conditioning systems.

CWU cannot meet this standard without expanding chiller capacity. The FDA directs that heating, ventilating, and air conditioning systems shall be designed and installed so that make-up air intake and exhaust do not cause contamination of food, food-contact surfaces, equipment, or utensils. The construction of Health Sciences, which the chiller supports, includes several food labs that required optimal operating temperatures in order to meet FDA guidelines.

Clearly identify the applicable standard or code, and describe how the project will improve consistency with it. Provide selected supporting documentation in appendix and reference in the body of the proposal.

The engineering and equipment sizing abide by Washington Administrative Code (WAC) 51-11c-40331 for the appropriate capacity of the building it is designed to support (Health Science & campus redundancy)

Detailed engineering will be performed to support building adherence to the calculation of total HVAC system performance ratios as calculated with WAC 51-11C-80500

5. Evidence of increased repairs and/or service interruption

Identify prior facility repairs, work order repair history or contractor repair call-outs, increased utility and/or maintenance costs, and/or system unreliability. Provide selected supporting documentation in appendix, and reference them in the body of the proposal.

A summary of work orders associated with chiller repairs is enclosed in **Appendix F**

- In 2005 one of the two chillers (Chiller 3) in the central plant experienced a major mechanical failure ($250,000).
- In 2012 Chiller 2 required a compressor rebuild ($77,831).
- In 2015 a motor-bearing failure occurred in the 900-ton chiller. Estimated repair costs exceeded the value of this chiller, which was replaced earlier this year with a new chiller with capacity of 3600 tons of cooling. However, increased cooling demand from anticipated new buildings will require an additional 1,200 tons of cooling for a total plant capacity of 4,800 tons of cooling.
- In the spring of 2020, a chiller-starter replacement was completed to ensure full capacity of chiller operation was available for the anticipated summer heat loads. ($43,000)
- Since 2008, the sum of miscellaneous of small work order repairs on the chillers is approximately $203,000.

6. Impact on institutional operations without the infrastructure project

Describe how and the extent to which there would be an impact on existing operations and programs. Describe the potential impact on future, already funded or planned construction projects or program needs should this infrastructure project not occur.

Central Washington University will not have enough cooling capacity when the Health Sciences building is complete in the fall of 2021Failure to secure an additional chiller creates significant risk of temperature control for science facilities: scientific equipment, lab samples, consistent lab environments required to accurate lab testing, the microscopic temperature tolerances of sensitive research samples (e.g. blood, tissue, plant, microbiota, and other cultures).

Without additional capacity peak demand cooling capacity could cause operation failure of existing equipment being overworked at constant volume leading to multiple buildings experience cooling issues.

7. **Reasonable estimate**

Provide as much detailed cost estimate information as possible, including documentation of professional assessment of costs (may contain opinions of external experts or experienced project management staff from the institution).

The total project cost will not exceed the estimated project cost of $3,108,404. **A C-100 and CBS0003 can be found in Appendix B**.

An estimate accounts for construction escalation and is intended to include the formal engineering services (roughly $330k) for system connection, equipment procurement, installation, testing and balancing.

The estimate is supported by the engineering evaluation by Abacus Resource Management in **Appendix E.**

Summary of Estimate

Chiller Module	$1,672,000
Construction Contingency	$220,363
Construction Escalation	$119,622
Consultant Services (Engineering)	$367,647
Extended Warranty	$56,000
Module Insulation	$40,000
Plant Electrical	$104,000
Plant Piping	$86,000
Project Administration	$195,810
Shipping	$44,000
Site Fabrication	$54,000
Site Work	$20,000
Structural Base	$8,000
Tax	$201,191
TOTAL	**$3,188,633**

8. **Engineering Study**

Identify whether there is a completed comprehensive engineering study, site survey and recommendations or opinion letter. Provide referenced supporting documentation in appendix.

The Abacus Load Impact Study and opinion letter can be found in ***Appendix* D**. Within the study are references to CWU's Central Plant on-going modernization, which includes updates to the campus cooling capacity and miscellaneous plant appurtenances. Abacus Resource Management Company is the consultant and contractor services utilized by CWU to generate the 2012 study that identifies and demonstrates the need of a new chiller to meet the anticipated demand of campus at the completion of the new Health Science Building in fall of 2021.

The primary information of the Abacus study is located on **page 49 of Appendix D** focusing on the chilled plant peak load. The loads are divided into three categories: immediate term (IT), near term (NT) loads, and unknow term (UT)loads. The most updated estimate for the new Health Science building is between 3,200 and 3,330 tons. At the time of the study estimates of UT for renovations of Randall and Michaelsen were illustrated, however similar data is being calculated and engineered for Health Education, which would be the next facility to demand increased cooling capacity.

This project would result in 20-percent energy efficiency on the load of the existing chiller. The measured output of energy usage is estimated to reduce operational wear and tear by providing consistent cooling loads throughout campus.

9. Support by planning

Describe the proposed project's relationship and relative importance to the institution:

A. Campus/facilities master plan

Chapter 4: of The Capital Master Plan under section Facilities Priorities in Appendix C specifically articulates concerns about the capacity of the utility infrastructure for energy and resource distribution, calling out the need to expand the heating and cooling plant. RCW 39.5D and RCW 70.235.070 require CWU to maintain, build, and renovate agency facilities and systems, and to make improvements that save money and enhance the operation of the university. The expansion of modern chiller technology supports these responsibilities by:

- Providing efficient utility infrastructure to gain capacity for future facility growth,
- Considering the impacts on the utility infrastructure distribution systems in any major capital project,
- Increasing and improving the central plant operating capacity to provide for new buildings and renovations, and
- Coordinating utility upgrades with other capital projects and developments.

B. Ongoing academic and/or research program need and strategic plan

The completion of the new Health Science building is scheduled for the fall of 2021 with first classes beginning January of 2022. The chiller will ensure the typical operation of the laboratory and class spaces that make-up the academic programming of Exercise Science, Clinical Physiology, Food Science & Nutrition, Emergency Medical Services Paramedicine, Integrative Human Physiology and Public Health Programs.

The academic and research functions of these human-health related programs are directly impacted by climate. Increased temperatures place at risk for decomposition all types of biological matter, from the cadaver lab to blood and tissue samples. As well, several programs focus on human performance and the interactions of systems in the human body, all of which are directly impacted by ambient temperature, as well as temperatures in controlled environment: exercise science studies human functioning across the spectrum, from general health to athletic performance; nutrition science considers how the body metabolizes nutrients, how the preparation of food affects its nutritional value, and the relationship of nutrition to chronic disease. These and other measurements would be skewed by abnormally high ambient temperature.

The expansion of chiller capacity supports four of the five themes of the university's strategic plan (Please see Appendix C of the Capital Master Plan page 9):

- **Teaching and Learnin**g, by ensuring classroom climate control that is conducive to teaching and learning;
- **Scholarship and Creative Expression**, by ensuring climate control necessary to preserve sensitive research materials and equipment, and to maintain temperatures that allow faculty and students to conduct research related to human performance, both artistic and scientific;
- **Enhance the level of engagement, collaboration, and goodwill between the university and surrounding communities**, by providing stable climate control required for community events and meetings at CWU, the location of which makes it a sought-after meeting place for state agencies, as well as corporate and non profit organizations;
- **Resource Development and Stewardship**: Objective 5.4 within this theme prioritizes providing "the facility and technology infrastructure and services appropriate to meet the university objectives, while maximizing sustainability and stewardship." The request to obtain a reliable and modern chiller responds directly to this theme, including the following three outcomes:
  - Outcome 5.4.1: Operate, preserve, and increase the functionality of state physical assets, buildings, and technology infrastructure.
  - Outcome 5.4.2: Provide facilities, campus buildings, and grounds that are welcoming, safe, and secure.
  - Outcome 5.4.3: Provide the technology infrastructure, systems, and campus services necessary for all units to achieve their objectives and the objectives of the university.

10. Resource efficiency and sustainability

Document project benefits associated with low-impact stormwater management techniques, improvements in energy and resource conservation, and use of renewable energy sources

The proposed chiller project enhances sustainability and energy efficiency. The efficiency of the new technology is such that when moderate weather prevails, CWU will be able to operate on a single, new chiller, reducing overall electricity consumption. The new technology can produce the same amount of cooled water with a lower rate of energy consumption, while supporting control of indoor air pollutants of the new facility. As ventilation is introduced into our buildings for control of pollutants, in the summer months with no air conditioning, the inside space temperatures can approach or exceed outside air temperatures when internal and solar heat gains are factored. The outside air temperatures in Central Washington regularly approach 98 degrees in the cooling season that can stretch from June through September.

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CAPITAL PROJECT PROPOSALS 2021-23

1200 Ton Chiller Addition
Infrastructure – Stand Alone

APPENDICES

Appendix A	Capital Project Report CBS002
Appendix B	Project Cost Estimate CBS003 & C100
Appendix C	CWU Capital Master Plan 2019-2029
Appendix D	Abacus Central Steam & Chilled Water Load Impact Study
Appendix E	Abacus Support Letter

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CAPITAL PROJECT PROPOSALS 2021-23

1200 Ton Chiller Addition
Infrastructure - Stand Alone

APPENDIX A

Capital Project Report CBS002

OFM

375 - Central Washington University
Cost Estimate Summary
2021-23 Biennium
*

Cost Estimate Number: 185
Cost Estimate Title: Modular Chiller
Report Number: CBS003
Date Run: 8/14/2020 11:48AM

Version: 1A CWU Working Version 2021 - 2023
Agency Preferred: Yes
Project Number: 40000075
Project Title: Chiller Addition
Project Phase Title:

Contact Info **Contact Name:** Steve DuPont **Contact Number:** 509.963.2111

Statistics

Gross Sq. Ft.:	0
Usable Sq. Ft.:	0
Space Efficiency:	
MACC Cost per Sq. Ft.:	0
Escalated MACC Cost per Sq. Ft.:	0
Remodel?	Yes
Construction Type:	Heating and Power Plants
A/E Fee Class:	A
A/E Fee Percentage:	14.00%

Schedule

	Start Date	End Date
Predesign:		
Design:	07-2021	01-2022
Construction:	03-2022	06-2023
Duration of Construction (Months):	15	

Cost Summary Escalated

Acquisition Costs Total			**0**
Pre-Schematic Design Services		0	
Construction Documents		0	
Extra Services		0	
Other Services		0	
Design Services Contingency		33,936	
Consultant Services Total			**367,647**
Site work		0	
Related Project Costs		0	
Facility Construction		2,203,622	
Construction Contingencies		220,362	
Non Taxable Items		0	
Sales Tax		201,191	
Construction Contracts Total			**2,625,175**
Maximum Allowable Construction Cost(MACC)	**2,203,622**		
Equipment		0	
Non Taxable Items		0	
Sales Tax		0	
Equipment Total			**0**
Art Work Total			**0**
Other Costs Total			**0**
Project Management Total			**195,809**
Grand Total Escalated Costs			**3,188,631**
Rounded Grand Total Escalated Costs			**3,189,000**

Additional Details

Alternative Public Works Project:	No

375 - Central Washington University
Cost Estimate Summary
2021-23 Biennium
*

Cost Estimate Number: 185
Cost Estimate Title: Modular Chiller
Report Number: CBS003
Date Run: 8/14/2020 11:48AM

Version: 1A CWU Working Version 2021 - 2023
Agency Preferred: Yes
Project Number: 40000075
Project Title: Chiller Addition
Project Phase Title:

Contact Info **Contact Name:** Steve DuPont **Contact Number:** 509.963.2111

Additional Details

State Construction Inflation Rate:	2.38%
Base Month and Year:	06-2020
Project Administration By:	AGY
Project Admin Impact to DES that is NOT Included in Project Total:	$0

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375 - Central Washington University
Cost Estimate Detail
2021-23 Biennium
*

Cost Estimate Number:	185	**Analysis Date:**	September 18, 2019
Cost Estimate Title:	Modular Chiller		

Detail Title:	1200 Ton Chiller
Project Number:	40000075
Project Title:	Chiller Addition
Project Phase Title:	
Location:	

Contact Info	**Contact Name:**	Steve DuPont	**Contact Number:**	509.963.2111

Statistics

Gross Sq. Ft.:
Usable Sq. Ft.:
Rentable Sq. Ft.:
Space Efficiency:
Escalated MACC Cost per Sq. Ft.:
Escalated Cost per S. F. Explanation

Construction Type:	Heating and Power Plants
Remodel?	Yes
A/E Fee Class:	A
A/E Fee Percentage:	14.00%
Contingency Rate:	10.00%
Contingency Explanation	

Projected Life of Asset (Years):	20
Location Used for Tax Rate:	
Tax Rate:	8.30%
Art Requirement Applies:	No
Project Administration by:	AGY
Higher Education Institution?:	Yes
Alternative Public Works?:	No

Project Schedule

	Start Date	End Date
Predesign:		
Design:	07-2021	01-2022
Construction:	03-2022	06-2023
Duration of Construction (Months):	15	
State Construction Inflation Rate:	2.38%	
Base Month and Year:	6-2020	

Project Cost Summary

MACC:	$ 2,084,000
MACC (Escalated):	$ 2,203,622
Current Project Total:	$ 3,020,879
Rounded Current Project Total:	$ 3,021,000
Escalated Project Total:	$ 2,659,111
Rounded Escalated Project Total:	$ 2,659,000

ITEM	Base Amount	Sub Total	Escalation Factor	Escalated Cost
CONSULTANT SERVICES				
Construction Documents				
A/E Basic Design Services				221,446
SubTotal: Construction Documents				**0**
Other Services				
Bid/Construction/Closeout				99,490
SubTotal: Other Services				**0**
Design Services Contingency				
Design Services Contingency	32,094			
SubTotal: Design Services Contingency		**32,094**	1.0574	**33,936**
Total: Consultant Services		**353,030**	1.0414	**367,647**
CONSTRUCTION CONTRACTS				
Facility Construction				
D30 - HVAC Systems	2,084,000			
SubTotal: Facility Construction		**2,084,000**	1.0574	**2,203,622**
Construction Contingencies				
Allowance for Change Orders	208,400			
SubTotal: Construction Contingencies		**208,400**	1.0574	**220,362**
Sales Tax		**190,269**	1.0574	**201,191**
Total: Construction Contracts		**2,482,669**	1.0574	**2,625,175**
Maximum Allowable Construction Cost (MACC)		**2,084,000**	1.0600	**2,203,622**
PROJECT MANAGEMENT				
Agency Project Management	185,180			
Total: Project Management		**185,180**	1.0574	**195,809**

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Cost Estimate Summary and Detail

2021-23 Biennium

*

Cost Estimate Number: 185
Cost Estimate Title: Modular Chiller

Report Number: CBS003
Date Run: 8/14/2020 11:48AM

Parameter	Entered As	Interpreted As
Associated or Unassociated	Associated	Associated
Biennium	2021-23	2021-23
Agency	375	375
Version	1A-A	1A-A
Project Classification	*	All Project Classifications
Capital Project Number	40000075	40000075
Cost Estimate Number	185	185
Sort Order	Cost Estimate Title	Title
Include Page Numbers	Y	Yes
For Word or Excel	N	N
User Group	Agency Budget	Agency Budget
User Id	*	All User Ids

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375 - Central Washington University
Capital Project Request
2021-23 Biennium

*

Version: 1A CWU Working Version 2021 - 2023

Report Number: CBS002
Date Run: 8/14/2020 10:59AM

Project Number: **40000075**
Project Title: **Chiller Addition**

Description

Starting Fiscal Year: 2020
Project Class: Preservation
Agency Priority: 2

Project Summary

CWU requested state funding in the 2006 supplemental capital budget, and in each of the last three consecutive biennia. None of these requests was funded. Since 2012, several large cooling loads have been added to the campus system including Science II (physics and geology), Samuelson Hall (computer science), portions of Randall and Michaelsen Halls, and Dugmore residence hall, which opened in the fall of 2019. The anticipated demand of the Health Sciences building will be between 3,200 and 3,300 tons, exceeding the capacity of the university's cool system.

Project Description

Identify the problem or opportunity addressed. Why is the request a priority? Identify: Priority, undeserved people/communities, operating budget savings, public safety improvements & clarifying details. Include information about the current condition of the facility/system.

Central Washington University will not have enough cooling capacity when the Health Sciences building is complete in the fall of 2021 Failure to secure an additional chiller creates significant risk of temperature control for science facilities: scientific equipment, lab samples, consistent lab environments required to accurate lab testing, the microscopic temperature tolerances of sensitive research samples (e.g. blood, tissue, plant, microbiota, and other cultures).

Without additional capacity peak demand cooling capacity could cause operation failure of existing equipment being overworked at constant volume leading to multiple buildings experience cooling issues.

In 2012, CWU commissioned the Abacus Load Impact Study (Appendix D), which indicated the need for an additional chiller once Discovery Hall ("Science II") and Samuelson Hall became occupied, and before the completion of the new Health Sciences building. Discovery Hall was occupied in 2013 and Samuelson in 2017. CWU has requested state funding for chillers, but, lacking funding, none has been added to the system during that period. Cooling capacity is now being stretched to its maximum and has no redundancy in the case of a failure.

Ellensburg is located directly in the Cascade rain shadow and experiences very hot weather from the spring through fall; outdoor temperatures can exceed 100 degrees from May through September. Unlike the mild weather in Western Washington, air conditioning is a necessity for day-to-day operations.

One chiller is more than 20 years old and nearing the end of its useful life. It experiences mechanical failures more frequently and must be taken offline for costly repairs several times a year. With the chillers running at maximum capacity on an almost continuous basis during summers, the aging of the chillers is being accelerated and breakdowns are increasing. These breakdowns come at a monetary cost for repairs, and disrupt faculty and students when the academic buildings heat to uncomfortable temperatures.

In the 2006 supplemental capital budget, CWU requested funding to replace a chiller that had failed; that request was not funded. Central has requested chiller funding every biennium since 2015-17 as part of a comprehensive Energy Efficiency package of infrastructure upgrades, but the package has never received capital budget funding. Since the chiller component of the package is now urgently needed, CWU is submitting an individual decision package in order to highlight its need.

What will the request produce or construct (i.e., building predesign or design, construction of additional space, etc.)?

The project promotes the reliability and securing of institutional cooling. Currently, mechanical failures during a peak-demand period would require one third of the current cooling capacity (one of three coolers) to be taken offline for repairs. Adding a

Project Number: **40000075**
Project Title: **Chiller Addition**

Description

fourth creates capacity to absorb the cooling load in the event of a system failure.

When will the project start and be completed?

The request will accomplish the engineering, procurement and installation of a modular chiller within the existing boiler house. Based up the anticipated 28-week, lead-time, construction would occur in 2022 during the first year of construction of the New Health Sciences building. Total construction duration is estimated 15 months.

How would the request address the problem or opportunity identified in question #1? What would be the result of nottaking action?

Full funding of the request will accomplish the following:
· Produce sufficient cooling capacity to meet peak demand at all times.
· Enhance the reliability of the system and reduce the need for costly repairs.
· Establish a more environmentally friendly system that consumes less electricity.
· Create capacity to designate the oldest chiller as a backup so that even if one chiller fails, the system will still have enough capacity to meet peak demand.
· Generate surplus capacity that enables CWU to serve more students.

Central Washington University will not have enough cooling capacity when the Health Sciences building is complete in the fall of 2021Failure to secure an additional chiller creates significant risk of temperature control for science facilities: scientific equipment, lab samples, consistent lab environments required to accurate lab testing, the microscopic temperature tolerances of sensitive research samples (e.g. blood, tissue, plant, microbiota, and other cultures).

Without additional capacity peak demand cooling capacity could cause operation failure of existing equipment being overworked at constant volume leading to multiple buildings experience cooling issues.

What alternatives were explored? Why was the recommended alternative chosen? Be prepared to provide detailed cost backup. If this project has an associated predesign, please summarize the alternatives the predesign considered

No other alternatives were explored because the proposal was previously submitted as a necessary requirement to provide the adequate infrastructure systems to support the Capital Master Plan expansion of campus.

A summary of work orders associated with chiller repairs is enclosed in **Appendix F**
· In 2005 one of the two chillers (Chiller 3) in the central plant experienced a major mechanical failure ($250,000).

· In 2012 Chiller 2 required a compressor rebuild ($77,831).

· In 2015 a motor-bearing failure occurred in the 900-ton chiller. Estimated repair costs exceeded the value of this chiller, which was replaced earlier this year with a new chiller with capacity of 3600 tons of cooling. However, increased cooling demand from anticipated new buildings will require an additional 1,200 tons of cooling for a total plant capacity of 4,800 tons of cooling.

Project Number: **40000075**
Project Title: **Chiller Addition**

Description

· In the spring of 2020, a chiller-starter replacement was completed to ensure full capacity of chiller operation was available for the anticipated summer heat loads. ($43,000)

· Since 2008, the sum of miscellaneous of small work order repairs on the chillers is approximately $203,000.

Which clientele would be impacted by the budget request? Where and how many units would be added, people or communities served, etc.

The impacted clientele would include 50 faculty and staff and 500 students who will be the primary occupants of the new Health Sciences building. Due to the layout of the campus distribution piping, cooling capacity issues also will impact residents of in Wendell Hill (residence) Hall, McIntyre Hall (music), Hogue Technology, Barge Hall (administrative), Shaw-Smyser Hall (business), Science II and Samuelson STEM (computational sciences).

Will non-state funds be used to complete the project? How much, what fund source, and could the request result in matching federal, state, local, or private funds.

Chapter4: of The Capital Master Plan under section Facilities Priorities in Appendix C specifically articulates concerns about the capacity of the utility infrastructure for energy and resource distribution, calling out the need to expand the heating and cooling plant. RCW 39.5D and RCW 70.235.070 require CWU to maintain, build, and renovate agency facilities and systems, and to make improvements that save money and enhance the operation of the university. The expansion of modern chiller technology supports these responsibilities by:

· Providing efficient utility infrastructure to gain capacity for future facility growth,

· Considering the impacts on the utility infrastructure distribution systems in any major capital project,

· Increasing and improving the central plant operating capacity to provide for new buildings and renovations, and

· Coordinating utility upgrades with other capital projects and developments.

A. **Ongoing academic and/or research program need and strategic plan**

The completion of the new Health Science building is scheduled for the fall of 2021 with first classes beginning January of 2022. The chiller will ensure the typical operation of the laboratory and class spaces that make-up the academic programming of Exercise Science, Clinical Physiology, Food Science & Nutrition, Emergency Medical Services Paramedicine, Integrative Human Physiology and Public Health Programs.

The academic and research functions of these human-health related programs are directly impacted by climate. Increased temperatures place at risk for decomposition all types of biological matter, from the cadaver lab to blood and tissue samples. As well, several programs focus on human performance and the interactions of systems in the human body, all of which are directly impacted by ambient temperature, as well as temperatures in controlled environment: exercise science studies human functioning across the spectrum, from general health to athletic performance; nutrition science considers how the body

Description

metabolizes nutrients, how the preparation of food affects its nutritional value, and the relationship of nutrition to chronic disease. These and other measurements would be skewed by abnormally high ambient temperature.

The expansion of chiller capacity supports four of the five themes of the university's strategic plan (Please see Appendix C of the Capital Master Plan page 9):

· **Teaching and Learnin**g, by ensuring classroom climate control that is conducive to teaching and learning;

· **Scholarship and Creative Expression**, by ensuring climate control necessary to preserve sensitive research materials and equipment, and to maintain temperatures that allow faculty and students to conduct research related to human performance, both artistic and scientific;

· **Enhance the level of engagement, collaboration, and goodwill between the university and surrounding communities**, by providing stable climate control required for community events and meetings at CWU, the location of which makes it a sought-after meeting place for state agencies, as well as corporate and non profit organizations;

· **Resource Development and Stewardship**: Objective 5.4 within this theme prioritizes providing "the facility and technology infrastructure and services appropriate to meet the university objectives, while maximizing sustainability and stewardship." The request to obtain a reliable and modern chiller responds directly to this theme, including the following three outcomes:

- Outcome 5.4.1: Operate, preserve, and increase the functionality of state physical assets, buildings, and technology infrastructure.

- Outcome 5.4.2: Provide facilities, campus buildings, and grounds that are welcoming, safe, and secure.

- Outcome 5.4.3: Provide the technology infrastructure, systems, and campus services necessary for all units to achieve their objectives and the objectives of the university

Does this project include IT-related costs, including hardware, software, cloud-based services, contracts or IT staff? If yes, IT Addendum

This projects does not include nor funds IT-related costs, including hardware, software, cloud-based services, contracts or IT staff.

If the project is linked to the Puget Sound Action Agenda, describe the impacts on the Action Agenda, including expenditure and FTE detail. See the Puget Sound recovery chapter of the 2021-23 Operating Budget Instructions.

This project is not associated with the Puget Sound Action Agenda.

How does this project contribute to statewide goals to reduce carbon pollution and/or improve energy use? Please elaborate.

375 - Central Washington University
Capital Project Request
2021-23 Biennium
*

Version: 1A CWU Working Version 2021 - 2023

Report Number: CBS002
Date Run: 8/14/2020 10:59AM

Project Number: **40000075**
Project Title: **Chiller Addition**

Description

The proposed chiller project enhances sustainability and energy efficiency. The efficiency of the new technology is such that when moderate weather prevails, CWU will be able to operate on a single, new chiller, reducing overall electricity consumption. The new technology can produce the same amount of cooled water with a lower rate of energy consumption, while supporting control of indoor air pollutants of the new facility. As ventilation is introduced into our buildings for control of pollutants, in the summer months with no air conditioning, the inside space temperatures can approach or exceed outside air temperatures when internal and solar heat gains are factored. The outside air temperatures in Central Washington regularly approach 98 degrees in the cooling season that can stretch from June through September.

Is there additional information you would like decision makers to know when evaluating this request?

The Abacus Load Impact Study and opinion letter can be found in **Appendix D**. Within the study are references to CWU’s Central Plant on-going modernization[LS1] [DP2] , which includes updates to the campus cooling capacity and miscellaneous plant appurtenances. Abacus Resource Management Company is the consultant and contractor services utilized by CWU to generate the 2012 study that identifies and demonstrates the need of a new chiller to meet the anticipated demand of campus at the completion of the new Health Science Building in fall of 2021.

Location
City: Ellensburg
County: Kittitas
Legislative District: 013

Project Type
Infrastructure (Major Projects)

Growth Management impacts
Central Washington University (CWU) is required to adhere to the State Environmental Policy Act (SEPA). The SEPA process is where growth management act impacts are considered. CWU coordinates planning efforts with all applicable city and county jurisdictions

Funding

Acct Code	Account Title	Estimated Total	Expenditures Prior Biennium	Current Biennium	2021-23 Fiscal Period Reapprops	New Approps
057-1	State Bldg Constr-State	3,189,000				3,189,000
	Total	**3,189,000**	**0**	**0**	**0**	**3,189,000**

Future Fiscal Periods

		2023-25	2025-27	2027-29	2029-31
057-1	State Bldg Constr-State				
	Total	**0**	**0**	**0**	**0**

Schedule and Statistics

	Start Date	End Date

OFM

375 - Central Washington University
Capital Project Request

2021-23 Biennium

*

Version: 1A CWU Working Version 2021 - 2023

Report Number: CBS002
Date Run: 8/14/2020 10:59AM

Project Number: **40000075**
Project Title: **Chiller Addition**

Schedule and Statistics

	Start Date	End Date
Predesign		
Design	7/1/2021	1/1/2022
Construction	3/1/2022	6/1/2023

	Total
Gross Square Feet:	0
Usable Square Feet:	0
Efficiency:	
Escalated MACC Cost per Sq. Ft.:	0
Construction Type:	Heating and Power Plants
Is this a remodel?	Yes
A/E Fee Class:	A
A/E Fee Percentage:	14.00%

Cost Summary

		Escalated Cost	% of Project
Acquisition Costs Total		**0**	**0.0%**
Consultant Services			
Pre-Schematic Design Services		0	0.0%
Construction Documents		0	0.0%
Extra Services		0	0.0%
Other Services		0	0.0%
Design Services Contingency		33,936	1.1%
Consultant Services Total		**367,647**	**11.5%**
Maximum Allowable Construction Cost(MACC)	**2,203,622**		
Site work		0	0.0%
Related Project Costs		0	0.0%
Facility Construction		2,203,622	69.1%
GCCM Risk Contingency		0	0.0%
GCCM or Design Build Costs		0	0.0%
Construction Contingencies		220,362	6.9%
Non Taxable Items		0	0.0%
Sales Tax		201,191	6.3%
Construction Contracts Total		**2,625,175**	**82.3%**
Equipment			
Equipment		0	0.0%
Non Taxable Items		0	0.0%
Sales Tax		0	0.0%

375 - Central Washington University
Capital Project Request
2021-23 Biennium

*

Version: 1A CWU Working Version 2021 - 2023

Report Number: CBS002
Date Run: 8/14/2020 10:59AM

Project Number: 40000075
Project Title: Chiller Addition

Cost Summary

	Escalated Cost	% of Project
Equipment Total	0	0.0%
Art Work Total	0	0.0%
Other Costs Total	0	0.0%
Project Management Total	195,809	6.1%
Grand Total Escalated Costs	3,188,631	
Rounded Grand Total Escalated Costs	3,189,000	

Operating Impacts

No Operating Impact

Capital Project Request

2021-23 Biennium

*

Parameter	Entered As	Interpreted As
Biennium	2021-23	2021-23
Agency	375	375
Version	1A-A	1A-A
Project Classification	*	All Project Classifications
Capital Project Number	40000075	40000075
Sort Order	Project Priority	Priority
Include Page Numbers	Y	Yes
For Word or Excel	N	N
User Group	Agency Budget	Agency Budget
User Id	*	All User Ids

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CAPITAL PROJECT PROPOSALS 2021-23

1200 Ton Chiller Addition
Infrastructure - Stand Alone

APPENDIX B

C100 Estimate

STATE OF WASHINGTON

AGENCY / INSTITUTION PROJECT COST SUMMARY

Updated June 2020

Agency	Central Washington University
Project Name	1200 Ton Chiller Addition
OFM Project Number	40000075

Contact Information

Name	Steve Dupont
Phone Number	509-963-2111
Email	Steve.Dupont@cwu.edu

Statistics

Gross Square Feet	0	MACC per Square Foot	
Usable Square Feet	0	Escalated MACC per Square Foot	
Space Efficiency		A/E Fee Class	A
Construction Type	Heating and power plant	A/E Fee Percentage	14.00%
Remodel	Yes	Projected Life of Asset (Years)	40

Additional Project Details

Alternative Public Works Project	No	Art Requirement Applies	No
Inflation Rate	2.38%	Higher Ed Institution	Yes
Sales Tax Rate %	8.30%	Location Used for Tax Rate	Elensburg
Contingency Rate	10%		
Base Month	June-20	OFM UFI# (from FPMT, if available)	
Project Administered By	Agency		

Schedule

Predesign Start		Predesign End	
Design Start	July-21	Design End	January-22
Construction Start	March-22	Construction End	June-23
Construction Duration	15 Months		

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Project Cost Estimate

Total Project	**$3,020,879**	Total Project Escalated	**$3,188,633**
		Rounded Escalated Total	**$3,189,000**

STATE OF WASHINGTON

AGENCY / INSTITUTION PROJECT COST SUMMARY

Updated June 2020

Agency	Central Washington University
Project Name	1200 Ton Chiller Addition
OFM Project Number	40000075

Cost Estimate Summary

Acquisition			
Acquisition Subtotal	**$0**	**Acquisition Subtotal Escalated**	**$0**

Consultant Services			
Predesign Services	$0		
A/E Basic Design Services	$221,446		
Extra Services	$0		
Other Services	$99,490		
Design Services Contingency	$32,094		
Consultant Services Subtotal	**$353,030**	**Consultant Services Subtotal Escalated**	**$367,647**

Construction			
Construction Contingencies	$208,400	Construction Contingencies Escalated	$220,363
Maximum Allowable Construction Cost (MACC)	$2,084,000	Maximum Allowable Construction Cost (MACC) Escalated	$2,203,622
Sales Tax	$190,269	Sales Tax Escalated	$201,191
Construction Subtotal	**$2,482,669**	**Construction Subtotal Escalated**	**$2,625,176**

Equipment			
Equipment	$0		
Sales Tax	$0		
Non-Taxable Items	$0		
Equipment Subtotal	**$0**	**Equipment Subtotal Escalated**	**$0**

Artwork			
Artwork Subtotal	**$0**	**Artwork Subtotal Escalated**	**$0**

Agency Project Administration			
Agency Project Administration Subtotal	$185,180		
DES Additional Services Subtotal	$0		
Other Project Admin Costs	$0		
Project Administration Subtotal	**$185,180**	**Project Administation Subtotal Escalated**	**$195,810**

Other Costs			
Other Costs Subtotal	**$0**	**Other Costs Subtotal Escalated**	**$0**

Project Cost Estimate

Total Project	**$3,020,879**	Total Project Escalated	**$3,188,633**
		Rounded Escalated Total	**$3,189,000**

Cost Estimate Details

Acquisition Costs					
Item	**Base Amount**		**Escalation Factor**	**Escalated Cost**	**Notes**
Purchase/Lease					
Appraisal and Closing					
Right of Way					
Demolition					
Pre-Site Development					
Other					
Insert Row Here					
ACQUISITION TOTAL	**$0**		**NA**	**$0**	

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Cost Estimate Details

Consultant Services					
Item	**Base Amount**		**Escalation Factor**	**Escalated Cost**	**Notes**
1) Pre-Schematic Design Services					
Programming/Site Analysis					
Environmental Analysis					
Predesign Study	$0				
Other					
Insert Row Here					
Sub TOTAL	**$0**		**1.0258**	**$0**	Escalated to Design Start
2) Construction Documents					
A/E Basic Design Services	$221,446				69% of A/E Basic Services
Other					
Insert Row Here					
Sub TOTAL	**$221,446**		**1.0319**	**$228,510**	Escalated to Mid-Design
3) Extra Services					
Civil Design (Above Basic Svcs)					
Geotechnical Investigation					
Commissioning					
Site Survey					
Testing					
LEED Services					
Voice/Data Consultant					
Value Engineering					
Constructability Review					
Environmental Mitigation (EIS)					
Landscape Consultant					
LCCA					
Traffic Impact Analysus (TIA)					
Insert Row Here					
Sub TOTAL	**$0**		**1.0319**	**$0**	Escalated to Mid-Design
4) Other Services					
Bid/Construction/Closeout	$99,490				31% of A/E Basic Services
HVAC Balancing					
Staffing					
Other					
Insert Row Here					
Sub TOTAL	**$99,490**		**1.0574**	**$105,201**	Escalated to Mid-Const.
5) Design Services Contingency					
Design Services Contingency	$32,094				
Other					
Insert Row Here					
Sub TOTAL	**$32,094**		**1.0574**	**$33,936**	Escalated to Mid-Const.
CONSULTANT SERVICES TOTAL	**$353,030**			**$367,647**	

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Cost Estimate Details

Construction Contracts					
Item	Base Amount		Escalation Factor	Escalated Cost	Notes
1) Site Work					
G10 - Site Preparation					
G20 - Site Improvements					
G30 - Site Mechanical Utilities					
G40 - Site Electrical Utilities					
G60 - Other Site Construction					
Other					
Insert Row Here					
Sub TOTAL	**$0**		**1.0420**	**$0**	
2) Related Project Costs					
Offsite Improvements					
City Utilities Relocation					
Parking Mitigation					
Stormwater Retention/Detention					
Other					
Insert Row Here					
Sub TOTAL	**$0**		**1.0420**	**$0**	
3) Facility Construction					
A10 - Foundations					
A20 - Basement Construction					
B10 - Superstructure					
B20 - Exterior Closure					
B30 - Roofing					
C10 - Interior Construction					
C20 - Stairs					
C30 - Interior Finishes					
D10 - Conveying					
D20 - Plumbing Systems					
D30 - HVAC Systems	$2,084,000				
D40 - Fire Protection Systems					
D50 - Electrical Systems					
F10 - Special Construction					
F20 - Selective Demolition					
General Conditions					
Other					
Insert Row Here					
Sub TOTAL	**$2,084,000**		**1.0574**	**$2,203,622**	
4) Maximum Allowable Construction Cost					
MACC Sub TOTAL	**$2,084,000**			**$2,203,622**	

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7) Construction Contingency				
Allowance for Change Orders	$208,400			
Other				
Insert Row Here				
Sub TOTAL	**$208,400**	**1.0574**	**$220,363**	
8) Non-Taxable Items				
Other				
Insert Row Here				
Sub TOTAL	**$0**	**1.0574**	**$0**	
Sales Tax				
Sub TOTAL	**$190,269**		**$201,191**	
CONSTRUCTION CONTRACTS TOTAL	**$2,482,669**		**$2,625,176**	

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Cost Estimate Details

Equipment					
Item	**Base Amount**		**Escalation Factor**	**Escalated Cost**	**Notes**
E10 - Equipment					
E20 - Furnishings					
F10 - Special Construction					
Other					
Insert Row Here					
Sub TOTAL	**$0**		**1.0574**	**$0**	
1) Non Taxable Items					
Other					
Insert Row Here					
Sub TOTAL	**$0**		**1.0574**	**$0**	
Sales Tax					
Sub TOTAL	**$0**			**$0**	
EQUIPMENT TOTAL	**$0**			**$0**	

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Cost Estimate Details

Artwork					
Item	**Base Amount**		**Escalation Factor**	**Escalated Cost**	**Notes**
Project Artwork	$0				0.5% of total project cost for new construction
Higher Ed Artwork	$15,943				0.5% of total project cost for new and renewal construction
Other	-$15,943				
Insert Row Here					
ARTWORK TOTAL	**$0**		**NA**	**$0**	

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Cost Estimate Details

Project Management					
Item	**Base Amount**		**Escalation Factor**	**Escalated Cost**	**Notes**
Agency Project Management	$185,180				
Additional Services					
Other					
Insert Row Here					
PROJECT MANAGEMENT TOTAL	**$185,180**		**1.0574**	**$195,810**	

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Cost Estimate Details

Other Costs					
Item	**Base Amount**		**Escalation Factor**	**Escalated Cost**	**Notes**
Mitigation Costs					
Hazardous Material Remediation/Removal					
Historic and Archeological Mitigation					
Permiting / Plan Review					
Shop Support					
Insert Row Here					
OTHER COSTS TOTAL	**$0**		**1.0420**	**$0**	

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C-100(2020)
Additional Notes

Tab A. Acquisition
Insert Row Here

Tab B. Consultant Services
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Tab C. Construction Contracts
Insert Row Here

Tab D. Equipment
Insert Row Here

Tab E. Artwork
Insert Row Here

Tab F. Project Management
Insert Row Here

Tab G. Other Costs
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Central Washington University

CAPITAL PROJECT PROPOSALS 2021-23

1200 Ton Chiller Addition
Infrastructure – Stand Alone

APPENDIX C

Central Washington University

Capital Master Plan 2019-2029 is located at

www.cwu.edu/facility/master-plan

See Chapter 4: CWU Capital Planning Priorities under section

"Facilities Priorities: Teaching & Learning"

An Interactive online campus map is located at

www.cwu.edu/map

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CAPITAL PROJECT PROPOSALS 2021-23

1200 Ton Chiller Addition
Infrastructure - Stand Alone

APPENDIX D

Abacus Load Impact Study

FINAL REPORT

CENTRAL STEAM AND CHILLED WATER LOAD IMPACT STUDY

for:

Central Washington University
Ellensburg, Washington

prepared by:

Abacus Resource Management Company
14845 SW Murray Scholls Drive, Suite 110-308
Beaverton, Oregon 97007

July 24, 2012

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

II. STEAM SYSTEM

III. CHILLED WATER SYSTEM

SECTION I: EXECUTIVE SUMMARY

A. STEAM SYSTEM

The Central Heating Plant was constructed in 1975. It contains four high pressure steam boilers which can operate on natural gas or fuel oil. Steam is distributed to 46 buildings totaling just under three million gross square feet. Steam is used in these buildings for heating and domestic hot water production. The central steam system is a critical asset of the University requiring nearly 100 percent up time (especially during cold weather) to prevent buildings from freezing up which would lead to catastrophic water damage. The Plant is manned 24 hours per day 365 days per year and has not experienced a significant outage in the past 30 years.

The nameplate capacity of the four boilers totals 210,000 pounds per hour. Currently the plant can produce only 159,000 pounds per hour due to various conditions with each boiler which have degraded their capacities. However, the peak steam load over the next ten years is not expected to exceed 75,000 pounds per hour (an increase of about eight percent over current loads) and the longer term load forecast predicts future loads up to 100,000 pounds per hour. So, by these numbers, it appears there is not a capacity concern. The largest boiler could be out of service and the plant could still meet the peak load. This gives the University N+1 redundancy in the Central Heating Plant.

Unfortunately, Boiler No. 3 is currently 42 years old and has significant deficiencies with its controls and refractory. It has not been placed into service for several years although it is routinely tested and fired. It is not used because the load never demands three boilers and the other boilers are much more efficient and reliable. It is reasonable to count B-3 as backup capacity in its current condition and there is no reason it could not be used for periods of time should B-1 or B-2 be taken out of service. However, it is unrealistic to plan on B-3 providing reliable capacity beyond the next ten years.

Without B-3, the total plant capacity is reduced to 114,000 pounds per hour and the firm capacity (capacity with the largest boiler out of service) is only 69,000 pounds per hour which is below expected peak loads. Therefore, the University clearly needs to begin planning replacement capacity for B-3 and this new capacity should be online no later than 2020. The budget for this project is estimated to be $1.5M.

Although Boilers No. 1, 2, and 4 are a few years newer than B-3, they will all be near the end of their service lives by 2020. The planning process for replacing B-3 should also consider alternatives for extending the lives of these boilers through 2050. We estimate the budget required to make upgrades to these three boilers is $1.8M.

Compounding the need to make investments in the Central Heating Plant to address end of life issues, the University is up against the limits of its current synthetic minor emissions permit. The portfolio of emission units (boilers, water heaters, and emergency generators) currently located on campus brings current emissions to ninety two percent of the upper limit of the emissions permit. The planned addition of water heaters and emergency generators at the Samuelson Building, Science II, and the new NEHS Building are likely to push emissions over the permit limit.

Exceeding the limits of the synthetic minor permit will require CWU to secure a Title V emissions permit and begin conducting more rigorous compliance monitoring and reporting functions. Securing the new permit should pose no great problem other than cost. The Title V permit fee will be around $55,000 per year and it is estimated monitoring and reporting costs will be another $20,000 per year.

Options are available for replacing B-3 which would significantly reduce emissions and probably preclude going to a Title V emissions permit.

Outside the Central Heating Plant, several improvements remain to be completed within the steam distribution system. These include:

> Replace the 12- inch section of main header piping with 18-inch ($150,000)
>
> Replace the direct buried steam lines to Farrell Hall and Brooks Library ($600,000).
>
> Replace the remaining direct buried steam lines along Nicholson Blvd. ($1.8M).
>
> Replace the direct buried steam lines to Munson Retreat Center ($300,000).
>
> Revise condensate return pumps and piping so that all condensate returns directly to the Central Heating Plant and abandon the old hot well at the Old Heating Plant ($600,000).

One final issue for reliably meeting the steam loads is the condition of the backup fuel oil storage system. Oil is currently stored in two 150,000 gallon single-wall underground tanks. Although there was a ground water contamination event over 20 years ago, it was related to a tank overflow. Monitoring wells placed around the tanks indicate the tanks themselves have probably not leaked additional oil. However, having such a large quantity of oil stored underground in single wall tanks should be considered an unacceptable risk to the University. Most State owned facilities have already mitigated this risk with double wall tanks. Planning for the Plant renovations should include alternatives for mitigating the underground fuel oil storage risk at CWU.

B. CHILLED WATER SYSTEM

The Central Cooling Plant was constructed in 1978 and is located on a partial upper floor of the Central Heating Plant. It contains three water cooled centrifugal chillers, cooling towers, and associated pumps. The Plant also incorporates a flat plate heat exchanger to perform waterside economizer cooling and a one million gallon chilled water storage tank which is charged at night and acts like a chiller during the day. Chilled water is distributed to 28 buildings totaling just under two million gross square feet. The cooling season begins in April and runs into October. However, the Plant serves some process cooling loads requiring chilled water to be circulated year round. This winter operation does not require running any chillers or towers. The ground serves as the heat sink for these small loads.

The nameplate capacity of the three chillers totals 3,300 tons. Due to pumping limitations, and to some degree the piping leaving the Plant, the current maximum output is around 2,800 tons. The peak cooling load in each of the past two years has approached this 2,800 ton limit. With an additional 220 tons of load coming on line by September 2012, it is safe to say the existing Plant cannot meet any future load growth beyond 2012. In fact, it is possible during extremely hot weather, the Plant may fail to meet some loads this summer.

Not only can the current Plant not meet any future load growth, the Plant has no redundancy to meet existing loads. There is N+1 redundancy in the chillers, meaning any one chiller could fail and the Plant could still meet the load. However, the failure of any primary or secondary chilled water pump reduces Plant capacity below the current peak campus load.

Another constraint to meeting future campus loads from this Plant is the size of the main chilled water distribution piping leaving the Plant. This 20-inch pipe is at the upper range of prudent fluid velocity (eight feet per second) under current peak loads. Increasing this velocity to meet future loads would lead to excessive erosion of this pipe and premature failure.

In order to reliably meet the cooling needs of the campus, now and into the future, CWU should plan the following improvements:

Immediately increase the capacity of the primary and secondary chilled water pumping in the Plant ($100,000).

Plan to meet future cooling loads with a separate cooling plant. The new Plant should be located somewhere on the east side of D Street to overcome the limitation of the 20-inch distribution pipe leaving the existing Plant. This could alternatively be accomplished by incorporating cooling equipment inside new buildings. ($1,800,000). If CWU desires to keep all central cooling equipment in the existing Plant, then a Plant expansion will be required and new chilled water piping will need to be run from the Plant to the east side of D Street. (add another $800,000 to the $1,800,000 budget)

If cooling is added to Randall/Michelson, or if other buildings are added to the cooling system in the northeast section of campus, then a cooling loop bypass needs to be constructed connecting the chilled water lines on the north side of Stephens/Whitney to the lines serving Barto. ($300,000)

SECTION II: STEAM SYSTEM

A. OVERALL SYSTEM DESCRIPTION

The Central Heating Plant was constructed in 1975 as a replacement to the original heating plant. The original construction included two new 60,000 pound per hour steam boilers. These boilers (B-1 and B-2) are Cleaver Brooks D-Style watertube boilers. The third boiler (B-3) is of the same manufacturer, style, and capacity but it was originally installed in the Old Heating Plant in 1970 and moved to the new plant in 1975. In 1980 a 30,000 pound per hour Cleaver Brooks firetube boiler (B-4) was added to the plant to better meet summer loads. Thus, the current installed nominal capacity of the heating plant is 210,000 pounds per hour.

All boilers in the plant can operate on natural gas or No. 2 fuel oil. Gas is supplied by the City of Ellensburg and is the primary fuel source due to its low price relative to oil. The plant has two 150,000 gallon underground fuel oil storage tanks. The current emissions permit would not allow continuous operation on oil. The permit limits oil use to 600,000 gallons per year which is only one-fourth of the annual equivalent fuel consumption at the Plant.

The plant is designed to produce steam at 150 psi but has traditionally been operated at 90-100 psi.

Plant controls were originally pneumatic but were upgraded to electronic single loop controllers manufactured by Johnson Yokogawa in 1998. Primary control of air, fuel, and feed water is still done via pneumatic actuators. The controls for B-1 and B-2 were recently upgraded, and the two boilers re-tuned. The boilers were tuned for higher efficiency; which has resulted in a reduction in steam capacity.

Steam is distributed to 46 buildings totaling about 2,988,000 gross square feet. The original distribution system employed direct buried steam and condensate piping. That piping began failing in the late 1970's and the University has been systematically replacing the distribution system since then. Of the approximately 20,000 lineal feet of steam distribution piping, only about 3,000 feet of the direct buried piping remains. One third of that will be replaced this summer and one third is valved off and not currently in use. The only remaining active sections of direct buried piping after this summer will be the lines serving Farrell Hall/Brooks Library and Munson Retreat Center.

These sections are known to be in poor condition and are scheduled for future replacement as funding allows.

Condensate return piping parallels the steam piping and thus most of the original direct buried piping has been replaced. Most of the condensate return does still flow to the Old Heating Plant where it is collected in the old hot well and pumped back to the Central Heating Plant. This situation will need to be corrected if the Old Plant is ever replaced.

B. CURENT SYSTEM CONDITION

Boilers B-1, B-2, and B-4 have proven to be very reliable but are all within ten years of their expected useful life. Planning should begin to make major renovation of their key components or for their replacement sometime before 2022. By that date B-1 and B-2 will be 47 years old.

Boiler B-3 has not operated reliably for the past several years. This is the boiler which was moved from the Old Heating Plant and it is now 42 years old. It could be reasonably argued that B-3 should not be counted on for continuous service and maybe not even as a reliable backup boiler unless a major renovation effort is completed on its key components.

The feedwater and deareation systems are in good condition.

The underground oil storage tanks have been determined to have leaked. However, this leak could have been an overflow incident as continuous ground water and tank sampling has revealed no subsequent leakage. Regardless, the underground storage tanks represent a serious environmental risk and should be replaced if oil firing is to be retained.

Specific details about current operating conditions of the plant are presented in the remainder of this section.

Controls and Combustion Efficiency: Boiler controls have long been an issue in the Central Heating Plant, and to some extent are responsible for limiting the plant’s steam capacity. Some of these control issues have recently been addressed, with implications for efficiency and output capacity. B-1 and B-2 especially have been re-instrumented and re-tuned to maximize efficiency. The general feeling seems to be that B-3 is less efficient and/or less reliable than B-1 or B-2.

The data used in this report come from a recent period of data collection (late 2011 / early 2012), but also from an extensive period of data collection that took place in early 2010. The 2010 data, which was collected as part of study on a biomass-fired CHP plant for CWU, used the calendar year 2009 as the base year. A year's worth of data was collected at that time.

The general staging pattern is to use B-4 in summer. As the weather gets colder, one of the watertube boilers is brought online and B-4 is taken offline. The operators choose how the watertube boilers are staged, but the current operations favor either B-1 or B-2 as the "lead" boiler. As the weather gets colder still, a second watertube boiler is brought on. To date, it appears that the steam load has never gotten high enough to require a third boiler. This is borne out by the calculations below.

In 2009, the efficiency of the boilers was calculated as shown in Figure 1 below. These calculations were based on past stack tests – the boilers were not re-tested at that time, nor were they re-tested (specifically for efficiency) for this report.

Estimated Boiler Efficiency, 2009

	average (1) combustion efficiency	estimated fuel to steam efficiency
B-1	0.816	0.801
B-2	0.816	0.801
B-3	0.811	0.796
B-4	0.831	0.816

(1) Over the full firing range

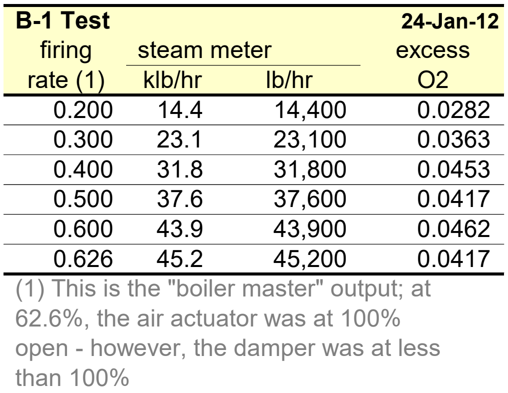
Figure 1, Estimated Boiler Efficiency, 2009

The differences between the combustion efficiency (measured) and the fuel to steam efficiency (estimated) are the boiler losses. These are heat loss from radiation (from the skin of the boiler to the room), and what are generally referred to as "unaccounted" losses (air leakage through the shell, etc). Combined, these are generally in the range of 0.010 to 0.020 (one to two percentage points of efficiency). In this case, an assumption of 0.015 was used.

In 2009, hourly natural gas data was combined with steam data to estimate the average annual fuel to steam efficiency of the plant at 0.806. This was an average across the entire year, and is not specific to any one boiler.

Since that time, B-1 and B-2 have been re-tuned, and each has a tuned and functioning oxygen trim system. These are thought to be the most efficient boilers at this time. Although no stack tests were available to confirm this, we can estimate the combustion efficiency of these boilers based on recent data. (There are many definitions of “combustion efficiency” – the one used here is that this value is what a stack test analyzer would record as the “efficiency” during a stack test.) Note that during the recent data collection period, B-1 and B-2 were the only boilers operating – no new data are available for B-3 and B-4.

Combustion efficiency can be estimated from net stack temperature and excess oxygen. Figures 2 and 3 below show the results of a recent test of B-1 and B-2. Efficiency was not measured, but excess oxygen and steam output were. In addition to helping to estimate combustion efficiency, these figures contain additional important information that will be expanded on further below.



B-1 Test			**24-Jan-12**
firing	steam meter		excess
rate (1)	klb/hr	lb/hr	O2
0.200	14.4	14,400	0.0282
0.300	23.1	23,100	0.0363
0.400	31.8	31,800	0.0453
0.500	37.6	37,600	0.0417
0.600	43.9	43,900	0.0462
0.626	45.2	45,200	0.0417

(1) This is the "boiler master" output; at 62.6%, the air actuator was at 100% open - however, the damper was at less than 100%

Figure 2, B-1 Test Results

B-2 Test			**24-Jan-12**
firing	steam meter		excess
rate (1)	klb/hr	lb/hr	O2
0.081	5.4	5,400	0.0750
0.160	8.9	8,900	0.0520
0.292	18.2	18,200	0.0400
0.324	20.2	20,200	0.0370
0.359	23.5	23,500	0.0380
0.476	28.8	28,800	0.0310
1.000	45.0	45,000	0.0428

(1) All of these except that last data point are the "boiler master" output signal - the 100% data point reflects the fact that at this point, the fuel valve was 100% open

Figure 3, B-2 Test Results

Figure 4 below shows excess oxygen as a function of steam output. It was mentioned above that B-1 and B-2 had oxygen trim systems. The boiler controls modulate gas flow to maintain steam pressure; the boiler air controls have two functions. First, modulate the airflow to provide enough combustion air for complete oxidation of the natural gas as it modulates to meet load - this is called stoichiometric air – the exact amount of air that will completely oxidize the fuel with no excess. Second, provide some excess air as a safety factor – should the boiler airflow fall below the stoichiometric rate, incomplete combustion occurs. This not only causes significant formation of carbon monoxide (CO), if enough unburned gas accumulates it can explode in the boiler once the air level returns to normal.

The function of the oxygen trim system is to “fine-tune” the air controls; to make sure that while there is enough excess air for safety, the excess airflow is minimized. Heating excess unburned air represents a boiler heat loss, so the greater the excess air, the lower the combustion efficiency. Excess air is not measured directly; instead excess oxygen is measured, and excess air then calculated from that. The oxygen trim system therefore tries to minimize excess air by measuring excess oxygen and modulating the trim system to maintain the oxygen setpoint programmed into the controller during boiler tuning. Oxygen makes up about 20.2 percent of the atmosphere by volume, so three percent excess oxygen equals 3 / 0.202 = 0.148, or 14.8 percent excess air.

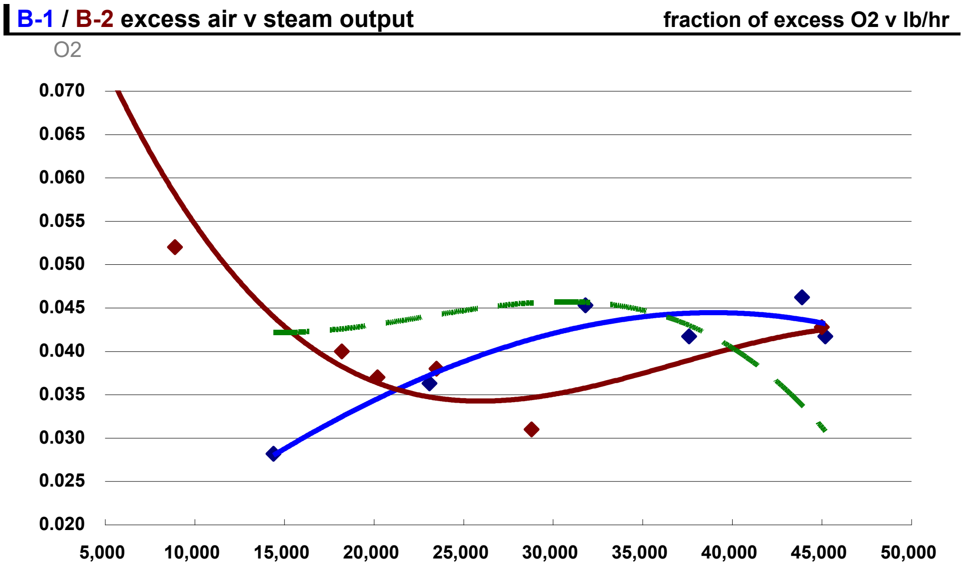


Figure 4, Excess Oxygen

The graph shows the significant difference between the two curves. B-2 (maroon) shows a more “normal” curve. The excess oxygen is highest at low loads. This is typical, because flame stability is lowest at the low end of the boiler output – thus more excess air is provided to ensure safety. The B-1 curve, however, is the opposite – it is very rare to see less than 3 percent oxygen at the low end of boiler output. So rare that we wondered if the data were recorded in an inverse fashion, and the values reversed. The dashed green curve represent this scenario (that the O2 readings were inverted compared to the steam readings). While this curve does not show the characteristic upturn at low loads (as with B-2), it does have the lowest O2 values at the high end of the output, as normally occurs.

Since the data were recorded by hand, and each reading was taken one at a time, it is hard to see how the data could have been inverted unless the final sheet sent to us was incorrectly transcribed from field notes. It will be assumed that the values shown are correct, although unusual.

The other value needed to calculate combustion efficiency is the net stack temperature, stack temperature minus inlet air temperature. In the current recording period, both the stack temperature and the inlet air temperatures were recorded (by data loggers) on five minute intervals for nine days in December 2011 and all of January 2012. Steam output during this time was not measured, because the values from the steam meters are suspect. Instead, the hourly natural gas data were used to calculate steam load for the hour – the average net stack temperature each hour was calculated from the logger data. The results are shown in Figure 5:

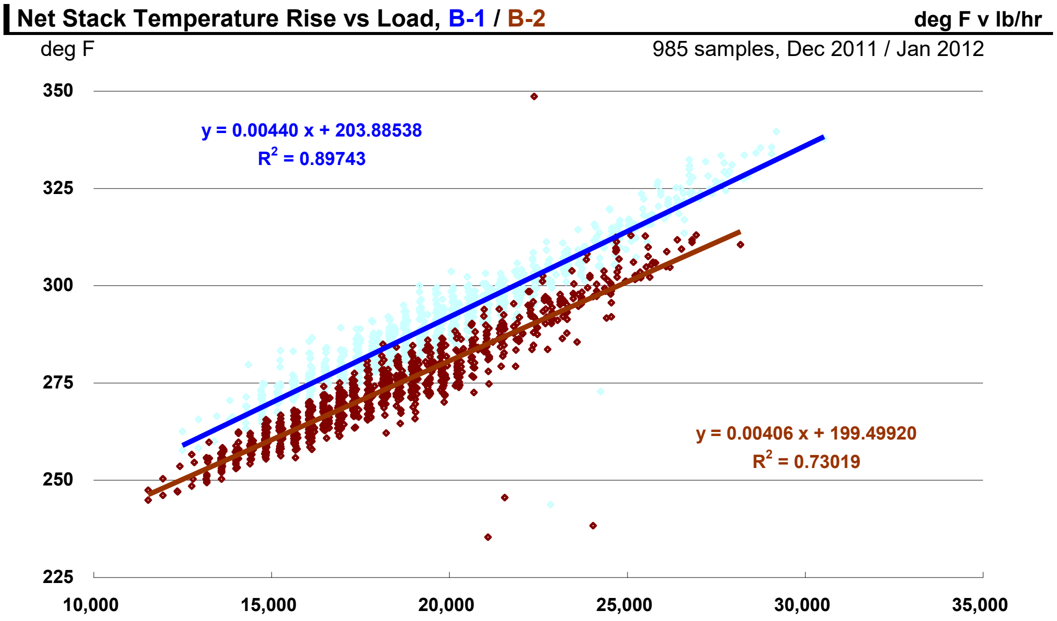


Figure 5, Net Stack Temperature

Note that at all load points, B-1 always has the higher net stack temperature, an average of 17 deg F over the 985 hours in the sample. This “delta T” will come into play in the capacity section below. In terms of efficiency, it means B-2, with the lower temperatures, would appear to be more efficient than B-1. However, because of the large amount of excess air that B-2 pulls at low loads, Figures 6 and 7 will show that at low loads, B-1 is actually more efficient despite the higher net stack temperature.

Figures 6 and 7 reproduce the data in Figures 2 and 3, with additional efficiency data added.

B-1 Test with calculated efficiency

firing	steam meter		excess	(1) load	net T	combustion	est FTS
rate	klb/hr	lb/hr	O2	fraction	deg F	eff	eff
0.200	14.4	14,400	0.0282	0.319	267	0.854	0.839
0.300	23.1	23,100	0.0363	0.511	306	0.844	0.829
0.400	31.8	31,800	0.0453	0.704	344	0.833	0.818
0.500	37.6	37,600	0.0417	0.832	369	0.829	0.814
0.600	43.9	43,900	0.0462	0.971	397	0.821	0.806
0.626	45.2	45,200	0.0417	1.000	403	0.822	0.807

(1) As a fraction of the highest recored output

Figure 6, B-1 Test Results with efficiency data added

We have again assumed 1.5 percent combined radiation and unaccounted losses when converting combustion efficiency to fuel to steam (FTS) efficiency. In all likelihood, given the age of the boilers, this value is probably closer to 2.0 to 2.5 percent – we used the same value as was used in 2009 for consistency, so direct comparisons could be made.

B-2 Test with calculated efficiency

firing	steam meter		excess	(1) load	net T	combustion	est FTS
rate (1)	klb/hr	lb/hr	O2	fraction	deg F	eff	eff
0.081	5.4	5,400	0.0750	0.120	221	0.849	0.834
0.160	8.9	8,900	0.0520	0.198	236	0.853	0.838
0.292	18.2	18,200	0.0400	0.404	273	0.849	0.834
0.324	20.2	20,200	0.0370	0.449	282	0.848	0.833
0.359	23.5	23,500	0.0380	0.522	295	0.845	0.830
0.476	28.8	28,800	0.0310	0.640	316	0.842	0.827
1.000	45.0	45,000	0.0428	1.000	382	0.826	0.811

(1) As a fraction of the highest recored output

Figure 7, B-2 Test Results with efficiency data added

Although B-1 and B-2 have the same nameplate capacity, we see from Figures 2 and 3 that they no longer have the same actual steam output capacity. Therefore, Figure 8 graphs combustion efficiency (calculated) v load fraction (faction of full load), rather than efficiency v output in lb/hr. This makes the two curves directly comparable, and allows the reader to visualize the efficiency data in Figures 6 and 7.

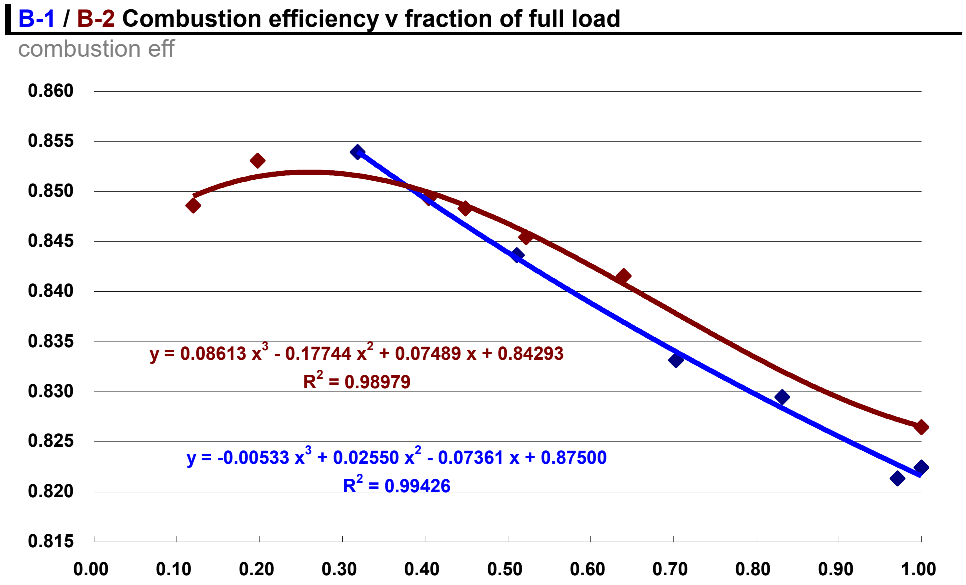


Figure 8, Combustion Efficiency

Going back to the 2009 data (Figure 1), we see that the weighted average combustion efficiency for B-1 and B-2 was calculated as 0.816. With the added controls and the functioning O2 trim, the efficiency of both boilers is now higher than this at all load points – this increase in efficiency represents a significant annual dollar savings.

In both cases, efficiency increases significantly at lower load fractions. This is because as the amount of gas (and air) decrease with falling load; the resulting stack gas has more boiler heat transfer area per pound of stack gas, as well as more dwell time in the boiler. The result is a higher heat transfer rate at low loads than at higher load (as thus the lower net stack temperatures). This effect can be offset, and often is, by high excess air (heating the excess air represent a loss). A “flatter” efficiency curve would indicate excessive air at low loads. The steepness of these curves shows graphically the effect of the oxygen trim. Note that at very low loads, when a significant amount of excess air is required for stability, the “excess air” effect overwhelms the “greater heat transfer area” effect, and the efficiency curve bends over the top (B-2 above). In the Test Data, B-1 never got below 32 percent of full load – still too high to show this effect.

There are operational reasons to use boilers known to be less efficient; the need to ensure the boilers remain useable, and to prevent excessive wear on a single boiler, and so on. There is also the issue of turndown – in summer, CWU uses B-4 because the load remains comfortably within the boiler's output range at all times, where it could easily drop below the minimum turndown of the larger boilers. In the absence of similar testing on B-3 and B-4, it has to be assumed that their efficiencies remain very close to those tabulated in Figure 1. Therefore, from a cost standpoint, operational considerations aside, CWU should maximize the use of B-2 first, then B-1, and only use B-3 and B-4 when required by other considerations.

<u>Stack Economizers</u>: All four of the boilers have feedwater heaters (stack economizers. Again, in the recent data collection period only B-1 and B-2 were operating, so only these two economizers were evaluated. The data indicate that while there are variations in the efficiency, they are small.

The operators report that the feedwater flow through the economizers is modulated by a control valve, which attempts to maintain a constant leaving stack gas temperature out of the economizer (240 deg F was the reported setpoint). This is intended to maximize heat recovery, while preventing the stack gas temperature from dropping so low it falls below the dewpoint of sulfuric acid (H2SO4). However, while leaving stack temperatures rarely drop below 240 deg F, they do in fact rise as inlet stack temperatures rise, so the control, if any, is ineffective. Figure 9 shows the "control" curves for the B-1 and B-2 economizers; as noted, they largely overlap, indicating similar heat transfer rates.

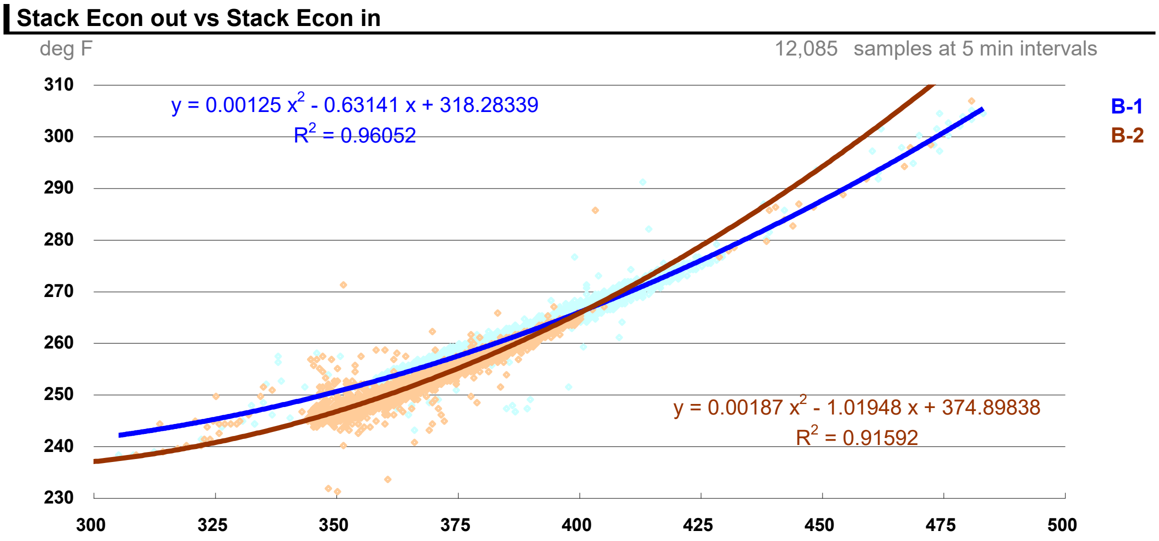


Figure 9, Stack Economizer Performance

Although the performance of the two economizers is similar, the B-1 economizer has the potential for greater heat recovery. This is because, as Figure 5 above shows, B-1 has higher stack temperatures at all load conditions.

This is borne out in Figure 10 below, these calculations assume that the average mass rate of stack gas is 1.12 times the mass rate of the steam, and the average Cp value (specific heat) of stack gas is 0.255 BTU/lb/deg F (both very average values):

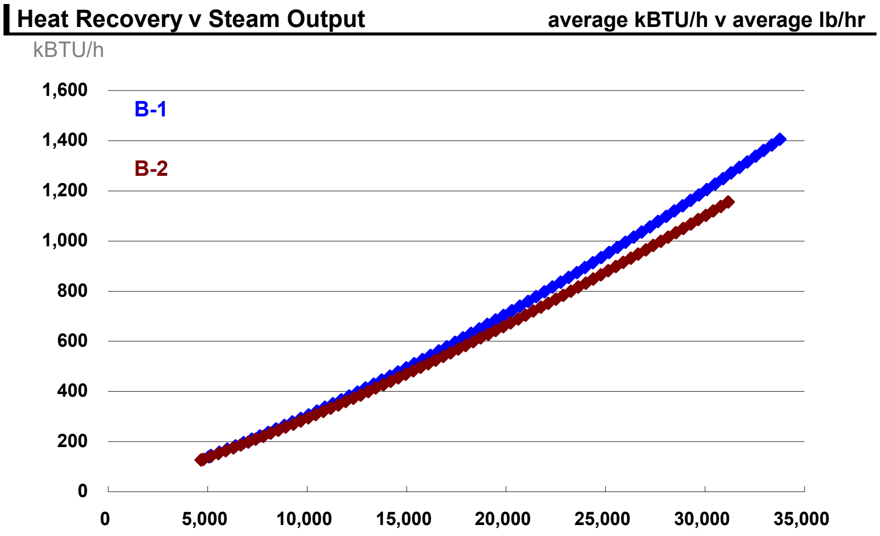


Figure 10, Stack Economizer Recovery

Using average Ellensburg weather (OAT bin data), and the assumed load profile (see Plant Capacity section below), one can predict the potential annual heat recovery from the B-1 and B-2 economizers. This assumes that B-2 is brought online (and B-4 taken offline) below 66 deg F (gas data shows this is when the heating load picks up), and that B-1 is brought on line in unison with B-2 when the load reaches 35,000 lb/hr. This is basically the load staging suggested above.

Given that staging scheme, and “average weather, with the current load profile, B-1 is calculated to recover 1,331.3 mmBTU per year. At the weighted average FTS efficiency calculated from Figure 6 above (0.815), this recovered heat would displace 16,334 therms of gas per year. B-2, because it runs so many more hours in the staging scenario (and despite less recovery per pound of steam), has the potential to displace more heat. The calculated recovery for B-2 would be 2,878.3 mmBTU; the associated gas displaced equals 34,872 therms (weighted average FTS efficiency of 0.825). At current prices, these 51,206 therms are worth about $37,280 per year.

In overall efficiency terms, the displaced gas represents about 0.021 of total gas use – a 2.1 percent savings. Given that B-3 and B-4 also have stack economizers, and are not included in the calculation above, the annual savings is probably closer to 2.25 percent.

Boiler / Plant Capacity: The nameplate capacity of the boilers was given above; however, as figures 2 and 3 above show, B-1 and B-2 are essentially now limited to 45,000 lb/hr each, a de-rate of 25 percent. This is not to say that they could not produce more steam if required, but it would require a re-programming of the controls, and would likely result in a loss of efficiency. Rework of the fuel valves and air dampers may also be required.

The footnote of Figure 2 indicates that currently B-1 is limited by the amount of air the boiler can pass. At 100 percent actuator travel, the air damper is actually less than 100 percent open, but that is how the boiler has been tuned for efficiency and stability, so barring a re-programming, the airflow control limits the output to about 45,000 lb/hr.

Likewise, the footnote of Figure 3 indicates that B-2 output is limited in a similar manner by the control of the gas valve. At 100 percent open, the boiler output is about 45,000 lb/hr.

The evidence for the capacity of B-3 and B-4 is more anecdotal, since the same tests have not been run on them. B-3, if anything, is expected to perform worse than B-1 and B-2. B-4 is believed to be limited to about 24,000 lb/hr. Figure 10, then, shows the nameplate and “current” (estimated) boiler and plant capacity. The term “Firm Capacity” is the plant capacity with the largest single boiler out of commission – it is considered unlikely that two boilers would be down at the same time, although it becomes more likely as the plant ages (see Plant Future below).

Boiler / Plant Capacity

	capacity, lb/hr		
Boiler	nameplate	current est	firm
B-1	60,000	45,200	
B-2	60,000	45,000	45,000
(1) B-3	60,000	45,000	45,000
(1) B-4	27,600	24,000	24,000
plant total	207,600	159,200	114,000

(1) estimated from anecdotal evidence

Figure11, Boiler / Plant Capacity

The current estimated plant capacity of 159,200 pounds per hour represents a twenty three percent de-rate in plant capacity compared to nameplate.

C. CURRENT SYSTEM LOADS

Steam Demand: Current steam demand was determined in detail in 2009, and has likely not changed much since then. Hogue Hall has been remodeled and expanded and Barto Hall is being replaced. However, for purposes of this study, the current load profile is considered to be very nearly the same as it was in 2009.

The steam load is considered to be comprised of three elements: 1) building demand, 2) system losses, and 3) DA steam.

Deareation: The amount of steam required to de-aerate the feedwater can be calculated if three enthalpies are known – the enthalpy of the water to the DA, the enthalpy of the feedwater from the DA, and the enthalpy of the DA steam. The latter values are considered constants, in that CWU does not change these values. DA steam is 5 PSIG, and feedwater temperature varies little from 225 deg F (the associated enthalpies can be looked up from this data). What does change is the temperature of the water going to the DA – this changes as groundwater temperature (make-up) changes, and as make-up water volume changes.

DA steam can be stated generically in the units of lb/lb – the number of pounds of DA steam it takes to raise a pound of incoming water to the feedwater enthalpy. The mass rate of the feedwater is assumed to be the same as the steam rate – it may vary from minute to minute, but long term they must equal or the boiler would trip off on low or high water.

In 2009, the annual DA steam rate was 0.0885 lb/lb – 8.85 percent of the plant steam went to de-aerating feedwater. The recent data collection period was not a year long, but for the duration of the period, at least, the make-up rate had dropped since 2009 (it fluctuates with leaks in the condensate system). For the Dec 2011 / Jan 2012 period, the DA steam rate was 0.0839 lb/lb.

Steam Distribution: The other “non-load” component is system losses, primarily heat lost from the steam piping. These losses are difficult to calculate directly – it would require knowing the length, diameter, and actual insulation value for every section of steam pipe in the system. However, it can be estimated by looking at a time when no “building load” is occurring, one can assume that any load present is a loss (not forgetting that some of the steam being used in these periods is in fact DA steam)

The 2009 data showed a distinct break in the steam load profile at 66 deg F. It is assumed that this is when actual space heating kicks in, although at a very low level, of course. It was further assumed that any other “load” user (DHW heating, reheat) would be zero or near zero between midnight and 4:00am. Sorting the 2009 data for data points that meet both criteria yields Figure 12:

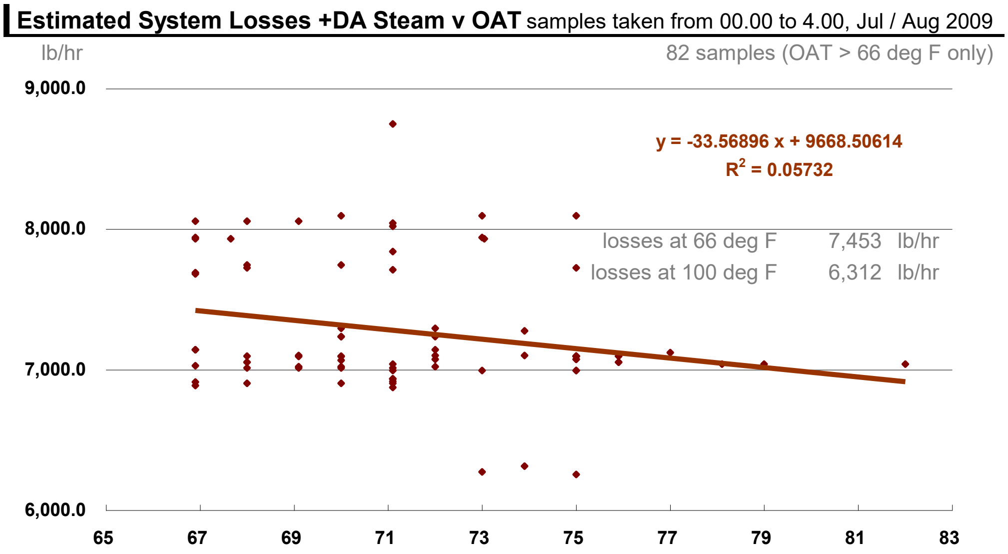


Figure12, System Losses and DA Steam

The correlation between data points and the trend line is not very good. In part, this is because the gas data is only reported to the nearest 1/10th of an MCF (thousand cubic feet of gas), or basically to the nearest 100,000 BTU. It also reflects the fact that some activity exists, even in the middle of the night. The trend line is best thought of as a long term average.

As noted above, this curve represents both system losses and DA steam (the DA never stops). The curve has a negative slope – losses increase as air temperature (and ground temperature) decrease. The graph shows two values, 7,543 lb/hr at 66 deg F, and 6,312 lb/hr at 100 deg F. Using the figures above, we can subtract out the DA steam, and the modified values would be 6,793 and 5,753 lb/hr, respectively.

These are the losses for the steam piping only – the boilers do not see the condensate piping losses directly. They manifest themselves as the difference between the condensate return temperature leaving the building, and the temperature of the condensate in the hotwell in the plant. Here, the condensate is then mixed with make-up water, and sent to the DA; so ultimately, condensate losses increase DA steam.

And of course, any leaks in the condensate system (leaks at CWU are almost exclusively in the condensate piping) must be made up with make-up water. This also lowers the overall temperature (and thus enthalpy) of the water to the DA. Every BTU lost in the system must be made up by burning additional gas. During the recent logging period, the average condensate temperature was 159.3 deg F (h = 127.3 BTU/lb). The average make-up temperature during the same time was 48 deg F (h = 16.05 BTU/lb. Therefore, for each thousand gallons (kgal) of condensate lost to leakage, the plant must generate 928,268 BTU to make up for the lost enthalpy. At an overall plant efficiency of 0.840 (boiler plus economizers), that requires 11.05 therms, or about $8.00 worth of energy per kgal. The actual cost of the water and the chemical treatment is not included in this calculation.

<u>Building Loads:</u> Having calculated total steam output from natural gas records, DA steam from make-up records and measured temperatures, and estimating losses by selectively sorting the steam data set, we estimated the actual building demand by subtraction. That graph is shown in Figure 13.

This graph shows not only the 2009 load (shades of blue), but also the expected load once the three buildings in the short term master plan of the University are added (shades of orange). The graph shows three curves for both load scenarios. The lowest line is losses only, and shows the same slight negative slope as in Figure 12. The second curve is DA steam + losses. DA steam is a constant fraction of total steam, so that curve follows the total steam curve at a much lower level. Finally, the last curve of each scenario is total plant steam. Building steam, then, is the area between total steam and DA + losses.

Note that total steam goes up with the addition of three buildings, as expected. However, the losses do not increase by the same percentage. In fact, they would be considered virtually constant between the two load cases (the amount of added pipe for the three buildings, plus their small size, means the additional losses fall well within the margin of error on the graph), except for the fact that CWU has lowered their steam pressure, in part to lower losses. The two curves are so close, they are hard to distinguish, but the "future" losses are actually 2.8 percent lower than the 2009 losses because of the lower pressure (temperature) steam.

Unlike losses, DA steam does increase with added building load, but as noted above, DA steam has dropped due to lower make-up mass rates. So the percent increase in DA steam is less than the percent increase in building demand. As with the "losses" curves, the DA + losses curves lie so close to each other they are hard to make out individually.

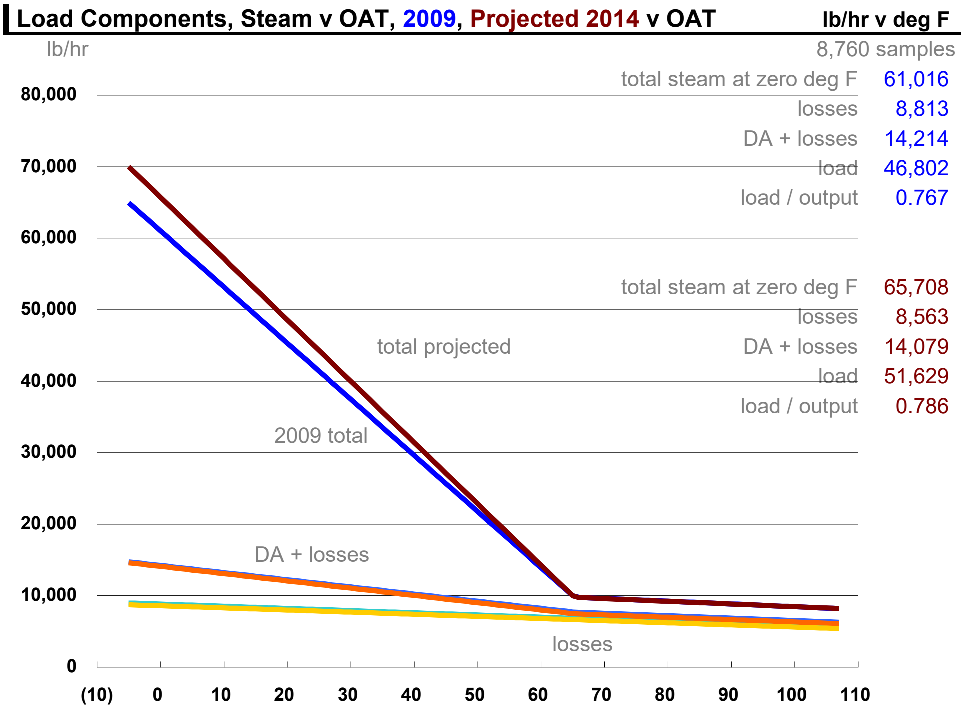


Figure13, Steam Demand by Component (instantaneous)

Note that at the peak existing load at zero deg F, 76.7 percent of the plant steam goes to building demand. This varies throughout the year, of course – the percent of "losses" is much higher in warm weather. Again using average Ellensburg OAT bin data, one can calculate the "system efficiency" on an annual basis using these curves. That calculation is shown in Figure 14 below.

total steam	207,683,282	lb/yr	1.0000
system losses	63,861,740	lb/yr	0.3075
DA steam	18,384,063	lb/yr	0.0885
building steam	125,437,479	lb/yr	0.6040

Figure 14, Steam Demand by Component (annual)

As Figure 14 shows, on an annual basis, 60.4 percent of the steam generated goes to the buildings.

In 2011, the average cost of gas was $0.728 per therm. The estimated gas usage based on the load curves was 2,429,090 therms, the estimated steam output was 204,674 klb (thousand pounds). At the stated gas cost, the cost of steam of was:

($0.728 * 2,429,090) / 204,674 = $8.64 / klb. This is based on "gross" pounds of steam.

The calculation in figure 14, however, indicates that on an annual basis only 60.4 percent of the steam is consumed in the buildings. The real (or net) cost of steam to the buildings, therefore, is $8.64 / 0.604, or $14.30 / klb. (This does not mean that saving 1 klb of steam therefore saves $14.30 – the system losses are unaffected by energy savings at the building level.) Another way to look at it is that while generating steam uses 0.840 of the heat content of the gas, only 0.840 * 0.604 = 0.507 of the heat content does "useful" work at the building level.

Boiler Loading: One final comment on boiler output, as it relates to B-1 and B-2. It was noted that B-1 always has a higher stack temperature than B-2, and this was attributed B-1 being to a less efficient boiler. However, if for some reason it was producing more steam than B-2 for a given firing signal, then that would also account for some or all of the discrepancy.

The test data indicate that the maximum capacity of B-1 is perhaps 200 lb/hr greater than that of B-2 (Figures 2 and 3) – this is only a 0.44 percent variation. One would expect that when modulating in unison, they would produce the same amount of steam. However, the data indicate that they don't.

Figure 5 shows net stack temperature vs load. During the recent data collection period, the average deviation of B-1 net stack temp minus B-2 net stack temp was 17.1 deg F. The average OAT was 29 deg F. Net stack temperature was measured independently for both boilers. Total steam load was determined by using gas data, as mentioned several times above. The first assumption was that both boilers provided one half of the total steam output. If this were true, then the plot shown in Figure 5 should show a 17 deg F difference at the load equivalent to 30 deg F – it did not. The "split" between the boilers was adjusted until the expected 17 deg F delta appeared (thus Figure 5 does now show the expected deviation).

This does not affect total steam output, just individual boiler output. Based on this data, it appears that when B-1 and B-2 are in "unison" modulation, B-1 is picking up 52 percent of the load, versus 48 percent for B-2. This is an eight percent difference in output (1-(52/48)), far more than the difference in "capacity" of 0.44 percent. Given that B-2 is more efficient than B-1, if anything the bias should be shifted to B-2.

D. PLANNED FUTURE LOADS

Near Term Additions: In the near term, steam loads will increase as the Hogue Hall renovation comes on line. The Samuelson Building renovation and the construction of Science II and NEHS may add significant load over the next 3-5 years. The affect of these load additions were shown previously in Figure 13 (a net addition of about 5,000 pounds per hour or just under eight percent).

Long Term Additions: There are no specific details on other future loads. However, the long term Campus Master Plan shows potential growth in several areas. There could be load growth in the northeast, northwest, and even in the middle of campus which could all be connected to the central steam system. These loads could total an additional 20,000 pounds per hour (or just under 30 percent).

E. SYSTEM CONSTRAINTS TO MEETING LOADS

Plant Capacity: The projected peak steam load with all planned near term future loads online is around 70,000 pound per hour. This is based on continuing recent winter weather which has not delivered temperatures in Ellensburg below zero for several years. Even if the longer term historical lows of minus 10 to 15 were to return, the peak steam load would only climb to 75,000 pounds per hour. The total plant capacity is currently 159,000 pounds per hour. The capacity with the largest boiler out of service is 114,000 pounds per hour. Thus, one could argue that plant capacity is not a constraint given the expected near term steam loads.

However, consideration should be given to the fact that Boiler No. 3 is 42 years old, its controls are obsolete, finding knowledgeable people who can work on this boiler is difficult, and it is known to have several deficiencies which keep it off line most of the time already. If B-3 is not going to be renovated in the very near future, one could also argue that its capacity should not be relied upon. That assumption takes the total plant capacity down to 114,000 pounds per hour and the firm capacity (using N+1 redundancy which assumes the largest boiler is then off line) is only 69,000 pound per hour. The system loads are projected to exceed this level and thus plant capacity becomes a serious issue.

Based on current conditions, it is probably not necessary to completely ignore any contribution from B-3. However, it is also not completely realistic to consider B-1 and B-2 completely reliable for the long term (beyond 2020). Our opinion is that B-3 needs complete renovation or replacement before 2018 (six years) and that B-1 and B-2 are in need of major renovation before 2022 (ten years) in order to sustain reasonable plant capacity and reliability.

Piping System Capacity:

Just as the plant has capacity constraints, the steam distribution piping has constraints as well. An issue for steam piping capacity is the fact that steam is compressible – the higher the steam pressure, the more of it you can force down a pipe. However, each increase in steam pressure has a corresponding increase in fuel required, and because temperature rises with pressure, piping heat losses also rise with rising pressure. Good energy practice is to always use the lowest pressure the system can handle.

This calculation is not always simple, because the specific volume of steam (in cubic feet per lb, the inverse of density) does not vary in a linear fashion as pressure varies. For that reason a model of the piping system was created.

Often, the variable which drives pipe sizing is pressure drop. If you need 5 psig at a building, the steam has to leave the plant at a high enough pressure such that when it reaches the building, it is still 5 psig or greater. The model shows that at any plant pressure above about 75 psig, pressure drop in the system is negligible – pressure drop is not the limiting variable on the piping system at CWU.

At CWU, the limiting variable is steam velocity. As the steam get less dense (higher specific volume), steam velocities go up. If velocities get too high, the steam and water droplets cause excessive wear on the pipe and fittings. Elbows are especially vulnerable to very small water droplets entrained in the steam at high velocity – the droplets cannot “make the curve” and impact the fitting walls.

Exposed piping is less of an issue, since leaks can be seen, and repaired inexpensively. The distribution piping at CWU is below grade which makes leaks very hard to find and expensive to repair. For these reasons, the model (although it calculates pressure drop, because pressure affects specific volume) uses velocity to highlight “hot spots” in the piping as load changes, plant pressure changes, or new building come on line.

The range of recommended velocities according to Spirax Sarco in their texts is 80 – 120 feet per second (fps). Converted to feet per minute (fpm), this is 4,800 to 7,200 (the model uses fpm). Because the piping is below grade, and is expected to last 40 years or more, it is better to operate towards the lower end of the recommended range.

CWU has historically generated steam in the range of 90 to 100 PSIG. Plugging 90 PSIG steam, zero deg F OAT, and the near-term additional steam loads into the model results in two sections of pipe being of specific concern. First is the ~ 100 foot long section of 12" pipe that leads from the plant header towards "D" street. This pipe jumps up to 18" after the first hundred feet, and there is no issue with the 18" section. The model shows that the velocity in this 12" section would be 1.261 times the limit, or 6,052 fpm. This section should be increased to 18".

The 18" pipe crosses "D" Street and then at a tee intersection (called N50 in the model), it splits north into a 12" section, and south into an 8" section. The second "failed" section is the 8" section of pipe that proceeds south from the N50 intersection. The velocity is this pipe is calculated at 1.177 times the limit, or 4,943 fpm. Raising the pressure to 100 psig helps, but both segments still exceed the 4,200 fpm limit.

In addition to these segments, 10 smaller segments (each feeding only one building) fail. These are of less concern. One thing the model cannot account for is that piping losses are constant, and do not "move" with the steam – the losses are not dependent on mass flow through the pipe, only on the temperature of the steam. For the two segments of concern, they are the closest to the plant, and little or no "loss" steam has dropped out of the pipe. In the case of the ten remote buildings, the actual flow to the building is less than the model indicates, because of the losses between the plant and the building have dropped out. The model assigns the building steam and loss steam to the building. DA steam is not counted – it never makes out of the plant.

There are no practical "failed sections" if CWU is willing to accept an upper limit of 7,200 fpm.

So how serious is the velocity related erosion issue? If the 8" pipe south of N50 fails, it is part of a loop, and can probably be back-fed around in all but the highest load conditions. There would likely be no disruption to normal services in any building. However, if the 12" segment near the Plant fails, no steam reaches the campus. This would be catastrophic making replacement of this 12" section of the highest priority.

In summary, the distribution system presents few constraints to meeting expected steam loads. There are however, some near term needs:

1. The 12-inch section of main steam header in the Central Plant should be increased to 18-inch.
2. The remaining sections of direct buried piping along the north side of Nicholson Boulevard are likely to fail within the next 10 years which would put delivering steam to all buildings north of Nicholson at some risk. This would leave only one flow path available to these buildings and any outage along that path would take out many buildings.
3. This same condition exists on the steamline serving Farrell Hall, Brooks Library, and Munson Retreat. All of these direct buried lines should remain on the Combined Utilities Improvement Plan.
4. The condensate return system should be modified so that each building condensate pump delivers directly back to the Central Plant (eliminate the path to the Old Plant hotwell).

Alternate Operating Modes (summer):

CWU would like to explore the possibility of operating in an “unmanned” mode in summer, using B-4. To do this, they need to reduce the steam pressure at the boiler to 15 psig or less. This raises a number of issues. Most are related to the specific volume of 12 psig steam (15.33 cf/lb) vs that of 90 psig steam (4.2426 cf/lb). The 12 psig steam takes up 3.6 times as much space as 90 psig steam. We use 12 psig steam as the basis because if the boiler is “rated” for 15 psig the actual steam pressure must be 10 – 15 percent below the rating, thus 12 psig was used as the basis. Several questions arise when considering lowering the plant pressure to 12 psig:

Can the boiler be adapted to lower pressure?

There is no issue with the boiler per se, but there may be an issue with the regulatory agencies. The boiler must be protected by pressure relief valves. These are currently set to protect the boiler at 150 psig. The regulatory agency may insist that the boiler relief protection be set at 15 psig to ensure that CWU is not simply claiming to be below 15 psig. Or they may simply ask for trend data or boiler pressure charts.

If they do require low pressure protection, the second question is, “will they accept partial relieving capacity?” The relief openings in the boiler were sized for higher pressure steam, and it may not be possible to relieve the nameplate 27,600 lb/hr of steam through those openings, even if new valves are installed. The summer load is not expected to exceed 15,500 lb/hr, so if they will accept partial capacity, it may be as simple as replacing the valves in summer.

How much steam can B-4 produce at 12 psig?

Output steam capacity is an issue due to the difference in specific volume. The steam nozzle (outlet) on a 150 psig rated 800 HP boiler has an 8" diameter. On the 15 psig version of the same boiler, the nozzle is 12" diameter (2.25 times the free area) to allow the "less dense" steam out of the boiler without excessive velocity. Excess velocity through the steam nozzle forces water into the nozzle with the steam (carryover), and can even fill the discharge with a solid plug of water (priming). The question is, "how much steam can reliably get out of B-4 at 12 psig?". The load profile (near-term loads included) predicts the average steam load at 60 deg F to be 14,250 lb/hr. Based on the logger data recently collected, the "morning warm-up "bump" in the load is expected to be between 8.5 and 9.5 percent, so assume a worst case summer load of 15,530. This is 0.563 of nameplate capacity.

Based on the past experience of some boiler experts we consulted, one should be able to get 50 - 70 percent of nameplate capacity without excessive carryover. A lot depends on water treatment. Some chemicals have the property of causing very large bubbles to form, instead of many smaller ones. Such large bubbles can literally get sucked whole into the nozzle if they form right below it. Determining the actual capacity of B-4 at 12 psig would require some trial and error process.

Installing a 12" diameter by 5 to 8 foot long spool piece above the existing isolation valves would not prevent carryover or priming at the nozzle, but it would likely eliminate water from getting to the header.

CWU could simply hire an ASME welder to make a 12" nozzle for the boiler. This would mean cutting into the shell, but it should eliminate any water issues at the lower pressure. Cost is estimated at $10,000. After an ASME spool piece of 5 – 8 feet above the new nozzle, CWU could neck back down to 8" and re-use the existing non-return and isolation valves.

The same welder could over-size the relief valve openings, if the regulatory agency required full 15 psig relief capacity.

Are there other plant issues?

The existing feedwater pumps may ride so far out on their curves that they cavitate, or flow fluctuates (which makes maintaining water level in the boiler harder). CWU could try it and see if it works first.

CWU could put a VFD on one pump, open the bypass around the B-4 feedwater valve, and just use the VFD to maintain water level.

They could buy a “pony pump” sized for the duty, and install it in the plant.

Can the distribution and building piping handle the lower pressure without excessive pressure drop or velocity?

This is simply not possible with Randall/Michelson on the system. This building alone has enough load to require its own boiler. If Randall/Michelson were retrofit with stand-alone capacity, then about 14,000 lb/hr would (worst case) would have to cross “D” Street. The model shows that the only issue is the infamous 12” section of the main plant to “D” Street segment. Even there, the velocity is only expected to be 4,625 fpm, above the strictest velocity limit, but well within the range of limits.

The model predicts that the pressure drop at the far end of the system will be as much as 4 psig, meaning those building would see only 8 psig.

The distribution traps are another potential issue. Relative steam flow through a fixed orifice size is proportional to the ratio of the absolute pressures. Dividing (8 + 14.7) / (90 + 14.7) = 0.217 means that the traps will pass only 21.7 percent of the “normal volume. However, traps are usually sized for at least twice the expected load, so capacity would be cut to perhaps 40 to 50 percent of that at 90 psig. Since the summer load is only about 20 percent of the peak, running trap load capacity should not be a limiting factor.

Warm-up trap loads could be an issue, however, since load typically doubles at this time (thus the over-sizing). Start-ups in summer could take substantially longer than they do now.

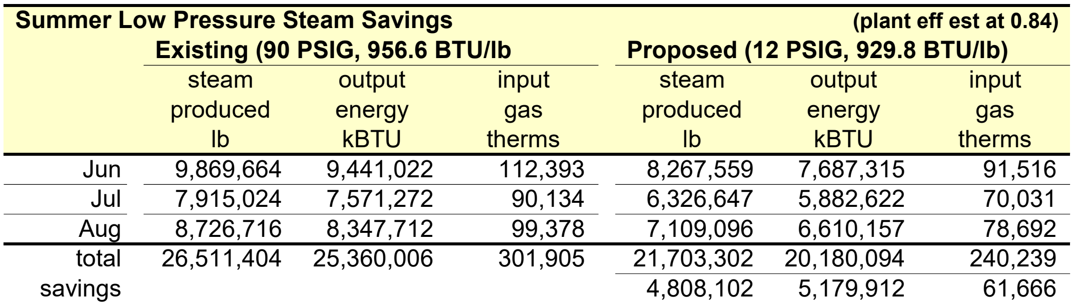
In the buildings, the PRVs will not function – they need to see an inlet pressure of 10 – 15 psig greater than the outlet in order to work. The staff would have to go to each building and manually open the bypass around the PRV. If the bypass is not “full size”, CWU would need to up-size the bypass or provide alternate heat to those affected buildings.

Aside from the ability to run the plant unmanned, the intent is to save money, which leads to the question of how much would this mode of operation save. There are four sources of savings, and they work together. In descending order of effect; first, the steam is cooler (a relative term – it is still over 212 deg F), so the piping losses are lower. Second, it takes less energy to make 12 psig steam than it does to make 90 psig steam. Third, less overall steam means less DA steam. Finally, the boiler is marginally more efficient, because the stack temperatures are lower. However, in this case, the lower stack temperatures mean the economizer is virtually useless, so this last effect has been considered “a wash”.

First, we can estimate the reduction in losses. At 100 deg F, the current losses are estimated at 5,590 lb/hr. Losses are proportional to the ratio of the temperature differentials (steam to ground). It is actually more complex, but this is good estimate. 90 psig steam is 331.2 deg F, and 12 psig steam is 243.7 deg F. Steam utilidor temperature was logged in two places recently, and averaged 114 deg F. The calculation would then be:

(243.7 – 114.0) / (331.2 – 114.0) = 0.693, or 69.3 percent of current losses (or a 30.7 percent reduction)

Using the same load profile we have been using for the rest of the report, and using the new loss values and DA steam values, we can plug the modified profile into the OAT bin model. The results are shown in Figure 15 below (June though August was chosen for simplicity):



Summer Low Pressure Steam Savings						**(plant eff est at 0.84)**
	Existing (90 PSIG, 956.6 BTU/lb			**Proposed (12 PSIG, 929.8 BTU/lb)**		
	steam produced lb	output energy kBTU	input gas therms	steam produced lb	output energy kBTU	input gas therms
Jun	9,869,664	9,441,022	112,393	8,267,559	7,687,315	91,516
Jul	7,915,024	7,571,272	90,134	6,326,647	5,882,622	70,031
Aug	8,726,716	8,347,712	99,378	7,109,096	6,610,157	78,692
total	26,511,404	25,360,006	301,905	21,703,302	20,180,094	240,239
savings				4,808,102	5,179,912	61,666

Figure 15, Summer Low Pressure Steam Operations

At $0.728 per therm, this would represent nearly $45,000 in gas savings alone.

However, there is one more issue not discussed above. That is the summer temperature range in Ellensburg. Using the four year average (2006 through 2009) OAT dry bulb data from the airport, it can drop as low as 38 deg F in June, as low as 40 deg F in July, and 44 deg F in August. These temperatures are rare; they are not reached very many hours in these months, but it does not take many hours to complicate this concept.

The project load at 44 deg F (even at 12 psig with lower losses) is ~25,500lb/hr (warm-up peak, ~ 28,000). B-4 might be able to produce this load, if the steam nozzle was enlarged, and the boiler had sufficient relief capacity at this level. There are three other issues, however:

Seven segments of pipe exceed the lower velocity limit of 4,800 fpm, and three fail even the most lenient limit of 7,200 fpm (the usual suspects). The 12" main section at the plant would exceed 9,000 fpm.

The load is approaching the calculated limit for the distribution traps.

The issue of building PRV bypasses gets much more critical.

None of this says it can't be done, but it may mean a lot of scrambling if cold temperatures occur unexpectedly. CWU could also always start up a watertube if B-4 cannot handle it, but this would mean A) going to each building and shutting the manual bypass (even if the watertube only produces 25 psig steam, for instance, it will still blow the pressure relief on the downstream building equipment if the bypass valves are open), and B) manning the plant.

<u>Alternate Operating Modes (winter)</u>:

The question has also been asked as to whether CWU could operate unmanned with 12 psig steam year round.

As with summer operation, Randall/Michelson would have a standalone boiler at that building.

The 12-inch section of header pipe at the Central Plant is also increased to 18-inch.

Then, at a minimum, CWU would have to convert all four boilers to larger steam nozzles, at a cost of perhaps $40,000.

The logical next step might seem to be to move B-4 to the Alford/Montgomery (A/M) site and have it feed from there. However, as the section above shows, in summer B-4 might handle the steam loads, but the 12” segment of pipe from the plant to “D” Street cannot. The back-feed pipe from the A/M to the campus is only 8”. There is no point in putting a boiler at A/M any bigger than the 8” back-feed can handle at 12 psig plus loads at Wendell Hill Hall and any future loads which might be added in this area.

Assuming CWU will accept 7,200 fpm for peak loads, since they do not last long, the capacity of the A/M back-feed is only 7,000 lb/hr. The 18” pipe from the Plant to the campus could deliver 44,000 lb/hr bringing the total capacity to the main campus to 51,000 lb/hr.

Since the assumption was that Randall/Michelson was to be taken off the grid, Wendell Hall A and B loads are on the “other side” the A/M site, and distribution losses are much smaller at 12 psig, the remaining peak load at 0F ambient is 55,000 lb/hr. So with a few modifications to warmup loads, the campus could possible run year round at 12 psig.

However, going back to the last section, we believe that to do this, CWU would have to replace all of the distribution traps. There is no way they keep water out of the pipes at full load and only 12 PSIG.

To summarize, the six potential costs would be:

1) Modify Randall/Michelson to be stand-alone building.
2) Modify the steam nozzle on all four boilers.
3) Install a new boiler at the A/M location.
4) Potentially upsize some building bypass piping (and perhaps even some steam branches)
5) Replace all the distribution traps, and
6) Replace the 100 feet of 12” pipe from the plant with 18” pipe.

Long Term Future Loads: If the campus grows by anything close to an additional 20,000 pounds per hour of steam load, then the need to renovate the heating equipment becomes magnified. The plant would operate many hours with three boilers online. Any boiler being out of service would leave the plant with no redundancy. It is safe to assume that by the time the campus grows this much, two or three of the existing boilers will be unreliable if a major renovation is not completed before then.

F. EMISSIONS

Overview: Because the CWU campus is a single facility type under common ownership, all air pollutant emission sources located on the campus must be considered together for purposes of air quality permitting.

The facility is currently permitted as a “synthetic minor” facility, which implies that potential emissions of one or more individual air pollutants could exceed 100 tons per year, but limits in the permit restrict maximum emissions to less than this threshold. Being classified as a synthetic minor facility allows CWU to avoid the requirements of the Title V permitting program.

So, any plans to add emission sources to the campus need to take into consideration whether or not the added source is likely to trigger Title V.

Existing Permitted Sources: The following table lists the emission sources (in addition to the paint spray booth) currently included in the existing air quality permit for the CWU facility. These emission units provide steam for space heating and electrical generation for emergency power loss replacement.

Boilers		Emergency Generators			
Description	Location	Size (hp)	Fuel	Make	Model
Boiler #1	Central Power Plant	749	Diesel	Caterpillar	3412T
Boiler #2	Central Power Plant	749	Diesel	Caterpillar	3412T
Boiler #3	Central Power Plant	643	Diesel	Detroit	8083-7416
Boiler #4	Central Power Plant	490	Diesel	Caterpillar	D346
Boiler #5	Student Village	470	Diesel	Cummins	DQAF
Boiler #6	Student Village	325	Diesel	Perins	1306-E8TTA300
Boiler #1	WAHLE	115	Nat Gas	Cummins/Ford	
Boiler #2	WAHLE	148	Diesel	Onan/A/C	3500
Boiler #1	Health Center	32	Diesel	Onan	
Boiler #2	Health Center	65	Diesel	Perkins	1100
Boiler #1	Brooklane				
Boiler #2	Brooklane				
Boiler #1	Student Union				
Boiler #2	Student Union				
Boiler #3	Student Union				
Boiler #1	President's House				

Table A. Central Washington University – Currently Permitted Emission Units

The existing air quality permit for the campus contains the following emission limits:

Emission Units	NO_x (tpy)	CO (tpy)	SO_2 (tpy)	VOC (tpy)	$PM_{10}/PM_{2.5}$ (tpy)
Central Steam Plant and Student Village Boilers #1-#6 (while fired on natural gas)	60.00	50.40	0.36	3.30	4.56
Central Steam Plant Boilers #1-#4 (while fired on No. 2 distillate fuel oil)	6.00	1.50	0.06	0.10	0.99
Other 10 Specified Boilers (fired solely on natural gas)	4.35	3.65	0.03	0.24	0.33
9 Specified Emergency Generators (fired solely on diesel)	19.48	3.72	1.88	2.27	1.16
Cummins/Ford Emergency Generator (fired solely on natural gas)	0.70	0.61	0.0001	0.07	0.002
Paint Booth	0	0	0	1.30	0
Total	**90.53**	**59.88**	**2.33**	**7.28**	**7.04**

Table B. Central Washington University - Currently Permitted Emission Limits

As long as the sum of all emission limits at the facility for each pollutant remain under 100 tons per year after the addition of new emission units, the facility can continue to be permitted as a synthetic minor source. If this was not feasible (emission sources were added to the point of taking one or more pollutants over 100 tons per year), then the facility would need to apply for a Title V air operating permit with the DOE. Although this would not affect the ability of the facility to operate onsite emission units, the Title V permitting program does require a higher level of compliance monitoring and has higher associated annual fees than are required under the current synthetic minor permit (discussed further below). Note that if potential emissions of any individual air pollutant were to exceed 250 tons per year, the facility would need to apply for a Prevention of Significant Deterioration (PSD) air permit, which can have significant permit application requirements.

The current emission permit also contains the following usage limits to ensure emissions will not exceed the limits shown in Table B:

Emission Unit Group	Permit Usage Limit
Central Steam Plant and Student Village Boilers #1-#6 (while fired on natural gas)	1,200 million (10^6) cubic feet of natural gas per 12-month period
Central Steam Plant Boilers #1-#4 (while fired on No. 2 distillate fuel oil)	600,000 gallons of No.2 distillate fuel oil per 12-month period
Other 10 Specified Boilers (fired solely on natural gas)	No limits – may operate at maximum capacity for all 8,760 hours per 12-month period
9 Specified Emergency Generators (fired solely on diesel)	500 hours per 12-month period maximum for each generator
Cummins/Ford Emergency Generator (fired solely on natural gas)	500 hours per 12-month period maximum
Paint Booth	55 gallons of paint per month

Table C. Central Washington University – Permit Usage Limits

Greenhouse Gases: Although the CWU facility is nowhere near emitting 250 tons per year of any individual air pollutant, there is one exception to this threshold. Greenhouse gases (GHGs) are treated different from all other air pollutants under air quality permitting programs. As a result of the U.S. EPA "Tailoring Rule", special emissions-based thresholds have been set for GHGs. A facility with GHG emissions (expressed as CO_2 equivalent emissions; CO_2e) exceeding 100,000 tons per year becomes a Title V major source.

As shown in the table below, the CWU campus is currently very close to exceeding the 100,000 ton per year threshold for GHGs, with estimated potential GHG emissions of 91,686 tons per year of CO_2e.

Table D. Central Washington University - Estimated Potential GHG Emissions

GHG Emission Source(s)	Annual Usage Data				GHG	lb/MMBtu	CO_2e (tpy)
Natural gas limit for Central Plant and Student Village Boilers #1 - #6	1,200,000,000	ft^3/yr	1.03E-03	MMBtu/ft^3	CO_2	116.644	71,946
	1,200,000,000	ft^3/yr	1.03E-03	MMBtu/ft^3	CH_4	0.0022	28.50
	1,200,000,000	ft^3/yr	1.03E-03	MMBtu/ft^3	N_2O	0.00022	42.07
Fuel oil limit for Central Plant and Student Village Boilers #1 - #6	600,000	gal/yr	1.38E-01	MMBtu/gal	CO_2	161.15	6,671.6
	600,000	gal/yr	1.38E-01	MMBtu/gal	CH_4	0.0066	5.7
	600,000	gal/yr	1.38E-01	MMBtu/gal	N_2O	0.00132	16.9
Other 10 Specified Boilers (fired solely on natural gas)	10.13	MMBtu/hr	8,760	hrs/yr	CO_2	116.644	5,175
	10.13	MMBtu/hr	8,760	hrs/yr	CH_4	0.0022	2.05
	10.13	MMBtu/hr	8,760	hrs/yr	N_2O	0.00022	3.03
9 Specified Emergency Generators (fired solely on diesel)	192.24	gal/hr	500	hrs/yr	CO_2	161.15	7,744.9
	192.24	gal/hr	500	hrs/yr	CH_4	0.0066	6.7
	192.24	gal/hr	500	hrs/yr	N_2O	0.00132	19.7
Emergency Generator (fired solely on natural gas)	0.81	MMBtu/hr	500	hrs/yr	CO_2	116.644	24
	0.81	MMBtu/hr	500	hrs/yr	CH_4	0.0022	0.01
	0.81	MMBtu/hr	500	hrs/yr	N_2O	0.00022	0.01
Total							**91,686**

These emission estimates are based on U.S. EPA factors provided in the federal mandatory GHG reporting rule (40 CFR Part 98, which could currently apply to the CWU facility depending on actual fuel usage levels) and the equipment usage limitations in the current air permit.

Therefore, if any new sources were to be added to the CWU air permit, it would be important to keep track of the effect on potential GHG emissions to ensure that the 100,000 ton per year CO_2e threshold was not exceeded if possible (to prevent becoming a Title V source). Any usage limit may be applied to any emission unit to restrict potential emissions as long as the usage can be monitored and recorded (e.g. based on monitoring hours of operation, fuel usage, etc.).

Consequences of Exceeding Title V/PSD Emissions Thresholds: As noted above, the CWU campus emission units are currently permitted under a synthetic minor air permit. If permitted emissions for any individual air pollutant were to exceed 100 tons per year, the facility would be required to obtain a Title V permit. Obtaining this permit would be relatively straightforward, but would entail likely additional monitoring, recordkeeping, and reporting, as well as the payment of annual emissions-based fees to support the DOE Title V permitting program.

DOE Title V annual permit fees for a facility of the complexity of the CWU facility would include an annual flat fee of roughly $55,000 plus an emissions based fee of about $40 per ton of actual emissions of PM_{10}, SO_2, NO_x, and VOC (based on data from 2009 – 2011). Fees are adjusted as necessary to cover the cost of the Title V permitting program. Also, as a Title V source, additional source emissions testing might be required, increasing annual compliance costs by another $20,000.

If, in the future, permitted emissions of any individual air pollutant exceeded 250 tons per year, the facility would become a major source under the PSD permitting program. While the operating permit under this program would still be a Title V permit, the requirements to obtain a PSD construction permit for new emission units becomes significantly more burdensome.

SECTION III: CHILLED WATER SYSTEM

A. OVERALL SYSTEM DESCRIPTION

Originally, there was a south chiller plant co-located with the old boiler plant, and a "north chiller plant", located on an upper floor of the current boiler plant. The south chiller plant was abandoned in 2000, and the "north" chiller plant is now the only central chilled water plant.

The chilled water plant (the "CW Plant", or "Plant") includes four "cooling units". Three of the units are water cooled centrifugal chillers, and one is a flat plate heat exchanger, designed to be used for "free cooling" when ambient conditions fall within certain parameters. The total mechanical cooling capacity is 1,200 / 900 / 1,200 = 3,300 tons. The flat plate heat exchanger (HX) appears to have been designed to produce a 5.0 F delta T with 1,800 GPM, or 365 nominal tons.

There are three cooling towers (CTs) to serve the four cooling units. Each tower was matched to a corresponding chiller. Originally, the condenser water pumps (CWPs) both pumped into and pulled from common condenser water headers. Thus any combination of CTs and CWPs could work with any combination of chillers, as long as the CT/CWP combination provided enough condenser water flow and heat rejection capacity to satisfy the operating chiller(s). Likewise, any CWP could also serve the "cold side" of the flat plate heat exchanger (HX) in the free cooling mode. When Chiller 1A was installed in 2006, however, new chilled water and condenser water pumps were installed, as was a new cooling tower. This tower can be connected to the common condenser water inlet / outlet piping shared by the other two towers, but only by operating the manual valves that isolate CT-1A. Normally, as Figure 17 below shows, CT-1A is isolated, and can serve only CH-1A.

The Plant chilled water pumping is configured in a primary / secondary arrangement. There are two constant volume primary chilled water pumps (CHPs), one variable speed thermal energy pump (TEP), and three variable speed secondary chilled water pumps (SCHPS).

The two CHPs (including CHP-1A) have common suction and discharge headers, and can thus serve any chiller or the flat plate HX. The TEP is piped such that it can also draw from the common chilled water suction header, and pump into the common discharge header. However, using actuated control valves, it can be isolated from the common headers in a number of configurations (or cooling modes – see below).

The plant also contains a 1,000,000 gallon chilled water storage tank. The tank uses the buoyancy principal to separate the colder, denser water on the bottom from the warmer, less dense water on top. CWU's experience indicates that about 90 percent of the volume is useable storage.

The secondary chilled water pumps (SCHPs) are a skid-mounted package, with built-in controls. The pre-packaged system is by the manufacturer Systecon – and uses commercially available pumps, variable frequency drives, etc, which are packaged with Systecon controls to produce a compact, factory-assembled pumping / control package.

The chilled water, condenser water, and thermal storage systems are controlled by a direct digital control (DDC) system, manufactured by Alerton. This system automates the control of the plant. As originally programmed, it contained a large number of "cooling modes", based on combinations of chillers, free cooling, storage charge/discharge, and so on. Depending on "mode", the status of the individual pieces of equipment and the flow of water is controlled by approximately sixteen 2-position control valves. See the cooling modes subsections below for more detail.

Figures 17 and 18 below show the control graphics for the chilled and condenser systems, respectively.

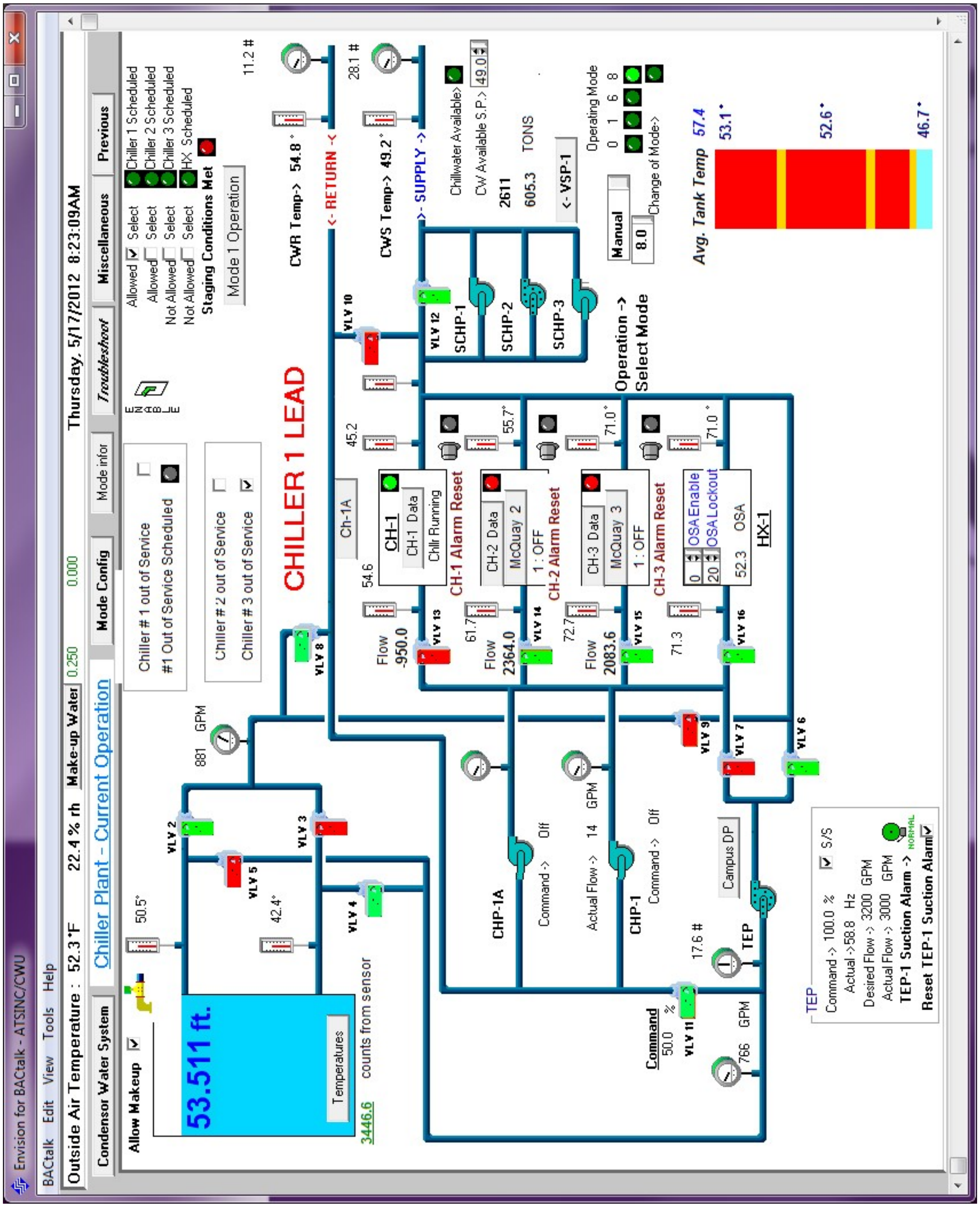
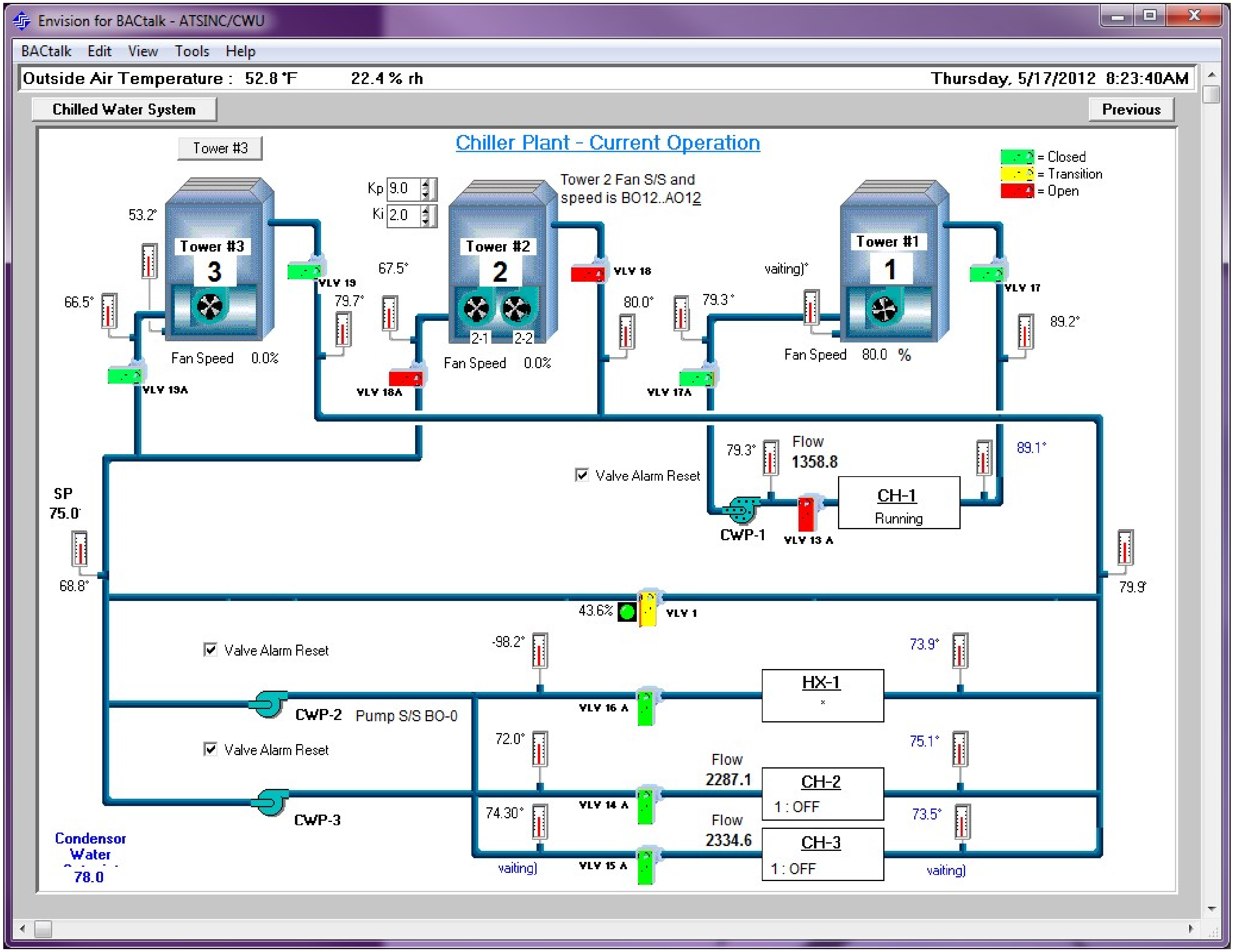


Figure 17, chilled water control graphic



Outside Air Temperature : 52.8 °F 22.4 % rh

Thursday, 5/17/2012 8:23:40AM

Tower 2 Fan S/S and speed is BO12..AO12

Figure 18, condenser water control graphic.

Cooling Modes – As Designed: As originally conceived, there were 10 distinct cooling "modes" – a mode here is defined primarily by the operating equipment and the flow path the water takes, which in turn is determined by the position of the 16 control valves. The location of the control valves can be seen in Figure 17 above. There are additional control valves associated with the condenser water flow, but this subsection deals specifically with cooling modes, and thus only those valves that control chilled water flow.

The primary reason for the thermal storage tank was not, as it is often is, because of punitive time-of-day electrical energy and demand charges. It was to take advantage of the fact that in the Kittitas Valley, nights are often relatively very cool and very dry, regardless of how hot it gets during the day (OATs in excess of 100 deg F are not uncommon). Given the cool, dry nights, there is generally little or no campus night-time cooling load to be met. Because the ambient wet bulb temperature is also low, the cooling towers can produce very cold condenser water with minimal fan energy. The storage tank full of warm return water (from the day's cooling load) provides a large, stable chilled water load.

Therefore, during night time tank charging, the active chiller can be run in the most energy efficiency manner; low inlet condenser water temperature and a stable fixed cooling load. Chillers are generally at their peak efficiency between about 80 and 90 percent of full load – in the charging mode, the chiller output can be fixed in this "sweet spot". These cooling modes were therefore devised to minimized energy use by taking advantage off the cool nights, and are made possible by the thermal storage tank.

The 10 cooling modes are summarized below (and abbreviated as CM1, CM2, etc):

- **CM1**: Normal Chiller (1 or 2 chillers). Chilled water return (CHR) from the campus distribution flows into the common CHP suction header. One or more CHPs pump through the active chiller(s). The primary chilled water supply (PCHS) water flows to the secondary chilled water pumps (SCHPs), which modulate the SCHS flow to meet campus cooling loads. If, as is usually the case, PCHS flow exceeds SCHS flow, the excess PCHS flows through the primary / secondary bridge into the CHR. If, on the other hand, SCHS flow exceeds PCHS flow, then CHR flows the other direction through the bridge to the SCHP inlet. This "reverse flow" would dilute (raise) the SCHS temperature, and is generally to be avoided.
- **CM2**: Normal Chiller (3 chillers). Same as CM1, except that all three chillers are one. This is considered a distinct mode.
- **CM3**: Manual. Same as CM1 or 2 (depending on No. of chiller operating), except that the SCHPs are bypassed. The operating CHPs pump all the way out to the

distribution system and back. The primary / secondary bridge still bypasses excess CHS into the CHR.

- **CM4**: Tank Discharge Only. CHR is diverted to the top of the storage tank. All CHPs are off. The variable speed TEP draws cold water off the bottom of the storage tank. This chilled water bypasses the SCHPs, and is pumped directly into the distribution system, and out to the buildings. Because TEP is variable speed, no flow through the bridge in either direction is required.
- **CM5**: Tank Discharge with Mixing. When the cooling load is low, there are times that the buildings do not require very cold chilled water. In such times, this mode can be used to lengthen the time the storage tank can operate before depleting the tank. In this mode, some of the CHR is diverted to the top of the tank, but some is bypassed to the inlet of TEP. This warm CHR mixes with the cold CHS flow that TEP is drawing from the bottom of the tank – the result is “warmer” (perhaps 45 – 48 deg F) chilled water. This lengthens the time before the cold stored chilled water is diluted with warmer CHR.
- **CM6**: Tank Discharge and 1 or 2 Chillers. The control valves isolate TEP from the common CHP suction header. TEP draws cold water from the storage tank, and pumps it into the common discharge header. One or more CHPs pull CHR from the common suction headers, through the operating chiller(s), and into the common discharge header. The tank water and chiller water mix, and then flow to the SCHPs (or through the primary / secondary bridge) as in CM1 or 2 - the SCHPs modulate the SCHS flow to the campus to meet load.
- **CM7**: Tank Discharge and 3 Chillers. Same as CM6, except all three chillers operate.
- **CM8**: Charge Tank with Chiller: TEP draws warm water from the top of the tank. It pumps though one operating chiller. The flow path to the SCHPs and the bridge are shut off by valves, and chilled water is diverted to the bottom of the tank. Because the colder water is the densest in the tank, it continually pushes the warmer water to the top, where it is drawn off to be cooled. The capacity of TEP is such that it can cycle all the tank water through the operating chiller twice in an 11 hour charging period (see Figure 3).
- **CM9**: Charge Tank with HX-1. Same as CM8, except that the tank is cooled using “free cooling” via the flat plate HX. This mode was intended to be used in during that part of the year when the temperature at night is in the 40’s or below, and the daytime temperature is in the 60’s or low 70’s (May and late Sept / early Oct). During such times, the night-time temperature low enough to allow the cooling towers and HX-1 to generate water cold enough to charge the tank. Given the lower flow rate through the HX, however, it cannot fully charge the tank as a chiller can. Thus, this mode can only be used when the subsequent day-time cooling loads are mild – i.e. when the OAT is in the 60’s or early 70’s. This is intended as an energy saving measure.
- **CM10**: Charge Tank and Serve Load. In its simplest form, this mode uses one chiller. TEP draws warm water from the top of the tank (as in CM8). The system CHR is diverted to the inlet of the TEP (as in CM5). The two warm flows mix, and

are pumped though the operating chiller. Unlike CM8, however, the flow path to the SCHPs is not shut off at the valves. The cold chilled water from the common discharge header splits – some goes to the SCHPs for distribution to the campus, and some flow to the bottom of the tank, charging it. A modulating control valve controls the tank inlet flow rate, while the speed of the SCHPs controls the flow to the campus. For the remainder of this report, this will be called **CM10-A**.

- **CM10-B**. CWU also uses a variation on this, which was not part of the original cooling mode programming. In this mode, two chillers are used, not just one. Both pump into the common chilled water discharge header. This increases the amount of flow that go to the campus SCHS loop, while still maintaining the tank charging flow.

<u>Cooling Modes – As Utilized</u>: In practice, CWU does not utilize all these cooling modes. Basically, CWU has reduced the operating modes to three simple schemes:

1) They charge the tank at night using one chiller **(CM8)**
2) They serve the day-time load with tank discharge water only (**CM4**, relatively cool weather)
3) As it gets hotter, they serve the day-time load with a combination of tank discharge water and up to two chillers (**CM6**).

CWU also uses the **CM10-A** mode, but they do not consider it a separate “mode”, simply a variation of their “basic three” modes. As the weather gets hotter, these modes are applied as follows:

<u>Minimal day load / No night load</u>: Tank is charged at night using one chiller. Tank is discharged during the day to meet load.

<u>Medium day load / Minimal night load</u>: Tank is charged at night using one chiller. Some chilled water is diverted from the night-time tank charging and used for campus cooling. The proportion of flow to the campus may be increased around 4.00 AM or later to make sure the loop is cool prior to the buildings switching to Occupied Mode. Once tank charging is complete, the campus may be cooled by the tank only during the early morning, but as day heats up, a chiller is brought on line to supplement the tank.

<u>Large day load / Medium night load</u>: A single chiller is used to charge the tank, with some diversion of chilled water to the night-time load. However, in order to meet the night load and make sure the tank gets fully charged, a second chiller (usually the 900 ton unit) is brought on line during the charging process (generally in the morning).

Day-time load is met with the tank discharge and two chillers, generally a 1,200 ton and the 900 ton unit.

Very Large day load / Medium night load: Charging is again done with one chiller dedicated to the charging, and second chiller brought on the help meet campus load. In the hottest weather (~ 95 - 100 deg F plus), however, CWU must use the tank and two 1,200 ton chillers to meet campus day-time loads. This need for two 1,200 ton chillers has only come about in the last year or two, as new chilled water loads have been added.

B. PLANT CAPACITY AND COOLING LOADS

There are currently three water-cooled centrifugal chillers, as shown in Figure 19 below: As noted above, on most occasions, only a single chiller is needed, and it is generally CH-1A or CH-3. When two chillers are required, it is often CH-2 that is used as the Lag Chiller.

Chillers

				evaporator		condenser			
tag	nom cap tons	mfg	year installed	temps deg F	flow gpm	temps deg F	flow gpm	refrig-erant	volts @ 3 ph
CH-1A	1,200	Carrier	2006	52>42	2,880	85>95	3,600	134A	4,160
CH-2	900	McQuay	1994	52>42	2,160	85>95	2,700	134A	4,160
CH-3	1,200	McQuay	1999	50>40	2,880	80>90	3,600	134A	4,160

Figure 19, chiller data.

Within the last year or two, the peak cooling load has reached a point where the two largest chillers are sometimes required; thus the plant mechanical cooling capacity has slightly less than n+1 redundancy (since the loss of a 1,200 unit would leave CWU unable to meet the worst case loads). Although the chilled water storage tank could be viewed as a "fourth chiller" (at least when charged), it does not add to the redundancy. This is because on the hottest days, the load requires three "chillers" – two chillers and the tank discharge. Chiller reliability is thus an important issue.

Using the data from Figure 20 below, if we use 660 tons as the "capacity" of the thermal storage tank, total plant capacity is 3,960 tons.

Peak Cooling Load – Current: Anecdotally, CWU believes their peak load to be about 2,700 – 2,800 tons. Part of the uncertainty arises from the fact that the thermal storage tank "stores" ton*hrs of cooling, not tons. The actual delivered cooling in tons depends on the rate at which the tank chilled water is pumped out.

The tank was designed for a 10 deg F delta T (the change in temperature between the warm CHR at the top and the cold CHS below that top layer), and has reportedly achieved a 15 deg F delta T. However, CWU personnel report that current practice is to charge the tank at 43 deg F. If the CHS setpoint is 44 deg F in hot weather, and the loop achieves the target loop delta T of 10 deg F, the tank would operate at about an 11 deg F delta T. As noted above, CWU considers the “fully charged” cold storage volume to be about 90 percent of the total volume (with the warm stratified layer taking up the other 10 percent).

At 43 deg F, the density of water is 62.4251 lb/ft^3. The peak storage capacity would be calculated as:

> 1,000,000 gal * 0.90 useable * 231 in^3/gal / 1,728 in^3/ft^3 * 62.4251 lb/ft^3 * 1.0 BTU/lb/deg F * 11 deg F / 12,000 BTU/h/ton = 6,885 ton*hrs.

If the tank were discharged at a uniform rate over the whole “cooling day” (~ 7.00 AM to 11.00 PM, or 16 hours), the tank would be equivalent to a 6,885 / 16 = 430.3 ton chiller. Of course, when the tank is the sole cooling unit, the output varies as the load does, so the tank does not discharge uniformly. When used in conjunction with chillers, however, the discharge rate is fairly stable. Figure 20 shows a matrix of “equivalent tank capacity” as a function of discharge period. In addition to a number of “whole-number” periods (16 hours, 12 hours, etc), the matrix calculates the discharge periods that correspond to 900 and 1,200 tons – the capacities of the existing chillers.

Chilled Water Storage Tank Capacity	
discharge period hours	equiv capacity tons
16	430.3
14	491.8
12	573.8
11	625.9
10	688.5
8	860.6
7.65	**900.0**
6	1,147.5
5.74	**1,200.0**
4	1,721.3

Figure 20, storage tank equivalent capacity.

CWU reports that on a typical “very hot” day, the tank would start discharging at about 9.00 AM and by “7.00 or 8.00 PM”, it would be depleted – a total of 10 to 11 hours of discharge. Figure shows that this is equivalent to an average output of between 626 and 689 tons.

The upper bound on the current peak load: 2 chillers at 1,200 tons + 689 tons of tank output = 3,089 tons. However, we know that until just recently a 1,200 ton and a 900 ton chiller (plus the tank) was sufficient and that two 1,200 ton chillers are needed only on the very hottest of days. A more likely peak load might be:

> 2 chillers at 1,100 tons + 660 tons of tank output (~ the average value) = 2,860 tons. This is a good match to the anecdotal value, so for this study, we will consider the current peak chilled water load to be 2,860 tons at 100 deg F OAT

The current estimated load profile is showed in Figure 21 below. In addition, the load profile calculated in a 2009 study is included. This study made use of data from the control system to plot the load. One major difference between the two (aside from the fact that the load has increased since 2009) is that the current profile shows the Shaw - Smyser (S-S) load. Due to internal loads, this building requires mechanical cooling in ambient conditions all the way down to 35 deg F OAT.

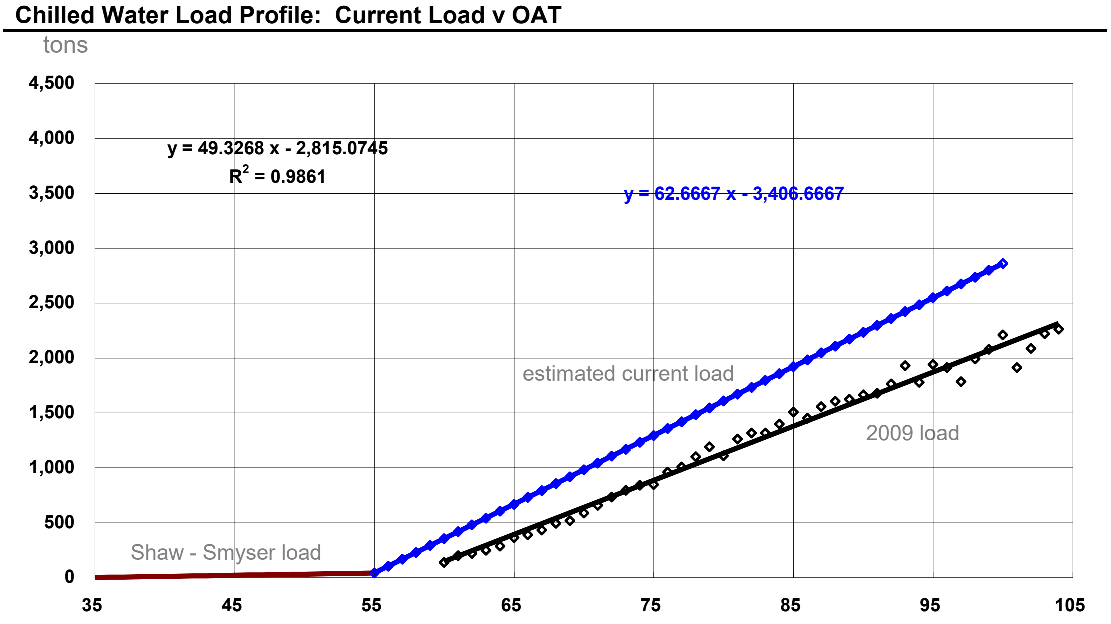
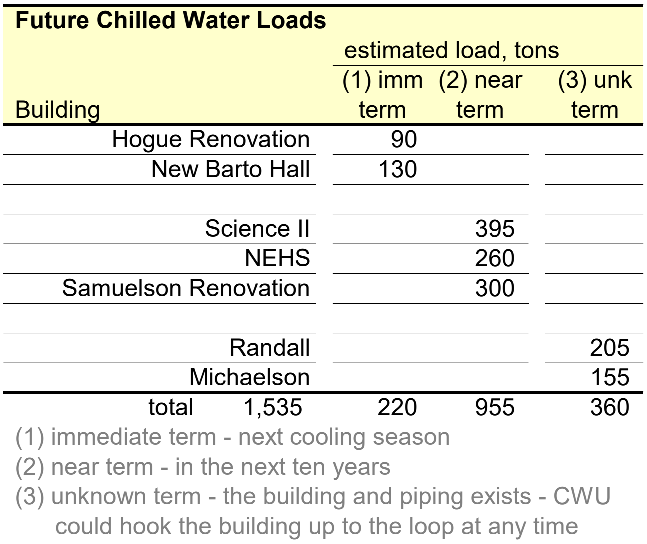


Figure 20, chilled water load profile.

Note that the 2009 data shows a very close correlation (R^2 = 0.986) between the OAT and the chilled water load – this linear relationship is assumed to hold for all of the projected load profiles.

Chilled Plant Peak Load – Future: Future chilled water loads (buildings to be added to the loop) are divided into three categories: immediate term (IT) loads, near term (NT) loads, and unknown term (UT) loads. Figure 22 below shows the estimate peak loads of all three types of load, by building.



Future Chilled Water Loads

Building	(1) imm term	(2) near term	(3) unk term
	estimated load, tons		
Hogue Renovation	90		
New Barto Hall	130		
Science II		395	
NEHS		260	
Samuelson Renovation		300	
Randall			205
Michaelson			155
total 1,535	220	955	360

(1) immediate term - next cooling season
(2) near term - in the next ten years
(3) unknown term - the building and piping exists - CWU could hook the building up to the loop at any time

Figure 22, future chilled water loads.

The values in Figure 22 pose a significant challenge to CWU; within 10 years, the peak cooling load could increase by 50 percent or more – easily exceeding the existing plant capacity. Assuming these estimates are valid, the peak load could increase to ~ 4,400 tons by 2022. This exceeds the combined capacity of all the chillers plus the tank (3,960 tons, see above) by 400 tons.

Even the IT loads pose a problem – if the current peak is in fact 2,860, the addition of Hogue and the new Barto would increase the peak load to 3,080 tons. Not a large increase, but the issue is that it pushes the peak right to the edge of or slightly beyond the capacity of the two 1,200 tons chillers plus the tank (estimated at 3,060 tons). By the end of the 2012 cooling season, CWU may require the tank plus all three chillers to meet the load on a 100 plus OAT day.

However, there are only three primary chilled water pumps (see below), and four "chillers" (if one counts the tank as a chiller), so it is not currently possible for CWU to run three chillers and discharge the tank at the same time. Since CH-2 has more instantaneous capacity than the tank, once the load exceeds about 3,060 tons, CWU would have to shut down the tank, and run three chillers. This extends their capacity out to 3,300 tons, but it defeats the purpose of the tank by running the chiller full out during the day. In addition, given that they have condenser water flow problems (see below) when both 1,200 ton chillers run, they may not be able to run three chillers in any event.

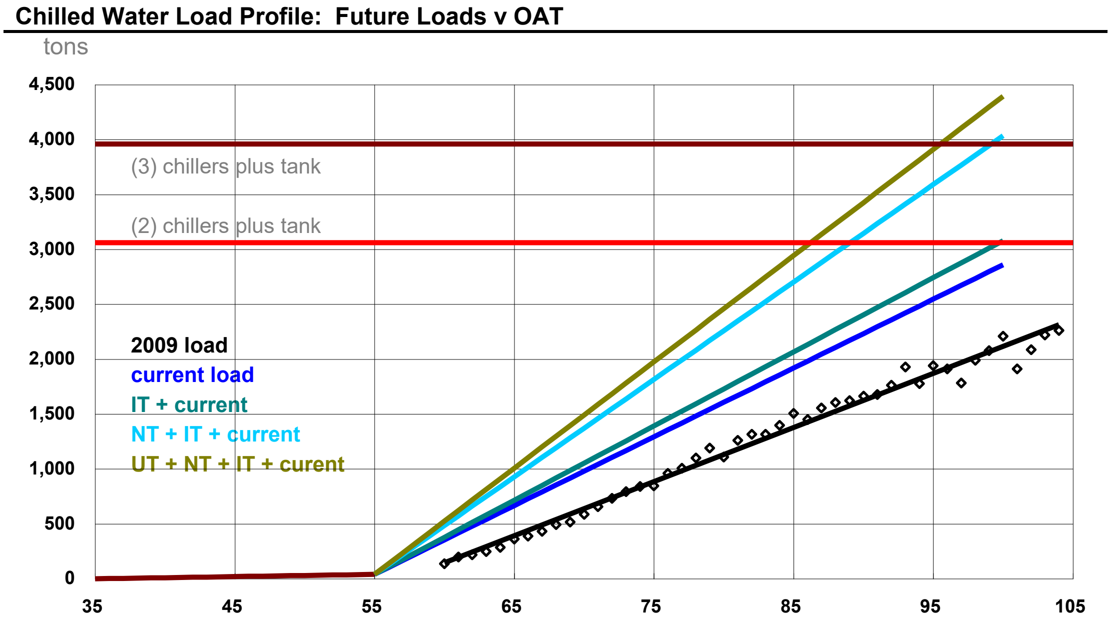
Even if CWU can successfully run three chillers, they may not be able to get the chilled water to the campus. Secondary chilled water pumps have a maximum scheduled SCHW flow of 6,480 GPM. At 2.4 GPM per ton (which equates to a 10 F loop delta T), this is enough water to transport 2,700 tons of cooling – this is less than the current peak load, even before the IT loads are added. The pumps appear to be able to meet the current peak, but it is obvious that CWU will run out of pumping capacity before it runs out of cooling capacity.

It is theoretically possible for CWU to use the primary chilled water pumps to pump water into the campus loop. The chiller flows are constant, and the loop flows are variable; there are two potential ways to resolve the differences in flow. First, CWU could simply let the primary pumps "ride the pump curve" – to reduce flow as system head pressure rises, and vice versa. In this scenario, the chiller flows would become variable. This is common today, but it is unknown how a 1994 chiller would respond to variable flow. In the second scenario, the valve in the primary secondary bridge could modulate to bypass excess primary chilled water back to the system return water. The existing valve is probably not suitable for this, and would likely need to be replaced.

Having said that it is possible, CWU has never tried using the primary pumps to pump the loop, so it is a very large unknown. What is known is that the primary pumps have enough flow capacity to pump all three chillers, and they have significantly more head capacity than the secondary pumps – 115 FT vs 90 FT. The combined flow capacity of the primary pumps plus TEP is 8,040 GPM, more than enough to transport 3,080 tons. By the end of 2012, therefore, CWU may be forced to attempt primary pumping in order to get the required cooling out the buildings on the campus loop. This should be considered a short term fix only.

Many facilities place more importance on redundancy in the heating plant than in the cooling plant; by the end of 2012 CWU will effectively have zero cooling redundancy based on their existing cooling units.

Beyond the IT loads, the NT and UT loads mean that within ten years, not only would CWU not have a redundant chiller, they could not meet load at all on the hottest days. The effect of these future loads on the load profile is shown in Figure 23 below:



Fgure 23, future chilled water loads.

In addition to the load profiles, Figure 23 shows the chilled plant capacity using two and three chillers in conjunction with the tank.

Finally, in terms of peak load, it should be noted that some buildings have dedicated chillers for process loads – the Computer Center, Dean Hall, Science, Archives, etc. In some cases, the "primary" cooling is the loop, and the back-up is the dedicated chiller; in some case it is the reverse. This brings up two issues: 1) should a dedicated chiller fail, that could increase the chiller plant load beyond even the figures shown above, and 2) except when the load is very high, it would seem to make sense that the campus loop be the "primary" chiller – since the loop runs year round. The exception would be cases in which the chilled water temperature required by the process is less than the loop temperature – one building should not "drive" the entire system setpoint.

In terms of redundancy, it is important to remember that the "balance of plant" (BOP) equipment can have an effect on Plant capacity as well as the chillers. The BOP equipment is those pieces, such as pumps, cooling towers, etc, that support the chillers. Each type of BOP equipment is discussed in its own subsection below, but BOP in general is included here due to its effect on redundancy.

There are only three CTs, and three chillers, so the loss of any tower means that one chiller would also need to be shutdown. Likewise, the loss of any condenser water pump (CWP) or primary chilled water pump or TEP would mean that one chiller would not be available. Because the pumps were sized for the associated chiller, CHP-1 (confusingly, CHP-1 is paired with CH-2) and CWP-2 cannot support CH-1A or CH-3 – the flow rate is too low. So despite the common pumping headers, it does matter which pump or CT fails. More detail is provided below.

Chiller Issues:

ASHRAE lists the service life of a centrifugal chiller as 23 years, on average. Chillers in the NW part of the country do not always get worked as hard as those in other areas, so 25 years is probably a fair life expectancy. That would mean that CH-2 should be schedule for replacement no later than about 2019, and CH-3 four years after. That is about the time scale on which CH-2 would need to be replaced for capacity reasons. Until that time, however, CWU must keep the chillers running, and there have been a number of operational issues with the chillers.

> CH-1A is the newest chiller. However, use has been limited until very recently by flow problems and an apparently faulty surge sensor. Surge occurs when the discharge pressure of the compressor is less than the compressor inlet pressure – the refrigerant then attempts to flow backwards through the compressor, causing a series of pressure waves, or surge, through the unit. This can quickly destroy the impeller. Thus a surge sensor trips the unit off-line before surge can occur. CH-1A has a history of tripping off-line due to incipient surge. There are a number of issues that can cause this pressure "reversal", including low condenser water temperature or flow. CWU did seemingly have a low condenser water flow problem, and so surge may in fact have been an issue. However, once the flow problem was solved, the chiller still tripped out on incipient surge. The manufacturer felt that it was still a flow problem, which delayed the use of CH-1A further. It seems to have finally been determined that the unit was not in pre-surge; the sensor was faulty, causing false trips. The operators have recently begun using CH-1A as the Lead Chiller.

CH-2 is the oldest chiller, and the smallest in capacity; however, it is the only chiller that has not had any major issues that would affect reliability.

Until very recently, CH-3 has been the most reliable chiller, and was generally the Lead Chiller. Historically, however, it has suffered several incidents of damage and subsequent rebuild. In 2005, due to internal faults, the compressor impeller shifted so far axially that it rode up against the thrust bearings – at that point, the impeller was destroyed, and shards of metal were strewn through the unit. All of these shards had to be removed for fear of future damage. Subsequently, the chiller has had tube failures – on a high pressure machine (such as an R134A machine), this means the refrigerant leaks into the water; but ultimately, both fluids end up contaminated. CH-3 had to have a complete refrigerant replacement after the tubes were fixed. Nevertheless, after several rebuilds and repairs, CH-3 was until recently the chiller of choice. Now that CH-1A is operating reliably, it is normally the lead chiller.

Flat Plate Heat Exchanger:

The flat plate heat exchanger (HX) was installed in 1999, and was intended as an energy saving measure. Given the cool, dry nights in the Kittitas Valley, the original intent (based on the control schematics) was that given the right conditions, the cooling towers could be used to generate water cold enough to charge the storage tank and meet low load cooling loads. The flat plate HX offers a way to transfer the heat from the chilled water to the condenser water, which is then cooled by the cooling towers. Cooling towers use much less energy than chillers, thus saving energy (despite the name “free cooling”, it does require cooling tower fan energy).

The HX, manufactured by Alfa Laval, was designed for 1,800 GPM flow on both sides, hot and cold (with a five degree delta T, or 375 nominal tons). A flat plate heat exchanger was used because the usefulness of the concept depends on the smallest practical “approach” between the two flows (chilled and condenser water). The approach temperature in this case is the difference in temperature between the cooling medium (condenser water) and the medium being cooled (chilled water). Flat plate heat exchangers, unlike shell and tube heat exchangers, can produce true counter-flow heat exchange, thus they produce significantly smaller approach temperatures. The value of a small approach temperature is shown below.

Cooling towers also transfer heat, from water to air, and thus approach temperature applies here as well. Because cooling towers use evaporative cooling, the relevant approach temperature for a cooling tower is the difference between the ambient wet bulb temperature and the leaving condenser water temperature. Ultimately, then, the ability of the system to utilize the HX depends on the total approach temperature between the ambient wet bulb and the desired chilled water storage temperature.

Storage Tank:

The storage tank is an above-ground, 1,000,000 gallon vertical storage tank. It was built on site, and is open to the atmosphere. It stores thermal energy by “floating” a layer of less dense, warm water on top of denser, colder water below. The border between these two layers, which must be kept distinct, is the thermocline.

The piping in the tank is arranged to avoid turbulence, and thus mixing. If excessive turbulence were to occur, the thermocline would be upset, and the tank water would mix, rending it largely or completely useless as a thermal storage device.

As Figure 16 shows, the piping is arranged such that the TEP and CHPs can draw from top and bottom of the tank; likewise, they can pump into the top or bottom as well.

At the end of a cooling day, the tank is largely filled with warm return water (CHR). The thermocline is at a very low elevation in the tank, if it still exists. To charge the tank, water is drawn off the top of the tank, pumped through a chiller, and then back into the bottom of the tank. Over the eight hours of charging the thermocline is gradually elevated as more cold water is pumped in – eventually about 90 percent of the tank water is cold water below the thermocline.

To discharge the tank, the pump (usually the TEP) now pulls from the bottom of the tank. The cold tank water is pumped out the campus distribution, and the warm CHR is piped into the top of the tank, above the thermocline.

The subsection Cooling Modes – As Designed above details all the pumping variations that the tank makes possible. Figure 19 above tabulates the storage capacity of the tank at various discharge rates.

Primary Pumping:

There are two primary chilled water pumps; in addition, TEP can act as a primary pump. Figure 24 provides detail on the pumps.

Primary Chilled Water Pumps / Thermal Energy Pump								
			flow			motor		
	assoc		rate	head	impeller			volts
tag	chiller	mfg	gpm	ft	in	HP	rpm	@ 3 ph
CHP-1A	CH-1A	PACO	2,880	115	11.55	100	1,800	480
CHP-1	CH-2	PACO	2,160	115	11.80	100	1,800	480
TEP	none	PACO	3,000	115	11.70	100	1,800	480

Figure 24, primary chilled water pumps.

TEP is a variable speed pump while the other two are constant speed. The pump head, at 115 ft, is high for a primary chilled water pump, but as noted above, in some cooling modes, the three pumps are expected to pump all the way through the campus loop without the use of the secondary pumps (as also noted above, CWU has never attempted this).

In terms of Plant redundancy, it was noted above that BOP equipment affect Plant operations as much as the chillers themselves. In this case, there are three pumps, just as there are three chillers. However, note that the combined flow of TEP and CHP-1 (5,160 GPM) is not enough to operate the two 1,200 ton chillers (required flow 5,760 GPM) – so not all pump failures are “equal”.

On the hottest days, CWU uses the storage tank and two 1,200 ton chillers. Any single primary pump failure would make this impossible; however, this mode represents very few days per year of operation. The most common summer configuration is the storage tank plus one of the 1,200 tons chillers. In this case, a failure of either TEP or CHP-1A would make this configuration impossible, although the tank and the 900 ton chiller could be used – lowering the plant capacity by about 12 percent. A failure of CHP-1, on the other hand, affects only the Tank + (2) chiller configuration.

Finally, a failure of TEP does not disable the storage tank, because either of the other two primary pumps can both charge and discharge the tank. These pumps are not as operationally flexible as TEP, however, because they are constant speed.

Secondary Pumping:

The three secondary pumps are part of the pre-packed, skid-mounted, package manufactured by Systecon. Originally, only two pump were installed, but the package was designed for a third pump, which has since been added. The three pumps are detailed in Figure 25 below:

Secondary Chilled Water Pumps							
		flow			motor		
		rate	head				volts
tag	mfg	gpm	ft	speed	HP	rpm	@ 3 ph
SCHP-1	Bell & Gossett	2,160	90	variable	75	1,785	480
SCHP-2	Bell & Gossett	2,160	90	variable	75	1,785	480
SCHP-3	Bell & Gossett	2,160	90	variable	75	1,785	480
	sum	6,480					

Figure 25, secondary chilled water pumps.

The original Plant design called for the campus loop flow to be 4,200 GPM (only SCHP-1 and -2 were installed). SCHP-3 was added in 2005. Using a 10 deg F delta between SCHS and CHR equates to 2.4 GPM per ton, so the original loop “capacity” was 1,750 tons and the current capacity is 2,700 tons. The current peak campus cooling load, estimated above, is 2,860 tons. Thus, it could be said that CWU is already out of SCHP capacity – by the peak of the 2012 cooling season, they may be failing to meet load due to lack of pumping capacity, especially as the IT loads come on line.

In some cooling modes (**CM3**, **CM4**, **CM5**), the primary pumps bypass the secondary pumps and pump directly into the campus loop. **CM3**, in particular, is called the “manual mode”, using 1, 2, or 3 chillers. In this mode, CWU could conceivably pump the entire chiller capacity (3,300 tons, 7,920 GPM) out to the campus loop.

If the primary pumps can in fact pump the loop (and they have 25 ft more head capacity than the SCHPs), and the secondary pumps are a near term constraint on campus cooling, it is not obvious why CWU even uses the secondary pumps. However, if they intend to continue using the primary / secondary pumping, they will have to upgrade the secondary pumping capacity by next cooling season.

Condenser Water Pumping:

The characteristics of the condenser water pumps are shown in Figure 26 below.

Condenser Water Pumps

			flow			motor		
tag	assoc chiller	mfg	rate gpm	head ft	impeller in	HP	rpm	volts @ 3 ph
CWP-1A	CH-1A (1)	PACO	3,600	80	10.05	100	1,800	480
CWP-2	CH-2	PACO	2,700	80	10.20	75	1,800	480
CWP-3	CH-3	B&G	3,600	80		100	1,800	480

(1) This pump can only serve this chiller

Figure 26, condenser water pumps.

Unlike the primary chilled water pumps, not all the condenser pumps connect to common suction and discharge headers. CWP-1A, is piped directly to CH-1A (and CT-1A). Thus a failure of CWP-1A means CH-1A cannot be used. (The condenser water piping associated with CT-1A and CWP-1A can be made "common" with the other units, but the valves are manual, thus an automated failure response cannot be made by the DDC system.)

CWP-2 and 3 are connected to common headers, so CWP-3 can work with CH-2 or CH-3. CWP-2, however, was sized for CH-2 (2,700 GPM) and thus cannot substitute for CWP-3 (3,600 GPM) in the event of CWP-3 failure.

To summarize,

A) a failure of CWP-1A takes CH-1A off-line,

B) a failure of CWP-2 does not take CH-2 or CH-3 off-line, but it does mean only one of the two can operate, and

C) a failure of CWP-3 takes CH-3 off-line.

In addition to the impact of pump failures, CWU has had an ongoing issue providing enough condenser water flow to run two chillers at a time, especially the two 1,200 ton chillers. As noted above, CWU is very close to having to run three chillers to meet peak load. Given the existing issues, it does not seem likely that the condenser water pumps / piping will support this mode of operation.

Cooling Towers:

The characteristics of the cooling towers are shown in Figure 27 below.

Cooling Towers

					temperatures			motor		
tag	assoc chiller	year installed	mfg	type (1)	inlet deg F	outlet deg F	wet bulb deg F	HP	rpm	volts @ 3 ph
CT-1A	CH-1A	2,006	BAC	ID	95	85	66	50	1,800	480
CT-2 (2)	CH-2	1,994	BAC	FD	95	85	70	(2) - 40	1,800	480
CT-3	CH-3	1,999	Marley	ID	90	80		50	1,800	480

(1) ID = induced draft, FD = forced draft

(2) This chiller originally had two 40 HP main motors, and two "pony" motors - the belts on the pony motors were removed when the VFDs were installed on the main motors

Figure 27, cooling towers.

The CT-1A cooling tower installed at the same time as CH-1A is piped only to CWP-1A and thus to CH-1A (unless manually valved into the common headers). The other two cooling towers have common supply and return headers, and can serve either CH-2, CH-3, or both. As with the condenser water pumps, CT-2 was sized for CH-2 and thus cannot serve CH-3 at full load.

CT-2 could serve CH-3, but only at partial loads; it cannot cool 3,600 GPM by 10 deg F (as required) except perhaps in the coolest of weather. It could keep CH-3 on line at reduced capacity in the event of a CT-3 failure.

To summarize,

A) a failure of CT-1A takes CH-1A off-line,

B) a failure of CT-2 does not take CH-2 or CH-3 off-line, but it does mean only one of the two can operate, and

C) a failure of CT-3 means that CH-3 can operate, but only at approximately ¾ capacity.

C. SYSTEM CONSTRAINTS TO MEETING LOADS

As pointed out in previous paragraphs, several things can go wrong within the Plant that will decrease cooling output. There is more to worry about than the fact that the existing plant cannot meet the future loads expected with the new buildings in the Science Neighborhood. Clearly, to meet those loads the Plant will need to be expanded or additional cooling capacity added elsewhere in the system.

However, other failures within the Plant would have significant impacts on meeting cooling loads. Figure 28 summarizes the effect of different failure modes: Secondary chilled water pumps are not shown because it appears the plant can function without them. This pumping concept is not proven, however, and as shown above, the SCHP package is already out of capacity at peak load. The failure of any SCHP would reduce Plant capacity by one third, or would force CWU to attempt primary-only pumping to make up for the failure.

Equipment Failure vs Plant Capacity

failed equip	avail cap tons (1)	CH-1A	CH-2	CH-3	storage tank
CH-1A	3,300	▨	1.00	1.00	1.00
CH-2	3,600	1.00	▨	1.00	1.00
CH-3	3,300	1.00	1.00	▨	1.00
s tank	3,300	1.00	1.00	1.00	▨
CHP-1A	2,100	0.33	1.00	0.33	0.33
CHP-1	2,400	0.67	▨	0.67	0.67
TEP	2,100	0.33	1.00	0.33	0.33
CWP-1	3,300	▨	1.00	1.00	1.00
CWP-2	3,600	1.00	▨	1.00	1.00
CWP-3	3,300	1.00	1.00	▨	1.00
CT-1A	3,300	▨	1.00	1.00	1.00
CT-2	3,600	1.00	▨	1.00	1.00
CT-3	3,300	1.00	1.00	▨	1.00

(1) This is the maximum capacity under this failure mode

▨ This unit cannot operate

🟩 A value of 0.33 spread across three units means only one of the three can operate in this mode. A value of 0.67 means any two can operate

Figure 28, failure modes.

As Figure 28 shows, only a primary chilled water pump failure can materially affect the Plant capacity. One of the reasons for this is that the storage tank, which functions as the “fourth chiller”, does not “run” (get charged) during peak load times – thus one chiller running at night charging the tank equates to two chillers the next day when the tank is discharging. It only takes one chiller, one tower, and one CHP to charge the tank, so the “fourth chiller” is always available unless a primary CHP goes down (or unless, as Figure 28 shows, the tank itself is down for maintenance)

Only primary chilled water pumps (including TEP) can deliver chilled water, either direct to the campus or to the secondary pumps – therefore, the loss of one of these three pumps limits the Plant Capacity to the output of two chillers, or one chiller and the tank.

The Plant is physically very crowded; however, if CWU were going to do one thing to improve Plant redundancy, it should probably be the addition of a third primary chilled water pump and a fourth secondary chilled water pump. A third primary chilled water pump would mean the plant could utilize all three chillers plus the tank, assuming: 1) they add another secondary chilled water pump, or 2) they use primary-only pumping in this mode, and 3) regardless of chilled water pumping, it would require good condenser water flow to maintain three chillers on line, which does not appear to be assured.

Plant Issues – flow:

The Chilled Water Plant has a long history of flow problems, both on the evaporator side of the chillers and the condenser side. The problem has often been too little total flow, but sometimes it is simply getting the flow to go where needed. In an attempt to at the least prevent excess flow through any one device (and divert it to the lower flow devices), a number of flow limiters have been installed in the piping.

These devices, manufactured by Griswold, will limit the flow to a pre-set value, as long as the pressure differential across the unit falls within the specified limits.

These appear to have significantly helped to solve the flow issues, although as noted above, when CH-1A was installed, it had low flow issues on the condenser side. This low flow condition manifested itself as incipient surge in the compressor. Even when the flow problem was solved, the chiller still tripped off on incipient surge – it now appears that a sensor was faulty. The unit was installed in 2006, and only now are the operators beginning to use it as the Lead Chiller.

Any future changes to the Plant must deal with both pipe sizing and flow issues in order to be successful, especially if the addition the IT loads forces CWU to use three chillers this season.

Plant Issues: - Water Treatment:

Condenser water loops are generally "open" loops, meaning they are open to the atmosphere at some point (in the basin of the cooling tower, generally). This is very common, and the water treatment regimens to take care of both particulate (dust from the air, silica in the water) and biologicals (organisms that grow in the water) are well established.

Condenser water loops are small compared to chilled water loops, and the water treatment generally occurs right at the tower basin (which is a small, well mixed body of water). Water sampling and chemical metering and monitoring are all automated, and generally effective.

Chilled water loops are usually closed – there is no contact with the atmosphere. Particulate is generally large (rust that spalls off the pipe, etc) and can usually be handled with strainers. With no sunlight and no exposure to air, biologicals generally do not exist. Chemical treatment is minimal in closed loops, and often focuses on combating corrosion in metal pipes. Most of CWU's chilled water pipe is plastic, and therefore not prone to corrosion.

CWU, however, has the storage tank, and that is open to atmosphere. As a result, they do have both wind-blown particulate and biologicals in their chilled water. Because of the low temperatures, the biological growth is slow, but it is also very difficult to treat. The storage tank is a very large volume of water, in which by definition, the water cannot be mixed. This makes distributing any sort of chemicals widely throughout the tank impractical. Likewise, the system is constantly collecting particulate too small to be removed by strainers.

CWU is trying to solve this ongoing water treatment issue – the ultimate solution is not known. In the meantime, they circulate chilled water all year round. In winter, 600 – 1000 GPM are circulated by the secondary chilled water pumps. CWU has found from experience that if the water flow stops, all the particulate and the biological organisms tend to settle to bottom the pipes, or in devices. On the next start-up, large concentrations of these particles are pumped into valves and heat exchangers, clogging up these devices and causing significant start-up issues. So for now, the SCHPs run all the time.

CHILLED WATER DISTRIBUTION

There are two flow-related constraints on chilled water piping, pressure drop and velocity. Pressure drop is important because if the delta P (pressure drop) of the system gets too large, the pumps will not be able to push the chilled water to the most remote buildings on the loop. Velocity is important in that higher flow rates cause greater pipe wear and scouring. Given that all of CWU's distribution piping is plastic, and the water contains significant amounts of particulate, scouring is an issue. CWU needs to set limits on both of these parameters so they can evaluate the distribution piping.

These two variables change at different rates depending on the overall size of the pipe. With larger pipes (~ 18 inch diameter and greater), pressure drop increases more slowly than velocity. With smaller pipes, pressure drop may become an issue before velocity.

<u>Pressure Drop</u>: The distance "as the pipe lays" from the Plant to the farthest chilled water load (Wendell Hill Hall B) is approximately 4,000 feet. Including the return trip back to the plant, the distance is lineal 8,000 ft. In piping design, the concept of equivalent feet is used. Each fitting, whether a coupling, a 90 deg F ell, or a tee, imposes an additional pressure drop on the system that can be expressed in feet of head loss. The total "hydraulic" length of the piping is usually expressed as a multiplier on the actual length of piping. For smaller (say building scale) systems, a multiplier of 1.5 is often used. However, at CWU, the distribution piping often travels tens or hundreds of feet with no fittings. For that reason, we will use a multiplier of 1.25 in this report. Using this value, the pumps "see" 8,000 * 1.25 = 10,000 ft of piping to the farthest load.

The head capacity of the secondary pumps is 90 feet of head. Assuming that 10 PSIG maximum is required at the buildings to get through control valves, etc., this leaves 90 – (2.307 * 10) = ~ 67 ft of head loss available for piping losses. Dividing by the hydraulic length of 10,000 ft, this means that in general, piping pressure drop should be limited to 67 / 10,000 = 0.0067 ft of head per foot. Because number like this are so small, they are generally given in ft of head loss per 100 feet of pipe – using this criteria, CWU should aim for a friction rate of 0.67 ft per 100 ft of pipe.

Obviously, not every segment need meet this criterion – that is an average over the entire 4,000 lineal feet out and 4,000 feet back. Nevertheless, an upper limit of 0.67 ft of pressure drop per 100 is a good guideline to use when evaluating individual pipe segments.

Velocity: Some designers use 12 feet per second (FPS) as an upper limit on water velocity within the pipe. This rule of thumb is generally applied to steel piping. However, it is not unusual to use 12 FPS as a limit for plastic pipe as well.

However, CWU has a heavy load of particulate in the pipe, which increases the rate at which the pipe is eroded. For that reason, we are suggesting that CWU use 8 FPS as an upper limit, at least until they find a way to mitigate the particulate in the piping.

Existing Piping: The majority of the chilled water loop piping is considered to be more than adequate to handle current and future loads; however, two sections of pipe are of particular concern.

The first is the 20 inch diameter pipe carrying the chilled water across "D" Street. The second is the 12" diameter pipe that runs past Randall / Michelson (R / M) out to Wendell Hill Hall.

The 20 inch pipe must carry the entire chilled water plant load (less only Jongeward). This pipe is asbestos cement except for the section under D Street which is steel. The pipe parameters of the D Street pipe under current and future loads is shown in Figure 29 below:

Pipe Parameters					**(20" dia segment crossing D street)**
		current peak	current peak plus		
			IT	IT + NT	IT + NT + UT
load	tons	2,860	3,080	4,035	4,395
flow rate	gpm	6,864	7,392	9,684	10,548
dp	ft/100 ft	0.79	0.90	1.49	1.75
velocity	ft/s	7.93	8.54	11.18	12.18

Figure 29, D street chilled water piping parameters.

The peak load conditions do not last very many hours per year, and this section of piping is only about 450 feet long. For that reason, the flow rate associated with the current peak, and even the current peak plus the intermediate term loads, are likely acceptable. However, this segment of pipe will experience excessive erosion if it carries the near term added cooling loads.

Once the pipe crosses “D” Street, it splits into two 20 inch segments – both of these segments are within limits for the foreseeable future.

The second pipe segment of concern is the 210 foot long section from the Walnut Mall loop piping to the R / M take off. This R / M pipe serves fewer buildings, but it is the “end of the line”, and the campus is expanding in that direction. The current and future pipe parameters for this segment are shown in Figure 30 below:

Pipe Parameters					**(12" dia segment in front of R / M)**
		current	current peak plus		
		peak	IT	IT + NT	IT + NT + UT
load	tons	571	791	791	1,151
flow rate	gpm	1,370	1,898	1,898	2,762
dp	ft/100 ft	0.36	0.67	0.67	1.35
velocity	ft/s	3.93	5.45	5.45	7.93

Figure 30, R / M chilled water pipe parameters.

The data in Figure 30 indicate that this segment of piping is within limits for at least the next ten years. The potential issue is that this segment feeds a very long leg, and if campus expansion proceeds to the Northeast, this leg will have more and more pressure put on it. If, or when, Randall/Michelson cooling is added, or additional buildings are constructed in this part of campus, a new cooling connection should be made between the 14” just north of Stephens/Whitney and the line feeding Barto. In fact, if CWU adds new communication ductbank form Stephens/Whitney to Randall/Michelson, the chilled water could parallel this route.

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CAPITAL PROJECT PROPOSALS 2021-23

1200 Ton Chiller Addition
Infrastructure - Stand Alone

APPENDIX E

Abacus Support Letter

WILLDAN | ABACUS

August 28, 2019

Central Washington University
Facilities Management Department
Attn: Delano Palmer
400 East University Avenue
Ellensburg, Washington 98926-7523

Campus Heating and Cooling Needs

Delano,
This letter summarizing the improvements needed in the campus heating and cooling systems to support the New Health Sciences Building. These needs were summarized in your latest capital budget request but, unfortunately, CWU did not receive funding for these improvements. The following information is meant to inform your Supplemental Budget Request.

I have provided the cost data in two ways. The first number provided is the maximum allowable construction cost (MACC) which you could use in the typical project budget worksheets you create for a design-bid-build capital project. The second number is the total budget you would need to complete this work using the ESCO process. Both methods should up with about the same total budget request.

CAMPUS COOLING SYSTEM
We completed a Campus Cooling Master Plan in 2002 and an update in 2012. Those documents detail the need for additional capacity in the Central Cooling Plant. CWU has requested funding for this project in the past three capital budget cycles but has not received the funding. Since 2012, several large cooling loads have been added to the system including Science II (Discovery Hall), Samuelson, portions of Randall/Michaelson Halls, and the new dorm opening this fall. The Campus cooling system is on the ragged edge of not being able to provide adequate cooling to all the connected buildings. If any chiller, cooling tower, or pump were down for repair, the cooling plant would be about 25 percent short of being able to meet the campus cooling loads. Due to the layout of the campus distribution piping, the areas of campus most likely to experience cooling shortages are Wendell Hill Hall, Music Building, Hogue Technology, Barge Hall and Shaw Smeyser Hall.

The Campus Cooling Master Plan identified the need for a second modular chiller once Science II and Samuelson became occupied. It is paramount that CWU installs the planned second modular chiller before the New Health Sciences Building comes on line.

The budget estimates for this project are on the flowing page.

The MACC for the second modular chiller is estimated to be $2,084,000 broken down as follows:

Chiller Module	$1,672,000
Site Fabrication	$ 54,000
Module Insulation	$ 40,000
Structural Base	$ 8,000
Shipping	$ 44,000
Extended Warranty	$ 56,000
Plant Piping	$ 86,000
Plant Electrical	$ 104,000
Site Work	$ 20,000
Total MACC	$2,084,000

The total budget amount needed for the second modular chiller, if implemented as an ESCO project, is estimated to be $2,900,000 for construction in 2020/21. Note that it will take about 28 weeks to manufacture and deliver the modular chiller.

HEATING SYSTEM

The New Health Science Building was designed assuming heating would be delivered from the Low Temperature Hot Water Loop (LTHW) rather than the campus steam system. The LTHW system also serves Science II and Samuelson. The 2019/21 Capital budget request also included a funding request for an expansion of this LTHW loop but, like the Modular Chiller, these funds were not appropriated. The design of the LTHW loop requires an additional heat exchanger and heating water pump be installed in the Central Heating Plant in order to meet the added load of the Health Science Building.

The MACC for the LTHW Loop project is estimated to be $210,000 broken down as follows:

Equipment	$ 58,000
Structural Base	$ 12,000
Plant Piping	$ 106,000
Plant Electrical	$ 12,000
Insulation	$ 22,000
Total MACC	$ 210,000

The total budget amount needed for the LTHW system, if implemented as an ESCO project, is estimated to be $320,000 for construction in 2020/21.

I hope this letter provides the information you needed. If not, feel free to call me at 503-819-5593.

Mark Kinzer, P.E.
Energy Project Manager

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CAPITAL PROJECT PROPOSALS 2021-23

1200 Ton Chiller Addition
Infrastructure - Stand Alone

APPENDIX F

Chiller Work Order Log

Central Washington University Chiller Work Order Log

2007 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS			
Work Order	Description	Date Created	Billed Total
19235	9243 TOOLS PURCHASED FOR SUPPORT OF CHILLER	7/12/2007	
19729	1534 CHILLER 3 ROUTINE MAINT	7/13/2007	
19453	13212 CHILLER #2 PROBLEM	7/13/2007	
19666	13297 CHILLER RESET	7/13/2007	
20172	5810 CHILLER #1 ANNUAL MAINTENANCE	7/16/2007	
20509	7858 MODINE HEATER ON CHILLER DECK	7/16/2007	
20298	13192 WO#7274 REPLACEMENT-CHILLER PLANT IMPROVEMENTS	7/16/2007	
20174	5812 CHILLER #2 ANNUAL MAINTENANCE	7/16/2007	
21061	1957 CHILLER SUPPORT (OLD ONE WAS CLOSED DUE TO END OF BIENNIUM).	7/27/2007	
21111	INSTALL ELECTRICAL METERS ON 4160 CHILLERS, BTU METER TO ION ENTERPRISE SYSTEM. PROVIDE NETWORK CONNECTIVITY AS REQUIRED (FIBER) MODIFY ENCLOSURE FOR ELECTRICAL METERS NEED ASAP	7/31/2007	
21420	9277 FLOOR DRAINS IN CHILLER DECK WITH SUMP PUMP AND SURGE TANK QUESTIONS SEE PAT NAHAN	8/8/2007	
21652	ELECTRIC METER IN CHILLER 2 NEEDS REPAIRED OR REPLACED	8/16/2007	
21716	CHILLER #1 IN ALARM	8/20/2007	
23038	CHILLER PLANT METER REPAIRED - ION METER REPLACED/REPAIRED IN THE LINE SWITCH	9/25/2007	
23389	SENSORS CHANGED IN CHILLER TOWER	10/4/2007	
23851	CHILLER DECK - CLEAN "WITCHES HAT" STRAINER	10/18/2007	
23960	CHILLER PLANT WINTERIZED	10/22/2007	
24072	PUMP SEAL. OUTBOARD SEAL ON CWP #3 SBAD AND NEEDS REPLACED; CHILLER DECK	10/24/2007	
25912	REMOVE END BELTS AND ROD CHILLERS	12/13/2007	
	2007 TOTAL WORK ORDER COSTS		**$66,360.63**

2008 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS			
27833	HEAT PLANT - VFD'S CLEANED ON CHILLER DECK	2/11/2008	
	COOLING PLANT		
	SERVICE CHILLER PLANTS		
28753	REOPENED MECH-4 FOR TIME CARD USEAGE.	3/11/2008	
29613	CHILLER #3 ANNUAL MAINTENANCE	4/7/2008	
30368	FLUX CAPACITOR FOR #3 HEATING UNIT NEEDS TO BE REPLACED -HEAT PLANT CHILLER DECK	4/29/2008	
30494	CHECK STRAINER PLATE CHILLER ON CHILLER DECK NEW HEAT PLANT	5/2/2008	
31328	CHILLER ALARM #1	5/27/2008	

Central Washington University Chiller Work Order Log

31333	CHILLER ALARM #2	5/27/2008	
31902	REPLACE FLOW METER CHILLER PLANT	6/10/2008	
33091	CLEAN STRAINER ON CHILLER DECK	7/9/2008	
33139	CHILLER ALARM #3 CALLBACK FOR RYAN MACE ON 7/8/08 9:00 -10:00 PM	7/10/2008	
33223	CHILLER #1 ALARM	7/14/2008	
33407	CHILLER PLANT PROBLEM	7/21/2008	
34010	CHILLER DECK INSTALL 2" UNION	8/12/2008	
34371	CHILLER PLANT ISSUES	8/25/2008	
36554	CHILLER PLANT PROBLEMS	10/13/2008	
		2008 TOTAL WORK ORDER COSTS	**$12,858.68**

2009 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

40398	CHECK AIR VENT ON CHILLER #1 ON CHILLER DECK	1/20/2009	
41218	REPAIR SYSMIC BRACING NEW HEAT PLANT CHILLER DECK	2/5/2009	
45901	CHILLER PLANT - REPLACE COUPLING ON TOWER #1	6/9/2009	
47243	MAIN CHILLER - CLEAN STRAINER ON CHILLER #1	7/13/2009	
47498	CHILLER DECK - REPLACE AIR ELIMINATOR ON CHILLER DECK	7/21/2009	
47778	INSULATION FOR COLD WATER COPPER PIPES FROM CHILLER TO HEAT EXCHANGER MECHANICAL ROOM - CONDENSATE FI	7/31/2009	
48891	REPLACE MAKE-UP METER ON THE CONDENSOR SIDE IN THE CHILLER PLANT.	9/14/2009	
53334	CHILLER DECK - REPAIR TOOL COMPRESSED AIR REGULATOR	12/31/2009	
		2009 TOTAL WORK ORDER COSTS	**$2,502.91**

2010 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

57433	CHILLER DECK - REPAIR VFDS	4/29/2010	
58943	CHILLER PLANT ROOF - TOWER 1 SAFETY PLATFORM MATERIAL AND LABOR SEE PAUL JOHNSON	6/9/2010	
60303	HEAT PLANT CHILLER 2 ALARM	7/12/2010	
		2010 TOTAL WORK ORDER COSTS	**$4,878.18**

2011 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

68801	SHOP SUPPORT FOR THE CHILLER CONDENSER MODIFICATIONS	2/17/2011	
69647	BUILD STANDS FOR CHILLER END CAPS CHILLER #1	3/10/2011	
70496	NEW HEAT- INSTALL CONTROL LOOP FOR CHILLER #1 CHEMICAL FEED	4/5/2011	
70619	NEW HEAT-REPLACE EXPANSION JOINTS ON CHILLER #3	4/8/2011	

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72246	HEAT PLANT - CHILLER DECK, CHANGE ELECTRICAL OUTLET BEHIND CHILLER #2 AND CHILLER #3	5/18/2011	
72901	NEW HEAT - CHECK AND CALIBRATE FLOW METERS ON CHILLER DECK	6/2/2011	
73002	CHILLERS IN ALARM	6/3/2011	
74114	CHILLER- RUN CONDUIT FOR CHEMICAL SYSTEM	6/23/2011	
74210	CHILLER FAILURE	6/27/2011	
74524	NEW HEAT- CHANGE FLOW DIRECTION ON CHEMICAL PIPING ON #1 CHILLER TOWER	7/7/2011	
74686	PRESSURE VESSEL INSPECTION 2011 -HEAT PLANT CHILLER #3 VESSEL MAWP 180, HAS 185 PSI SV INSTALLED. CURRENT PERMIT 4/13	7/13/2011	
74841	NEW HEAT PLANT - CHECK BELTS ON CHILLER TOWER #2	7/18/2011	
74844	NEW HEAT PLANT - INSPECT VALVES ON CHILLER TOWER #2. NOT CLOSING PROPERLY.	7/18/2011	
75377	CHILLER #1 ALARM	8/2/2011	
75977	CLEAN STRAINER ON CONDENSOR SIDE OF CHILLER #1	8/25/2011	
	2011 TOTAL WORK ORDER COSTS		**$15,465.55**

2012 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

81845	NEW HEAT - CHILLER PLANT UPGRADES USE 81904	1/24/2012
82399	NEW HEAT CHILLER DECK- CHANGE MEDIA IN THE SAND FILTER	2/6/2012
82716	NEW HEAT CHILLER DECK DRAIN PLUG	2/14/2012
83835	CHILLER 3 TOWER UPGRADE	3/15/2012
86488	CHILLER PLANT ALARM	5/22/2012
87760	RESET CHILLER #1 FAILURE	6/18/2012
88289	ORDER CHILLER CHEMICALS	7/3/2012
88370	SHORE UP LADDER ON CHILLER #3 TOWER AT NEW HEAT SEE ED CASTANEDA	7/6/2012
88401	CHILLER PLANT FAILURES	7/9/2012
88477	NEW HEAT - CHILLER PLANT FAILURE CALLBACK AND OVERTIME FOR PAUL JOHNSON 07/08-09-12 9-12, 12-1	7/11/2012
88494	DIAGNOSE/REPAIR CHILLER #2	7/11/2012
88509	NEW HEAT - INSPECT CHILLER #1 CONDENSER TOWER	7/11/2012
88617	CHILLER PLANT CALLBACK	7/16/2012

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88840	NEW HEAT - RESET BREAKER AT CHILLER PLANT CALLED 99	7/20/2012	
88857	NEW HEAT - REPAIR LIGHTS AT WEST ENTRY STAIRS TO CHILLER PLANT	7/23/2012	
88940	CHECK VFD ON THE CHILLER PUMP PACKAGE. SEE PAUL JOHNSON.	7/24/2012	
89722	NEW HEAT - CHILLER IS ALARM CALLBACK AND OVERTIME FOR RYAN MACE 08/12/12	8/27/2012	
	CONTRACT 11078-01 CHILLER #2 COMPRESSOR REBUILD	8/23/2020	
90930	CHILLER #1 FAILURE	9/24/2012	
	2012 TOTAL WORK ORDER COSTS		**$206,871.13**

2013 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

96538	NEW HEAT INSTALL HOT TAPS ON CHILLER #3	2/20/2013	
99966	CHILLER #1 IN ALARM	5/15/2013	
102601	CHILLER #1 IN ALARM	7/22/2013	
103094	NEW HEAT - RUN CIRCUIT TO CHILLER TWO STARTER	8/8/2013	
106556	CHILLER DECK CLEANING	10/30/2013	
	2013 TOTAL WORK ORDER COSTS		**$1,706.03**

2014 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

112728	HEATING/COOLING - THE CHILLER DECK OF THE BOILER HOUSE REPAIR THE LEAKS IN THE FLOOR	4/9/2014	
113367	NEW HEAT - CHILLER DECK REPLACE AUTO SWITCH CHILL PUMP # 2 CONTACT BUBBA TOWNSEND WITH ANY QUESTIONS	4/23/2014	
116784	NEW HEAT- CHILLER 3 ALARM DAVE KOPCZYNSKI 6/27/14 7:00PM-8:00PM CALL BACK	6/30/2014	
116868	HEAT/COOLING - RESEAL DRAIN ON CHILLER DECK. CONTACT MARK WINTERER FOR SPECIFIC LOCATION	7/2/2014	
116888	ROOM#: GENERATOR ROOM CHILLER DECK DRIPPING INTO TEMPORARY CONTROL ROOM	7/2/2014	

	NEW HEAT- CHILLER 1 ALARM		
	DAVE KOPCZYNSKI		
	7/1/14		
	9:45PM-10:45PM		
116903	CALL BACK	7/2/2014	
	BOILER- CHILLER # 3 ALARM		
	DAVE KOPCZYNSKI		
	8/23/14		
	11PM-12AM		
118750	CALLBACK	8/25/2014	
	BOILER- CHILLER #2 ALARM TRIP		
	DAVE KOPCZYNSKI		
	8/24/14		
	3PM-4PM		
118751	CALL BACK	8/25/2014	
	NEW HEATING/COOLING - CHILLER #1 IN ALARM		
	CALLBACK 9/6/2014		
119220	RYAN MACH	9/8/2014	
120229	CHILLER PLANT PROBLEMS	9/29/2014	
		2014 TOTAL WORK ORDER COSTS	**$1,281.91**

2015 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

	LOCATION:ROOF	
127697	SHOP SUPPORT FOR RE ROOF BOILER CHILLER PLANT.	3/31/2015
128893	NEW HEAT - CHILLER DECK LEAKING HEADER PIPE	4/27/2015
	ROOM#: 0 #2 TOWER LEAKING ONTO ROOF AT UNION ON EAST SIDE WALL. # 1 CHILLER LEAKING AT UNDERSIDE SEAM.	
130659	MACE RESPONDED	6/8/2015
131804	NEW HEAT-SHOP SUPPORT FOR CHILLER PROJECT	6/30/2015
131920	CHILLERS NOT RUNNING AT HEAT/COOL PLANT	7/6/2015
132192	ROOM#: 0 CHILLER 3 IN ALARM EMCS HIGH OIL TEMP	7/13/2015
132193	ROOM#: 0 TEP GROUND FAULT ELECTRICAL EMCS CHILLER DECK.	7/13/2015
132503	BOILER HOUSE- SNAKE DRAIN ON CHILLER DECK	7/23/2015
132971	ROOM#: CHILLER DECK CHILLED WATER TANK LOW.. MARK WINTERER CALLED IN BY ED CASTANEDA	8/10/2015
132972	ROOM#: CHILLER DECK CHILLER 3 FAILURE LOUIE MCDONALD CALLED IN TO RESET CHILLER BY ED CASTANEDA	8/10/2015

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133231	BOILER- CHILLER ALARM # 3 RYAN MACE CALL BACK 8/16/15	8/18/2015	
		2015 TOTAL WORK ORDER COSTS	**$7,126.80**

2016 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

141080	NEW HEAT- ROD CHILLERS	2/24/2016	
142824	ROOM#: NA LIGHT SWITCH ON WEST ENTRY OF CHILLER DECK ELECTRICAL SHORT. TAGGED OUT AND TAPED OVER FAULTY	4/6/2016	
146190	ROOM#: 0 CHEMICAL ROOM SAMPLE VALVE FOR CHILLER 2 & 3 IS DRIPPING, BUCKET UNDER IT.	6/20/2016	
146263	BOILER- CHILLER #1 ALARM CALLBACK RYNA MACE 6/18/16	6/21/2016	
146601	NEW HEAT-CHILLER #1 ALARM REPAIR	6/30/2016	
151966	LOCATION:CHEMICAL ROOM PLEASE PUT BOIL AND EMCS ON THIS W/O. REPLACE AND RELOCATE CHILLER 1&3 CHEMICAL HEADERS AND CONTROLLER FROM EAST WALL TO THE WEST WALL.	12/8/2016	
		2016 TOTAL WORK ORDER COSTS	**$4,099.50**

2017 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

154706	NEW HEAT- RODDING CHILLERS, REMOVE END CAPS	3/2/2017	
156597	LOCATION:0 EAST CHILLER DECK DOOR DRAGS ON FLOOR WILL NOT CLOSE.	5/1/2017	
158466	LOCATION:NORTH WEST CORNER REINSTALL OUTSIDE OVER HEAD LED YARD LIGHT IT WAS TAKEN DOWN DURING NEW CHILLER INSTALLATION. ELECT SHOP BOIL SHOP	6/16/2017	
158687	LOCATION:2ND FL W/O CHILLER 3 IN ALARM,ED CASTENEDA CALLED IT IN, FROM HOME.	6/26/2017	
158819	LOCATION:CHEMICAL ROOM PLEASE ADD BOIL TO THIS W/O. #1 CHILLER DIE READING SENSOR IS DISPLAYING AN ERROR ON THE CONTROLLER.	6/29/2017	

	LOCATION:CHILLER DECK		
	INSTALL SHELVING		
159352	BOIL SHOP	7/19/2017	
	LOCATION:CHILLER DECK		
	PAINT HOUSE KEEPING PADS		
159356	BOIL SHOP	7/19/2017	
	LOCATION:NA		
	THE LIGHT SWITCH JUST INSIDE THE WEST ENTRANCE TO THE CHILLER ROOM NEEDS REPLACED, IT HAS BEEN TAGGED		
159433	(EMITTED SPARKS WHEN SWITCHED)	7/24/2017	
	LOCATION:CHILLER PLANT		
	PLEASE ADD EMCS TO THIS W/O. THE OSA TEMPERATURE SENSOR FOR THE CHILLER PLANT NEEDS TO BE REPAIRED /		
159767	REPLACED.	8/7/2017	
159887	NEW HEAT - CHECK CHILLER #2 , CONDENSER WATER AND VFD	8/10/2017	
	BOILER- RESET CHILLER PER LOUIE		
	CALLED BACK		
160792	9/2	9/12/2017	
	LOCATIONS:CHILLER DECK		
	CONDEX GLYCOL PUMP IN ALARM WILL NOT RUN		
	ATT. JEFF R. FROM ELECT. SHOP		
161383	WO FOR ELECT. AND BOIL. SHOPS	9/21/2017	
162190	BOILER HOUSE- TURN THE HEAT ON- CHILLER DECK	10/9/2017	
	LOCATIONS:CHILLER #1		
	PLEASE ADD EMCS TO THIS W/O. GIVE TO PAUL JOHNSON. #1 CHILLER TOWER HAS A PRETTY SIGNIFICANT BIOLOGICAL		
162278	GROWTH FLOATING AND GROWING IN IT.	10/11/2017	
162695	BOILER PLANT - REPLACE CORES IN CHILLER MODULAR OUTSIDE OF BOILER PLANT	10/19/2017	
		2017 TOTAL WORK ORDER COSTS	**$9,434.69**

2018 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

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	LOCATIONS:CHILLER DECK REMOVE END BELLS, ROD CHILLERS 1&3 AND PUT END BELLS BACK ON		
167231	MECH SHOP BOIL SHOP EMCS SHOP	3/1/2018	
168767	BOILER HOUSE - EVAP CHILLER #1 ON TOP OF HEAT PLANT ROOF LEAKING WATER ON EAST SIDE OF CHILLER	4/17/2018	
170053	CHILLER TANK OVERFLOWING - NO CHILLED WATER	5/24/2018	
171258	BOILER HOUSE - INSTALL NEW RELAY FOR CHILLER LOOP CHEMICAL CONTROLLER AND NEW FLOW SWITCH	6/25/2018	
172362	NEW HEAT- CHILLER #3 TRIPPED OUT LOUIE MCDONALD CALLBACK 8/4/18	8/7/2018	
	2018 TOTAL WORK ORDER COSTS		**$5,693.08**

2019 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

179887	HEAT - CHILLER PLANT REPLACE GAUGE ON CONDENSER WATER SYSTEM	3/15/2019	
179965	BOILER HOUSE- CHILLERS 1,2,3	3/19/2019	
182339	BOILER HOUSE- CHECK CHILLER 3 POWER ISSUES	5/22/2019	
184697	BOILER HOUSE- CHILLER #2 HIGH TEMP ALARM	7/23/2019	
184761	LOCATIONS: 2ND FL #94 CALLED FOR PAUL #126 TO COME IN AND TAKE A LOOK AT THE CHILLER PLANT,IT,S NOT RUNNING CORRECTLY.	7/24/2019	
189126	BOILER HOUSE- PM- CHILLER DECK	11/6/2019	
	2019 TOTAL WORK ORDER COSTS		**$23,922.16**

2020 CWU WORK ORDER SUMMARY OF COSTS FOR THE CHILLERS

193663	BOILER HOUSE- REPAIR LOCK ON CHILLER #2 DOUBLE DOORS	3/12/2020	
195214	BOIL/HEAT PLANT- CHILLER STARTER REPLACEMENT	5/22/2020	
195903	LOCATIONS:CHILLER DECK LIGHT OUT OVER CHILLER #3.	7/6/2020	
	2020 TOTAL WORK ORDER COSTS		**$40,286.58**