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Leaky Pipes, Leaky Wallet:
A Look at OSU's Steam/Water Condensate Return System

ACTION PLAN TO REDUCE POTABLE WATER CONSUMPTION ON THE OHIO STATE UNIVERSITY'S MAIN CAMPUS

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Executive Summary

One of The Ohio State University's (OSU) goal is to reduce 5% potable water consumption per capita every five years and reset the baseline every five years thereafter. The H2 Block O team consists of five undergraduate seniors working through a capstone course in the EEDS (Environment, Economy, Development, and Sustainability) major, working to figure out ways of reducing campus water consumption. To achieve a 5% reduction in water consumption, H2 Block O's research focuses on improving the efficiency of the steam condensate return system at McCracken Power Plant; a boiler plant that generates steam for 131 buildings on The Ohio State University's campus. The motivation for this undertaking is to increase OSU's water use rating with AASHE STARS, which is a tracking, assessment, and rating system used to measure sustainability among universities.

The research objectives include comparing McCracken's current state to an efficient system, calculating a payback period analysis in order to weigh the decision-making process, and finally, the third objective is to make recommendations the university can embark on in the future to continue down a path of increased reduction in potable water consumption.

The primary findings of the research show McCracken's inefficiencies are mainly in their condensate return in the steam system. At a current level of 41% efficiency, H2 Block O's proposal plan to replace the leaky pipes will result in an increase in efficiency and an associated 4.3% reduction in campus water consumption. When the First Year Costs of construction and installation are included, it will take 11.02 and 23.55 years for Phases Three and Four to have a return on investment, respectively. However, it is

worth noting several assumptions had to be made in order to reach the calculations in the payback period analysis.

The recommendations for OSU's future endeavors include an educational campaign to teach students and faculty about changing their water use habits and steps the University is taking to become more sustainable. In addition to education and awareness, a friendly competition between residence halls has the potential to raise more awareness and change the water use culture on campus. Other recommendations include retrofitting existing buildings with low-flow fixtures and requiring them to be installed in new buildings, which relates to the third recommendation of having a liaison between OSU's Office of Sustainability and construction manager.

Introduction

The Ohio State University laid forth several sustainability goals that it aspires to achieve in the coming years. The H2 Block O team elected the goal of reducing OSU's potable water consumption by 5% per capita every five years, resetting the baseline every five years thereafter. An initial assessment of water users on campus revealed McCracken Power Plant to be the highest water user on campus and most ideal for this project. Several different scenarios composed of various water user combinations were investigated, but none of them was as close to attaining the 5% target as our plan to fix inefficiencies at McCracken's. Doing so is estimated to result in the highest reduction (-4.3%) in water consumption in the next five years.

McCracken Power Plant provides steam, hot water, and chilled water for campus. There are five phases to correcting McCracken's wasteful problems. These five phases are centered on the replacements of piping systems throughout campus. Phase One was completed by the University along 12th Avenue, ended in 2009 at a cost of $6.8 million. Phase Two was located between McCracken and Drake Union, was completed in 2012 at a cost of $21 million. The third and fourth phases are currently being designed and are great research prospects for H2 Block O. Phase Three has already been determined by university officials to cost around $10.4 million and will be constructed on the north (around 18th Avenue) and central campus. Phase Four includes several old buildings' pipes on west campus that are in need of renovation. The fifth phase consists of future construction projects on the rest of the scattered buildings around campus.

There are several uncertainties for this project. The barriers for Phases Three and Four stem from necessary assumptions that had to be made. Certain assumptions had to be made in order to complete the analysis. Many of the failed pipes are located across the Olentangy River, which possesses its own unique hurdle; refer to Figure 4 in Appendix A for a map of the condensate pipes on campus.

The findings of the cost-benefit analysis reveal the total annual benefits of replacing McCracken's condensate return pipes to be $1.7 million, while the total annual costs will be $84,640. The payback periods for both projects are long due to high construction costs, but the need to carry out these phases is inevitable. Therefore it is more economic to replace these piping systems now rather than later. Phases Three and Four will achieve a 4.3% reduction in water consumption on campus by 2020, and a total 5% reduction will be achieved by the combination of this project and other suggested projects that OSU can implement in the future.

Motivation

H2 Block O's motivation for the aforementioned goal and research objectives is to assist OSU down a path that accomplishes their water sustainability goal in the most effective way possible. The Ohio State University emerged as a beacon among universities with its zero waste program at the Ohio Stadium, and now it is important OSU steps forward again as a leader in potable water reduction. The research project H2 Block O conceived is designed with that in mind. Concentrating on the boiler system affords the greatest opportunity of reducing water consumption in comparison to other water users on campus, and in many cases, compared to multiple combinations of water users. H2 Block O initially examined water use in the dorms, campus buildings, and water used for irrigation. However, none of them accounted for 5% water use and therefore would have greatly fallen short of the target.

It was quickly realized McCracken is the only way to reach OSU's goal. Research has revealed serious inefficiencies in McCracken's condensate water return pipes. Utilities and Facilities Operations are aware there are currently 29 failing pipes across campus (Brad Coy, 2016). However, no action has been taken at this time to replace these leaking condensate return pipes.

Objectives

H2 Block O's preliminary step was to have a meeting and take a tour of McCracken Power Plant to gain extensive knowledge on how the system operates, to learn who uses the steam and for what purposes, and to identify the system's strengths and opportunities. The second step was to isolate an opportunity the team could focus on for research purposes; i.e., the condensate water return pipes. The third step was to create research objectives based on OSU's water consumption goal and the insight gained from the McCracken tour and meeting.

Objective I: *Identify how an efficient boiler system operates and compare it to McCracken Power Plant*

- Research Methods: In addition to a tour and interview with Brad Coy, Utilities Plant Superintendent at McCracken, research included regular exchange of email communication with Brad Coy and Internet-based research that consists of trade publications, vendor websites, and user websites. Mr. Coy also provided student spreadsheet in Appendix B, compiled by an OSU student within the Facilities Operations and Development Utilities Office.
- Data Collected: The types of data collected were typical steam flow and capacity of a water tube boiler, water allocation between condensate and feed water for McCracken and an efficient system, typical blowdown rates, reverse osmosis efficiency, and steam pressure flow.

Objective II: *Conduct a cost-benefit analysis of fixing McCracken's inefficiencies in order to test the project's feasibility*

- Research Methods: Email communication from Brad Coy resulted in an outline for a cost-benefit analysis. Ross Parkman, Senior Director of Utilities at McCracken Power Plant, created the outline used in the cost-benefit analysis. We conducted mathematical calculations based on AASHE STARS and the information Mr. Parkman created via Mr. Coy.

- Data Collected: Condensate Analysis spreadsheet compiled by Ross Parkman contained average maintenance costs, water costs and savings, and energy savings, but some numbers were changed as information from other sources such as AASHE STARS was compiled. A Condensate Distribution pipe map provided by Brad Coy contained the number of pipes and length of pipes in need of replacing.

Objective III: *Recommendations for future projects OSU could undertake to continue reducing potable water consumption after the baseline resets*

- Research Methods: Internet-based research on other universities and their water conserving activities was required. Internet-based research on land area and rainfall covering the area around the Schottenstein Center was the final piece of information collected.
- Data Collected: H2 Block O reviewed AASHE STARS ratings for other universities. A collection of land area measurements for area around Schottenstein Center and Ohio's average rainfall measurement were recorded.

Discussion and Analysis of the Objectives

Objective I: Measuring McCracken's inefficiencies

There are 131 buildings connected to McCracken (Brad Coy, March 9, 2016). Each relies on the boilers for services such as, but not limited to, steam for heating buildings and steam sanitization processes, particularly at OSU's biological and medical research laboratories, as well as the medical center (Brad Coy, March 9, 2016). The hot water and steam produced by McCracken is not meant for direct human consumption and is separate from the domestic water system on campus (Brad Coy, March 9, 2016).

There are two sources of water entering McCracken's boilers. One source comes from the city of Columbus and the other from condensate water returned from the end users, the buildings on campus (Brad Coy, March 9, 2016). After the buildings have used the steam, the steam's temperature cools slightly and returns to a liquid state, this is condensate water (USGS, 2016). The water flows back to McCracken, where it goes through a filter designed to extract iron. The filtered water enters the polisher feed tank, where it mixes with the purchased municipal water (Brad Coy, March 9, 2016). Refer to Figure 4 in Appendix A for a diagram of the boiler system.

In its current state, the condensate pipes leading from the buildings back to McCracken is only capturing 41% of condensate water (Figure 1). The remaining 59% of water coming into the boiler system is purchased from the city of Columbus, known as feed water or makeup water (Brad Coy, March 9, 2016). The city water goes through a two-stage reverse osmosis (RO) process to remove impurities. After the first stage of RO, 50% of water goes onto the polisher feed tank to mix with condensate water, the remaining 50% goes through a second reverse osmosis process. In the second RO process, 50% of that water goes to the polisher feed tank and the other 50% of purchased water is rejected directly to the sewer (Brad Coy, March 9, 2016). OSU purchases 106,853,357 gallons/year from the city of Columbus for McCracken's system, which is equivalent to 292,749 gallons/day (Brad Coy, March 8, 2016). Approximately 187,200 gallons/day, or 130 gallons/minute, of purchased water goes unused after the second stage RO process and is sent to the sewer (Brad Coy, March 9, 2016). Of the daily purchased water, approximately 430 gallons/minute enters into the polisher feed tank from the RO processes; however, this amount varies from day to day depending on the amount of condensate water returning and the time of year (B. Coy, personal communication, March 9, 2016).

OSU uses water tube boilers. With this type of boiler, water is fed through tubes inside the boiler where heat is generated from flue gas (Milanco Industrial Chemicals, 2014). The heat from the flue gas circulates around the outside of the tubes heating the water inside them. A typical system of this type has a condensate efficiency of 75%-80% (Cleaver Brooks, 2010). This means 80% of the water coming into the boiler system comes from returned condensate water and 20%-25% is makeup water, which comes from another source, like the city. In its current state, McCracken's condensate efficiency is only 41% and water purchased from the city makes up the other 59%. McCracken has six boilers, five of which have a steam flow of 150,000 lbs/hr at 200 psi and one boiler produces 220,000 lbs/hr of steam at 600 psi (Brad Coy, March 7, 2016).

For an efficient system the average steam flow is approximately 150,000 lbs/hr with a temperature of about 384 degrees Fahrenheit (Paffel, 2015). Steam is pushed through the system at 150 psi (Breaux, 2014). Dissolved solids that make it through the RO processes and all the various filtration mechanisms turns back into a solid inside the boiler and collects at the bottom, this is known as blowdown (P.C. McKenzie Corp 2011). These solids must be discarded routinely to keep a boiler from corroding (P.C. McKenzie Corp 2011). Typical blowdown rates, which measure the amount of discarded solids, range between 4% and 8%, but this percentage loss can be higher if the makeup water is very poor quality with high concentrations of solids, or if water preparation and filtration is ineffective (NCDENR, 2004). McCracken is operating at a 1-2% blowdown rate, which reflects the high performance of the filtration and reverse osmosis processes that are in place (Brad Coy, March 3, 2016).

Fixing and replacing the returning condensate water pipes from the buildings for recirculation in boilers is the most effective approach for OSU to reduce water consumption and reach the 5% goal. The Midwest area of campus has a majority of the pipeline fails mostly due to leaks, bad connections, and corrosion; therefore, priority attention is recommended for this area. Refer to Figure 5 in Appendix A for a map of the condensate pipe distribution on campus.

The benefits of recirculating condensate water include a reduction in the amount of purchased makeup water required, the preparation costs and heating cost associated with purchased water, the need to add tempering water to cool condensate before discharging, the frequency, and the amount of blowdown (EPA, Office of Water, 2012 and Milanco Industrial Chemicals, 2014). Condensate water is returned to McCracken at 200 degrees Fahrenheit, and recirculating it decreases the amount of fuel needed to bring it back to boiling (EPA, Office of Water, 2012); whereas feed water comes into the boiler system at just below room temperature and requires additional fuel to bring it to boiling.

Objective II: Cost-Benefit Analysis Overview

A cost-benefit analysis is a key decision-making tool and is important for any large installation project. This analysis examines the reduction of potable water consumption by fixing the inefficiencies of the McCracken steam plant, specifically the condensate water return pipes. To holistically analyze the inefficiencies, the total costs and benefits must be included in the calculations. The following is a brief overview of the analysis.

Figure 1 displays data on total costs and benefits. The three lightest shades of green—Annual Water Savings, Annual Maintenance Savings, and Annual Carbon Savings at a 3% discount rate—are added together to get the Total Annual Benefits. The Total Annual Costs are estimated to be 10% of the avoided maintenance cost that is currently in affect on leaky pipes. H2 Block O determined Total Annual Costs to be the potential cost of future maintenance of the new pipes. The Net Annual Benefits are the amount of financial return that The Ohio State University will receive each year after these projects are implemented. The First Year Costs are a one-time construction expenditure. These construction costs are the estimated and assumed costs listed in the next paragraph, but Figure 1 assumes the mid-range construction cost for Phase four. Phase three's first year cost has already been determined by university officials to be $10.4 million (Patrick Smith, 2016). The Payback Period is calculated by dividing the First Year Costs by the Net Annual Benefits. This signifies how long it will take Ohio State to break even.

	Annual Water Savings	Annual Maintenance Savings	Annual Carbon Savings 3% Discount Rate	Total Annual Benefits	Total Annual Costs	Net Annual Benefits	1st Year Costs	Payback Period
Phase 3	$360,537	$423,203	$202,572	$986,312	$42,320	$943,992	($10,408,257)	11.02
Phase 4	$216,323	$423,203	$121,536	$761,062	$42,320	$718,742	($16,924,582)	23.55
Total	$576,860	$846,406	$324,108	$1,747,374	$84,640	$1,662,734	($27,324,582)	16.3

Figure 1. Costs and Benefits Summary for Phases 3 and 4

Several educated assumptions were made as part of the cost-benefit analysis to aid in the calculations and forecasts for the First Year Costs. The First Year Costs included materials, pre-construction, construction, administration, and being across the river. Within the material costs, it is assumed from Figure 4 in Appendix A that approximately 0.7 to 1 mile of steam and condensate piping needs to be replaced. Additionally, it is assumed also from Figure 4 that about ten steam and condensate piping elbows, five steam receivers, and five condensate pumps will need to be replaced. The pre-construction costs are assumed to be 10% of the total expenditures. Construction costs are assumed to be about double the materials costs (PERMA Pipes, 2016). Administration costs are about 20% of the total cost (Patrick Smith, 2016), and the cost of pipes crossing under the river will be about 25% of the total First Year Cost (PERMA Pipes, 2016). The assumptions are based on the amount of pipe materials needed which are estimated from the condensate pipe map and a chart distinguishing which buildings' piping systems need repair provided by Brad Coy; see Figure 4 in Appendix A. The pre-construction, construction, administration, and location costs were provided as rough estimates by Patrick Smith in the metering and billing department of Energy Services and Sustainability at OSU and by PERMA Pipes, OSU's current contractor for these projects.

Given these assumed costs for Phase Four, three options have been concluded: the lower end of the costs were $14,103,818, the mid-range costs were $16,924,582 (which was used in the cost benefit analysis), and the upper end of the costs were $23,750,181. These costs depend on the actual length of pipes (0.7 or 1 mile) and the actual construction/installation cost (1.5 or 2 times the materials cost).

The primary assumption that pertains to the Total Annual Benefits in H2 Block O's cost-benefit analysis is the discount rate of the social savings of carbon. The Annual

Carbon Savings for the discount rates of 5%, 3%, or 2.5% are $99,044; $324,144; or $504,224 respectively (The Social Cost).

From Figure 1, displayed above, Phase Three is shown to cost less than Phase Four while saving more water. These numbers imply that there is some gray area in what the actual cost may be. Phase Three may be more expensive than what university officials estimated, and Phase Four may be less expensive than what H2 Block O expects due to assumptions about costs within the calculations.

The numbers under the Annual Maintenance Savings in Figure 1 come from the average minor maintenance assignments that have occurred in the last three years from existing leaky pipes ($30,229). The average number of minor maintenance assignments is 14 per year. Instead of replacing these pipes as our team is proposing, minor fixes in the past have been put in place in incremental fashion, but these are much less reliable and more expensive in the long run than new piping systems that would be put in place in Phases Three and Four. Annual Maintenance Savings for Phases Three and Four are then calculated to be $423,203. The annual water savings calculations are shown in Figures 2 and 3.

Potential

Yearly Building Steam	Building Steam Along Working Pipelines	Potential Condensate Recovery	Actual Condensate Recovery	Condensate Lost to Working Pipelines	Fuel and Water Savings Per Unit	Potential Yearly Fuel and Water Savings	Prices	Yearly Cost Savings
(1000lbs)	(%)	(1000lbs)	(1000lbs)		mmbtu/1000lb	mmbtu	$/mmbtu	$
1,809,441	83.6%	1,512,693	622,280	890,412	0.125	111,302	$3.50	$389,555.45
			41%	59%	ccf/1000lb	ccf	$/ccf	
					0.211	187,877	$5.60	$1,052,111.35
							Total potential savings	$1,441,666.79
							Average savings / 1000lbs	$1.62

Figure 2. Tl

Project				Yearly Savings		
	% of Lost Condensate	(1000lbs)	$ Savings/1000lb	$ Fuel and Water	mmbtu	ccf
Phase 3 Target	25%	222,603	$1.62	$360,537	16,692	46,969
Phase 4 Target	15%	133,562	$1.62	$216,323	27,819	28,175
Total	40%	356,165	$1.62	$576,860	44,511	75,144
				% of Total McCracken Fuel and Campus Water Saved	1.7%	4.3%

Figure 3. Pl

The setup of this water-saving analysis was received from Ross Parkman, the Senior Director of Utilities. The numbers are adjusted to adhere to the AASHE Stars certified numbers and up-to-date numbers from 2015. Figure 2—the potential maximum savings—begins with the total amount of steam generated by McCracken, but 83.6% of condensate return is the maximum efficiency able to be reached as 100% efficiency is almost impossible. If at 83.6% efficiency, OSU could recover 1.5 billion pounds of condensate, but is currently only recovering 622 million pounds—or 41% of 83.6% possible efficiency.

Figure 3 displays H2 Block O's proposal for OSU broken down into Phase three—which will recover 25% of the 59% Condensate Lost to Working Pipelines—and Phase Four—which will recover 15% of the missing 59%--to result in a combined 64.6% efficiency. At a combined fuel and water savings of $1.62 per 1000 pounds of water, the yearly financial and physical savings are stated in the chart above as $576,860. The total percentage saved of McCracken fuel and of campus water is listed at the bottom of Figure 3, if both Phase Three and Four are carried out.

Objective III: Recommendations for The Ohio State University

Phase Three and Phase Four can be completed by 2020. If these projects are completed within the next five years, The Ohio State University will reduce their campus water consumption by 4.3% and increase their McCracken condensate return by 22% (Figure 3 above). The increase in condensate return will result in a total of 63.6% system efficiency. Phase Five consists of the remaining pipes that need to be repaired throughout campus, which would make up the remaining 11.4% needed to reach the maximum system efficiency of 75% (Patrick Smith, 2016). The fifth phase will consist of 16 buildings that are scattered throughout campus; therefore this project is more difficult to complete than the previous projects. The disbursement of buildings should be taken into consideration when assessing the costs and benefits of repairing these pipes. The buildings to be considered are the Schottenstein, Watts Hall, the Wexner Center for the Arts, Weigel Hall, Mershon Hall, Independence Hall, the Psychology Building, Wiseman Hall, the Comprehensive Cancer Center, Biological Science Building, Tzagournis Hall, Pomerene Hall, Hale Hall, Fry Hall, Meiling Hall, Graves Hall and Newton Hall (Ross Parkman). The improvements in the steam and condensate return system achieved in Phase Five will save the University 37,575 ccf or 28,108,050.46 gallons and will reduce The Ohio State University's total water consumption by 2.2% (Ross Parkman).

The size and scope of these projects are quite large due to the immense size of The Ohio State University's steam and condensate infrastructure. Phase One and Two each took over two years to complete. Therefore, it is feasible for OSU to complete two construction projects of this magnitude by 2020. H2 Block O suggests Phase Five of the condensate pipe replacement plan be the first recommendation for OSU's consideration after they reset the water consumption baseline and reevaluate how they plan on reaching their next target. The Ohio State University should consider focusing on resolving all existing condensate return inefficiencies in order to solve the large-scale "leaky faucet" problem on campus. H2 Block O is not recommending this as the only option OSU should take in achieving an improved AASHE STARS score. There are a variety of ways that The Ohio State University can and should approach reducing its water consumption; replacing the condensate pipes is just one such solution. Yet, replacing these pipes should remain at the top of the list due to the recurring maintenance costs The Ohio State University has to pay every year by not addressing these pipes earlier.

For The Ohio State University to achieve higher AASHE STARS ratings in addition to Phases One through Four, there are a few different avenues available. For example, after researching and analyzing what other schools across the country are doing for their sustainability initiatives, there are areas where OSU cannot only improve their water ratings, but also improve their ratings in building and construction. Another recommendation is for The Ohio State University's sustainability team to become in constant communication with OSU's construction systems management. By doing so, OSU's sustainability team can be actively engaged in campus construction, and their efforts can be directed at ensuring these new building projects are involving actions to help conserve water and energy from the start. A key example where this could be utilized is the proposed Schottenstein Concourse Renovation project. This project is to be completed by 2020 and will include building six new athletic facilities in that area. A suggestion is that OSU communicate with the construction manager in an attempt to design and implement rainwater catchment cisterns for these forthcoming facilities as a substitution for the use of potable water for irrigation. After doing some basic calculations of the land area as well as Ohio's annual average rainfall, conclusions were found. If a system were in place that could harvest just 19% of annual rainfall, then there would be enough water saved to replace all consumption for athletic facilities on the Schottenstein block (Alec Janda, 2016).

Designing with water conservation in mind is not a new idea by any means. However, The Ohio State University has not made it a priority like some of the global institutional sustainability leaders in AASHE STARS ratings have; such as Penn State, University of Michigan, Texas A&M, and University of Texas (AASHE STARS, 2014, 2015, and 2016). A third recommendation for The Ohio State University to improve its AASHE STARS ratings is to adapt and install low-flow, efficient utilities in their campus buildings. Retrofitting buildings is a low-hanging fruit for the sustainability team at OSU, yet there has been little effort to do so. Ultra low-flow toilets save up to 13,000 gallons of water per year (WaterSense, 2016). By implementing these technological improvements throughout campus, The Ohio State University will greatly improve its AASHE STARS ratings in regards to water consumption seen in the OP 26 credit under version 2.0. Colleges across the country are realizing the monetary gains to be made in switching to these efficient fixtures, causing OSU to lag behind. By combining these efforts with future construction and retrofitting old buildings, H2 Block O predicts a significant improvement in OSU's current 1.88 out of 4 AASHE STARS water rating.

Another avenue The Ohio State University can implement is an education campaign and competition among the dorms. Students that live in the dorms can directly compete against each other for which building uses the least amount of water.

Not only will this bring the student body together to meet a common goal, but will also be a fun and easy remedy for decreasing per capita water consumption and changing the water use culture on campus. By implementing metering and data recording, OSU could introduce the importance of water conservation to the students at a key point in their life. This idea could spark trends of behavioral change in the students that could last a lifetime, while contributing to decreasing annual water consumption for The Ohio State University.

Conclusion

There are a number of different, new projects that could have been undertaken to reduce campus water consumption, but it was realized after extensive research that they all fell short of The Ohio State University's goal. After H2 Block O assessed the inefficiencies currently plaguing The Ohio State University's water consumption, our team has decided it would be best to focus on the largest waste source of water on campus. The McCracken steam and condensate return system has been in desperate need of repairs for many years. Two large repair projects, Phases One and Two, have already been completed, but three more phases are needed to repair the remaining corroded pipes. The Third Phase is currently in the design process and is supposed to begin construction within the next year. While the locations of the failed pipelines are known, there is no set plan for the fourth and fifth phases of this project. Our team has created these plans in terms of location and costs. H2 Block O decided to focus mainly on finding realistic costs for Phase Four of the condensate repair, and has included the fifth as a future recommendation. Together, the remaining three projects would reduce OSU's water consumption by 6.5%. It is only feasible for The Ohio State University to fund and complete two construction projects of this size in the next five years. It is suggested that OSU complete Phase Three and Four by 2020 and readdress Phase Five after OSU resets the consumption baseline.

Using boilers generated by natural gas to create steam that cycles throughout campus is a truly effective way to provide energy to buildings, but the system demands large quantities of water and natural gas. Increasing the amount of returning steam in the form of condensate water for recirculation is the most efficient and effective way to reduce water consumption and energy use in the boiler system. An efficient system returns 75-80% of its condensate water, but it is notorious for corroding pipes. While pipe corrosion is a common factor of condensate return, OSU has delayed addressing the costly repairs needed to keep this system running properly. OSU's condensate return is currently operating at 41%, which costs the University nearly $1.5 million annually (Ross Parkman). It is recommended that The Ohio State University address this issue to reduce their water, which will improve their AASHE STARS score. The break down of the potential costs and benefits of fixing the steam and condensate return system provides a better sense of the magnitude of such a project. In the end, replacing the condensate return pipes will dramatically increase the efficiency of the boiler system.

Multiple assumptions were made about the costs of replacing the Phase Four pipes. We created three potential cost options to allow for a certain level of sensitivity. The low-end of total costs were $14,103,818, the mid-range costs were $16,924,582, and the high-end costs were $23,750,181. We have estimated that the payback period for Phase Three will be 11.02 years and 23.55 years for Phase Four. Although these payback periods are quite long, it is worth noting that the problems that these installations will fix are inevitable, and it is more financially sound to complete them today rather than tomorrow. These projects will save the university 4.3% of its total potable water consumption, and this is far closer to the 5% target than any other project researched by H2 Block O.

The 4.3% reduction does not factor in any additional projects the university might undertake in the next five years such as implementing rainwater systems and low-flow fixtures. Additional research was conducted to identify potential future projects that will help OSU improve their AASHE STARS water score. The AASHE STARS report looks at the various avenues through which a university can take to improve upon their institutional sustainability performance. For this reason, it is necessary to offer a few additional suggestions to The Ohio State University. Our first suggestion is to take advantage of the continuous construction on campus and add rainwater and grey water systems to the designs. This solution will save OSU a considerable amount of costs for building these systems, and it will solidify The Ohio State University as an institutional leader in sustainability amongst its academic peers around the globe. The second is for OSU to retrofit older buildings with low-flow toilets and automatic faucets. This is a relatively less capital-intensive solution for The Ohio State University to improve its water consumption and to mirror efforts from other leading sustainable universities. Lastly, our group recommends that OSU create an education program to promote water consumption in the dorms, where a majority of campus water users are located. The combination of the McCracken steam and condensate repair plans and the suggestions for the future shall help guide The Ohio State University to the 5% reduction by 2020, while setting this university to improve upon that reduction in subsequent five year plans.

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Appendix A

Figure 4. Basic diagram of boiler system at McCracken Power Plant

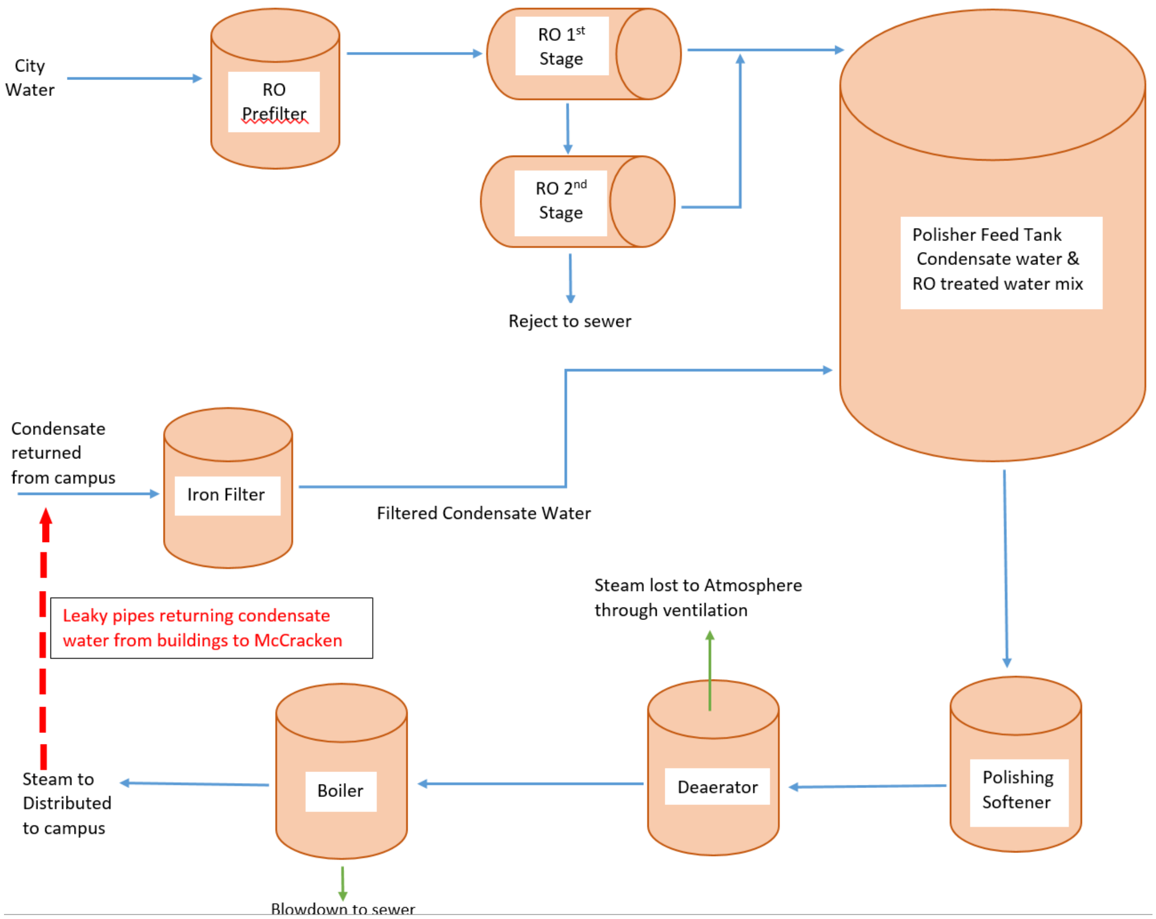
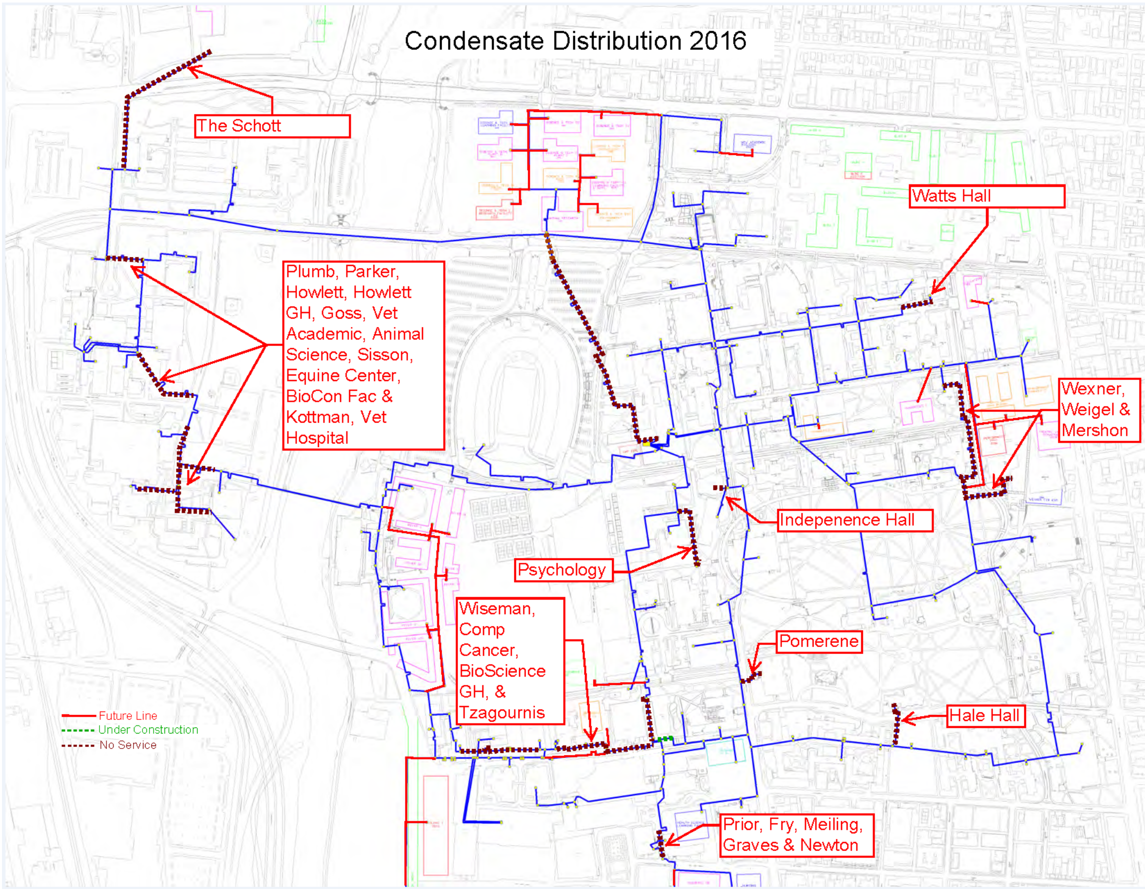


Diagram inspired by diagram provided to us on March 9, 2016 by Brad Coy, Utility Plant Superintendent at McCracken Power Plant, OSU

Figure 5. Condensate pipe distribution map 2016. Map is not to scale



Condensate pipe map created by Ryan Wester, Utilities Technical Director at OSU. Map provided to us by Brad Coy, Utilities Plant Superintendent at OSU. Red lines indicate future pipes, Green lines represent pipes that are under construction, and the dotted line represents failing pipes that need repaired or replaced.

Appendix B

Communication 1
Brad Coy, Utilities Plant Superintendent at McCracken Power Plant. Phone number: 614-292-7123 Email: coy.83@osu.edu

Email communication with Brad Coy regarding McCracken operation and inefficiencies on March 3, 2016.

Hi Brad,
Below are some questions our group had before the tour.

(Brad Coy's responses are in blue)

- How much city water are we buying/using to make up for water loss? How much of the supplemental water is going to the boilers as makeup? See student spreadsheet for boilers. I didn't include chiller plants.
- The attachment is a list of buildings that appear to be connected to the boiler system, are they any other buildings connected to the system that aren't on the list? See attachment Condensate Analysis 160301.xls. It was recently put together by Ross Parkman (Senior Director of Utilities). It lists buildings and also gives a summary of potential savings. In the McCracken Steam column YI indicates Yes/Internal to Utilities, YM indicates Yes/Metered, YMH indicates metered hot water (probably no direct steam/condensate), Y indicates Yes, YMP indicates Yes/Meter Planned.
- What type of boiler system do we have? Water tube or fire tube? Water Tube
- How much water is pumped through the pipes daily or annually, on average? See student spreadsheet Total Water to Boilers. It is the boiler make up (treated by reverse osmosis) and condensate return.
- What do the boilers operate at per minute? Steam ranges from 120,000 lbs./hr. in summer to 520,000 lbs./hr. in winter
- What numbers can he give us on the condensation inefficiency rate for the boiler? Daily, monthly, or yearly? See student spreadsheet. It isn't really related to the boiler. There is about a 1-2% loss in the boiler due to having to blowdown any concentrated solids in the water (high conductivity).
- What is the percentage of condensate return for the boilers? ~41% for 2015
- How much condensation is loss per minute, or hour, or day, or annually? See the Boiler Make Up column on the student spreadsheet.
- What is the overall water consumption of the boilers, what is the monthly? See spreadsheet Total Water to Boilers.
- How much is lost to leakage in the boilers? ~1-2% blowdown for conductivity control.
- How many miles of pipes need to be replaced? Is there a map of the pipes on campus? Most of the replacement is needed on Midwest.
- What is the horsepower of the boilers? Five of the boilers are rated at 150,000 lbs/hr steam flow which should be about 4348 horsepower. One boiler is rated for 220,000 lbs./hr. which should be about 6377 horsepower. I have never used boiler horsepower. We typically describe the boilers by operating pressure and steam

flow. There is a table in the attachment of an earlier email that listed the pressures and flows of our boilers.

- Can he explain the difference of the boiler, the condensation system, and the main water distribution on campus? Better to do in person.

Questions from Chemical Engineer group

- What companies supply the machines to process and pump water? Nalco supplied the reverse osmosis water treatment equipment. For pumping we use Goulds pumps and Spirax Sarco is a common manufacturer of condensate pumping equipment
- What machines are used? Filters, reverse osmosis for boiler water treatment. For chillers we have Trane and York machines. Cooling towers are BAC, Marley, and others. We have Vortisand side stream sand filters on the chiller plants cooling tower/condenser water streams.
- How clean is the water i.e. level of cleaning required for water? Need extremely clean water for boilers. Impurities scale tubes, reducing efficiency, and leads to tube failures . Target 0 ppm hardness, conductivity less than 15, chlorine target 0 ppm, Iron target 0 ppm.
- Is it possible to get the cost of each process within the different plants? Can give you more specific information after we discuss on Wednesday.

As far as a budget allocated for a project – I have no idea what a rainwater catchment system would cost or what is associated with it. I have never seen one in operation or researched it. Internally our budgets are very tight and we usually have to budget larger projects at least a year in advance.

Brad Coy
Utility Plant Superintendent
Facilities Operations and Development Utilities Division
134 McCracken Power Plant, 304 W 17th Ave., Columbus, OH 43210
Office 614-292-7123
coy.83@osu.edu

Communication 2
Brad Coy, Utilities Plant Superintendent at McCracken Power Plant. Phone number: 614-292-7123 Email: coy.83@osu.edu

Email communication with Brad Coy regarding McCracken operation and inefficiencies on March 7, 2016.

Heather,
Attached is a general information sheet about McCracken that shows some of the boiler information.

Brad Coy
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Attached Info referenced by Brad Coy in email communication above

UTILITIES

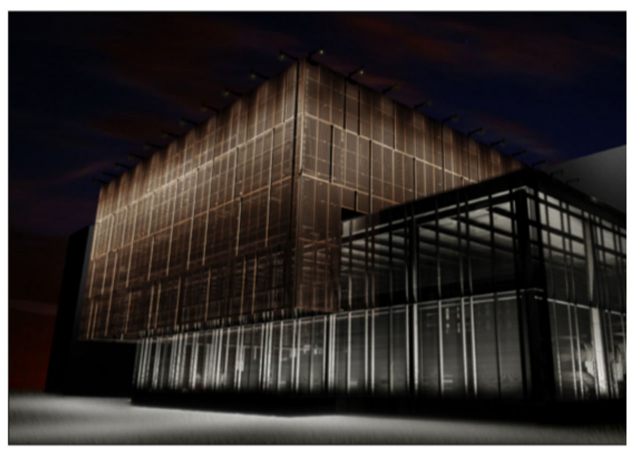
McCRACKEN POWER PLANT

The McCracken Power Plant was built in three phases starting in 1918, undergoing several renovations and fuels over the years. McCracken provides steam, hot water, and chilled water for campus consumption, generating 80% of the heating requirements of the main campus. Steam produced at the plant supplies space and water heating, absorption air conditioning, autoclaves, distillation units, food service, soil sterilization at some of the greenhouses, humidification, and laboratories. The average steam load during the summer is approximately 125,000 lbs/hr. The peak winter load is 520,000 lbs/hr, and the average winter load is 350,000 lbs/hr.

Boilers McCraken Power Plant has five boilers:

#	FUEL	STEAM CAPACITY (lb/hr)	STEAM PRESSURE (psig)	TEMP °F
1	Gas, #2 Fuel Oil	150,000	200	660
3	Gas, #2 Fuel Oil	150,000	200	660
5	Gas, #2 Fuel Oil	220,000	600	750
6	Gas, #2 Fuel Oil	150,000	200	660
7	Gas, #2 Fuel Oil	150,000	200	660
	Gas, #2			

There is storage capacity for 480,000 gal (a 7-day supply) of #2 fuel oil and 30,000 gallons of diesel fuel located in a tank farm behind the plant. A 600 psig coal-fired boiler was decommissioned in 2005, replaced by a gas/oil unit in November 2014 to support the Wexner Medical Center expansion. The 200 psi boilers supply a 200 psig loop header system that operates at 185 psig/650°F and feeds 6 campus main steam lines and auxiliary plant loads. The #5 boiler supplies 600 psig steam to a pressure-reducing valve that feeds the 200 psig steam header. The 600



psig steam turbine generators were decommissioned and removed after the coal boiler shutdown, and the plant no longer operates turbines for continuous electrical generation. New gas turbine cogeneration and combined heat and power options are under consideration. The plant has standby diesel-driven electrical generators for emergency power outage situations.

Communication 3

Brad Coy, Utilities Plant Superintendent at McCracken Power Plant. Phone number: 614-292-7123 Email: coy.83@osu.edu

Email communication with Brad Coy regarding McCracken operation and inefficiencies on March 8, 2016.

Heather,
Below is my first go at answering your questions. I've attached a couple of spreadsheets. One I made showing boiler make up, condensate return, total water to the boilers, steam production, water rejected from our reverse osmosis (RO) system, water sent through our RO system for 2015. The other (Condensate Analysis) was recently made by Ross Parkman. I described it a little under the 2nd bullet in your questions below.

If this triggers any more questions let me know and I'll see what I can throw together prior to tomorrow.

Brad Coy
Utility Plant Superintendent
Facilities Operations and Development Utilities Division
134 McCracken Power Plant, 304 W 17th Ave., Columbus, OH 43210
Office 614-292-7123
coy.83@osu.edu

Condensate Analysis email attachment from Brad Coy as aforementioned in his communication (created by Ross Parkman)

BLDG NUM	Building Size GSF	Facilities Group	District	Zone	BLDG NAME	McCracken Steam	Return Pipeline Condition
388	82,000	Utilities			Chiller Plant, South	YI	ok
376	35,000	Utilities			Chiller Plant, East	YI	ok
161	338,407	Student Life			OHIO UNION	YM	ok
271	322,374	Student Life			LINCOLN TOWER	YM	ok
272	321,244	Student Life			MORRILL TOWER	YM	ok
852	267,055	Student Life			Smith-Steeb (Replaced B-109 & B-141)	YMH	ok
851	264,330	Student Life			Park-Stradley (Replaced B-96 & B-104)	YMH	ok
95	227,010	Student Life			BAKER HALL (E&W)	YMH	ok
190	99,934	Student Life			MORRISON TOWER	Y	ok

99	79,942	Student Life			SIEBERT	YM	ok
100	78,880	Student Life			MACK HALL	YM	ok
97	70,349	Student Life			BRADLEY	YM	ok
103	64,303	Student Life			PATERSON	YM	ok
98	61,231	Student Life			CANFIELD	YM	ok
105	35,731	Student Life			KENNEDY COMMONS	YM	ok
82	808,359	other			Ohio Stadium	YM	ok
88	365,188	other			Parking Garage-Tuttle Park Pl	Y	ok
254	127,992	other			BLACKWELL INN	YM	ok
296	115,835	other			DRAKE PERFORMANCE CENTER	YM	ok
375	1,186,252	Hospital			James Cancer Hospital (new)	YM	ok
89	673,130	Hospital			DOAN HALL	YM	ok
354	507,803	Hospital			RHODES HALL	YM	ok
353	306,801	Hospital			Ross Heart Hospital	YM	ok
372	258,797	Hospital			300 W TENTH (Old James)	YM	ok
165	114,199	Hospital			Harding Hospital (Neuroscience)	YM	ok
356	90,747	Hospital			395 WEST 12th (Doan Add)	YM	ok
246	279,848	FOD OPS	1	1	RPAC	YMH	ok
279	185,430	FOD OPS	1	1	Dreese Lab	YM	ok
245	163,899	FOD OPS	1	1	PHYS ACTIV & EDUC SRVS BLDG (PAES)	YMH	ok
247	127,491	FOD OPS	1	1	McCorkle Aquatics Pavilion	YMH	ok
280	115,817	FOD OPS	1	1	BAKER SYSTEMS ENGINEERING	YM	ok
25	115,260	FOD OPS	1	1	Derby Hall	YM	ok
5	99,126	FOD OPS	1	1	Science & Eng. Library (18th Ave Library)	YM	ok
72	88,768	FOD OPS	1	1	Central Classroom Building (Enarson)	Y	ok
339	78,718	FOD OPS	1	1	University Hall	YMH	ok
1	73,877	FOD OPS	1	1	Bricker Hall	YM	ok
7	62,698	FOD OPS	1	1	Mathematics Tower	YMH	ok
63	59,866	FOD OPS	1	1	Cockins Hall	YH	ok
294	53,147	FOD OPS	1	1	Wilce Student Health Center	Y	ok
78	51,289	FOD OPS	1	1	Maintenance Building	Y	ok

337	42,300	FOD OPS	1	1	Dulles Hall	YMH	ok
187	29,038	FOD OPS	1	1	Mathematics Building	YMH	ok
4	25,077	FOD OPS	1	1	209 W 18th Ave (Math Classrooms)	YMH	ok
77	15,136	FOD OPS	1	1	Central Service Building	Y	ok
148	262,916	FOD OPS	1	2	Scott Lab	YM	ok
76	217,262	FOD OPS	1	2	St John Arena	YM	ok
160	132,250	FOD OPS	1	2	STUDENT ACADEMIC SERVICES BLDG	YM	ok
249	132,056	FOD OPS	1	2	Fisher Hall	Y	ok
274	118,612	FOD OPS	1	2	Hitchcock Hall	YH	ok
26	100,348	FOD OPS	1	2	Caldwell Lab	YMH	ok
86	88,424	FOD OPS	1	2	French Field House	Y	ok
46	84,561	FOD OPS	1	2	Journalism Building	Y	ok
146	82,179	FOD OPS	1	2	Bolz Hall	YMH	ok
250	69,508	FOD OPS	1	2	GERLACH	YMP	ok
252	68,150	FOD OPS	1	2	Mason Hall	YM	ok
251	62,748	FOD OPS	1	2	SCHOENBAUM	YM	ok
253	58,031	FOD OPS	1	2	PFAHL EXECUTIVE EDUC BLDG	YM	ok
229	33,845	FOD OPS	1	2	Ice Rink	YM	ok
70	238,732	FOD OPS	1	3	Physics Research Bldg	YM	ok
248	236,537	FOD OPS	1	3	CBEC	YM	ok
65	218,839	FOD OPS	1	3	Smith Laboratory	YM	ok
49	211,942	FOD OPS	1	3	Drinko Hall-College of Law	YM	ok
53	117,599	FOD OPS	1	3	McPherson Chemical Laboratory	YM	ok
150	117,574	FOD OPS	1	3	Evans Laboratory	YH	ok
371	110,310	FOD OPS	1	3	Celeste Lab of Chemistry	YMH	ok
145	83,437	FOD OPS	1	3	140 W 19th (Old Koffolt)	YM	ok
265	76,345	FOD OPS	1	3	MacQuigg Laboratory	Y	ok
147	62,058	FOD OPS	1	3	Newman & Wolfrom Laboratory	YH	ok
151	32,462	FOD OPS	1	3	Fontana Laboratory	Y	ok
106	135,883	FOD OPS	1	4	Sullivant Hall	YM	ok
11	129,371	FOD OPS	1	4	Arps Hall	YMH	ok
149	110,220	FOD OPS	1	4	Hopkins Hall	YMH	ok
30	103,832	FOD OPS	1	4	Denney Hall	YMH	ok
90	86,387	FOD OPS	1	4	Ramseyer Hall	YH	ok

84	67,284	FOD OPS	1	4	Stillman Hall	YH	ok
61	64,665	FOD OPS	1	4	Page Hall	YM	ok
42	60,883	FOD OPS	1	4	Hughes Hall	YH	ok
39	43,608	FOD OPS	1	4	Hayes Hall	Y	ok
112	412,640	FOD OPS	2	1	BIOMEDICAL RESEARCH TOWER	YM	ok
176	149,403	FOD OPS	2	1	Starling Loving Hall	YM	ok
38	141,461	FOD OPS	2	1	Hamilton Hall	YM	ok
113	139,528	FOD OPS	2	1	Davis Heart & Lung Institute	YM	ok
24	278,307	FOD OPS	2	2	Postle Hall	Y	ok
276	180,694	FOD OPS	2	2	Biological Sciences Building	YM	ok
17	174,422	FOD OPS	2	2	Knowlton Hall	YM	ok
266	130,130	FOD OPS	2	2	Riffe Building	YM	ok
273	119,237	FOD OPS	2	2	Parks Hall	YM	ok
18	115,204	FOD OPS	2	2	Campbell Hall	YM	ok
14	112,502	FOD OPS	2	2	Jennings Hall (B&Z)	YMP	ok
131	108,644	FOD OPS	2	2	Aronoff Lab	YM	ok
293	68,100	FOD OPS	2	2	Cunz Hall	YM	ok
50	302,050	FOD OPS	2	3	Thompson (Main) Library	YM	ok
37	142,512	FOD OPS	2	3	Hagerty Hall	YM	ok
54	126,300	FOD OPS	2	3	Mendenhall Laboratory	YM	ok
41	66,550	FOD OPS	2	3	Lazenby Hall	Y	ok
87	64,370	FOD OPS	2	3	Townshend Hall	YM	ok
60	39,797	FOD OPS	2	3	Orton Hall	YH	ok
28	32,711	FOD OPS	2	3	Faculty Club	YH	ok
102	31,148	FOD OPS	2	3	Oxley Hall	Y	ok
298	120,345	FOD OPS	2	4	Agriculture Engineering	YM	ok
3	100,271	FOD OPS	2	4	Agriculture Administration	YM	ok
81	604,784	other			SCHOTTENSTEIN CENTER	YM	line failed
338	15,891	FOD OPS	1	1	Independence Hall	Y	line failed
107	35,504	FOD OPS	1	3	Watts Hall	YM	line failed
277	223,221	FOD OPS			Graves Hall	Y	line failed
299	222,496	FOD OPS			Veterinary Hospital	YM	line failed

340	167,040	FOD OPS			Kottman Hall	YM	line failed
302	147,486	FOD OPS			Prior Health Sciences Library	YM	line failed
144	132,712	FOD OPS			Psychology	YM	line failed
386	131,071	FOD OPS			Wexner Center for the Arts	Y	line failed
55	120,223	FOD OPS			Mershon Auditorium	YM	line failed
136	113,459	FOD OPS			VETERINARY MED ACADEMIC BLDG	YM	line failed
157	82,032	FOD OPS			Wiseman Hall	Y	line failed
275	80,833	FOD OPS			Newton Hall	YMP	line failed
163	80,417	FOD OPS			TZAGOURNIS MEDICAL RESEARCH	YM	line failed
64	78,214	FOD OPS			PARKER FOOD SCIENCE & TECH	Y	line failed
281	76,545	FOD OPS			Meiling Hall	Y	line failed
59	75,040	FOD OPS			Fry Hall	YM	line failed
363	74,390	FOD OPS			Comp Cancer Center	Y	line failed
67	73,603	FOD OPS			Pomerene Hall	Y	line failed
180	67,943	FOD OPS			Goss Laboratory	Y	line failed
295	62,605	FOD OPS			Howlett Hall	Y	line failed
156	55,889	FOD OPS			Animal Science	Y	line failed
80	55,501	FOD OPS			Sisson Hall	Y	line failed
355	47,042	FOD OPS			Weigel Hall	Y	line failed
85	47,001	FOD OPS			HALE, FRANK W, JR, HALL (Old Enarson)	YM	line failed
66	45,196	FOD OPS			Plumb Hall	Y	line failed
297	41,484	FOD OPS			Howlett Greenhouse	Y	line failed
282	40,822	FOD OPS			Equine Center, Galbreath (vet hospital)	Y	line failed
10	35,173	FOD OPS			BioScience Greenhouse	Y	line failed
12	18,258	FOD OPS			Ornamental Plant Germplasm Center	Y	line failed
GSF on ok lines	15,544,862	83.6%	100 Buildings				

GSF on Failed lines	3,051,875	16.4%	29 buildings
Total Steam GSF	18,596,737		

Yearly Building Steam	Building steam along working pipelines	potential condensate recovery	actual condensate recovery	condensate lost adjacent to working pipelines	fuel and water savings per unit	Potential yearly fuel and water savings	prices	Yearly cost savings
(1000lbs)	(%)	(1000lbs)	(1000lbs)		mmbtu/1000lb	mmbtu	$/mmbtu	$
1,600,000	83.6%	1,337,427	625,500	711,927	0.125	88,991	$ 3.50	$ 311,468
			47%	53%	ccf/1000lb	ccf	$/ccf	
					0.211	150,217	$ 5.60	$ 841,213
							Total potential savings	$ 1,152,681
							average savings / 1000lbs	$ 1.62

				Yearly Savings		
	% of lost condensate	(1000lbs)	$/1000lb	$	mmbtu	ccf
Phase 1 target	15%	106,789	$1.62	$ 172,902	13,349	22,532
Phase 2 target	20%	142,385	$1.62	$ 230,536	17,798	30,043
Phase 3 target	25%	177,982	$1.62	$ 288,170	22,248	37,554
Total	60%	427,156		$ 691,609	53,395	90,130
				% of Total McCracken fuel and campus water saved	2.1%	4.9%

Summary

Even at todays low fuel prices, condensate is worth $1.61 / klb when the boiler makeup water savings are included
53% of the condensate in buildings adjacent to working pipelines is being lost
Modest repairs to building condensate pumps could save $172,000 in purchased fuel and water
Over time, recovering 60% of lost condensate saves $691,000 annually, 2.1% of McCracken fuel and 4.9% of campus water
If domestic water is being used in buildings to quench condensate to the sewer, there will be additional water savings
If fuel prices increase to $5/mmbtu, savings would be $771,000 annually

Student Spreadsheet as aforementioned in Brad Coy's email

Month	Boiler Make Up (gallons)	Condensate Returned (gallons)	Total Water to Boilers (gallons)	% Condensate Return	Steam Production (lbs.)	RO Reject (gallons)	% Reject	Total Water Flow Through RO's
January-15	15,462,931	9,454,551	24,917,482	37.94%	256,361,000	4,138,911	21.11%	19,601,842
February-15	14,253,847	11,247,438	25,501,285	44.11%	257,836,000	4,192,339	22.73%	18,446,186
March-15	10,639,097	9,554,608	20,193,705	47.31%	199,575,000	2,909,551	21.47%	13,548,648
April-15	7,036,896	6,706,903	13,743,799	48.80%	139,036,000	2,013,828	22.25%	9,050,724
May-15	6,015,413	5,055,104	11,070,517	45.66%	103,838,000	1,706,220	22.10%	7,721,633
June-15	5,321,830	4,696,595	10,018,425	46.88%	96,982,000	1,510,987	22.11%	6,832,817
July-15	6,275,028	3,974,371	10,249,399	38.78%	100,367,000	1,901,368	23.25%	8,176,396
August-15	6,041,614	3,843,077	9,884,691	38.88%	99,101,000	1,809,638	23.05%	7,851,252
September-15	6,559,117	3,484,364	10,043,481	34.69%	98,013,000	1,932,807	22.76%	8,491,924
October-15	8,364,661	4,836,310	13,200,971	36.64%	131,183,000	2,517,169	23.13%	10,881,830
November-15	9,486,761	5,886,907	15,373,668	38.29%	154,119,000	2,811,108	22.86%	12,297,869
December-15	11,396,162	5,784,351	17,180,513	33.67%	173,030,000	3,383,288	22.89%	14,779,450
2015 Total	**106,853,357**	**74,524,579**	**181,377,936**	41.09%	**1,809,441,000**	**30,827,214**	22.39%	**137,680,571**

Communication 4

Brad Coy, Utilities Plant Superintendent at McCracken Power Plant. Phone number: 614-292-7123 Email: coy.83@osu.edu

Notes from conversation with Brad Coy regarding McCracken operation and inefficiencies. Face-to-face interview and tour of McCracken Power Plant on March 9, 2016.

How does the system function overall?

- 106 million gallons annually bought from city; goes through RO pre-filter then 2 stage RO filter: 1st stage 50% goes into polisher feed tank, other 50% goes to 2nd stage RO; 50% goes to polisher feed tank and other 50% (130 g/m) rejected to sewer directly. This has hard conductivity
    - 3 RO; 2 run during winter and 1 as back up; 1 runs during summer
- Efficiency ideal: reduce city water to 20%; increase condensate to 80%
- Polisher feed tank receives 520g/m intake
- 430 g/m coming from RO but varies sometimes
- 74.5 million gallons from condensate (returned from end users) going into boiler system.
    - $1.61/1,000 lbs will save $1.61
- Deaerator drives oxygen out; big heater 200/221 degrees
    - Steam uses to heat water
    - Steam released from atmosphere from deaerator. It's low pressure water; no use for it
- 6 boilers range from 120,000 lbs/hr, 150,000 lbs/hr, 220,000 lbs/hr
    - Steam comes out at 600 psi for 220,000 lbs/hr boiler
- Blowdown sent to sewer; essentially solid waste loss 1-2%.
- Steam loss from boiler used to heat deaerator
- Then steam sent to distribution (sent to end users). All this steam could potentially feed back into condensate return
    - Looped back after its been condensed (used by bldg.)
    - To condensate directly from bldg. vented to atmosphere or condensate steam receiver may lose some to vented atmosphere
- Doesn't treat their steam because the end users don't want it treated. So steam is corrosive due to low pH level
    - Pipes corrode because high temp of steam, low pH of steam, and the chlorides in it

Are the new dorms connected to McCracken?

- New north dorms are separate
- South dorms use McCracken as back up

Do you know where a majority of the pipes are broken and leaking steam?

- Midwest buried condensate lines failed. This is where most of the failed pipes are

Do you know what type of pipes OSU uses?

- Pipes tried in past include carbon steel and some others. Currently using 316L

What is the steam used for?

- Steam heat for the buildings & sanitation at research labs

Communication 5

Patrick Smith, metering and billing department of Energy Services and Sustainability at OSU. Phone Number: 614-247-6538 Email: smith.6507@osu.edu

Notes from telephone meeting with Patrick Smith on March 27, 2016 about different phases of this construction project and costs.

- Current maintenance and renovations: piecemealed, coupled with construction, costs more
- Movers: end-users and buildings
- Pipes: utilities
- Steam: design for condensate
    - Phase 3: Jennings, Wexner, etc. Midwest campus
    - Tunnel repairs make it complicated
    - Phase 1: 12th Avenue to oval $6.8 million, completed
    - Condensate pumps: $5,000
    - Steam receiver: $18,000
    - Phase 2: McCracken to Drake $21 million, completed
    - Map by Francisco Sevadra
    - Never better than 75%
- Phase 4
    - Vet Hospital, Kottman Hall, Plumb Hall, Howlett Hall, Howlett Greenhouse, Parker Food Science, Sisson, Ecklen, Goss, Animal Science Building, Vet Med Academic
    - No costs associated yet
    - Phase 3 and 4 = recover 40% of condensate loss
    - more difficult = more costly
    - range of costs: materials, design, management, construction, administration (20% of costs)

Communication 6
PERMA Pipes. Phone Number: 847-966-2235 Email: marketing@permapipe.com

Notes from telephone meeting with PERMA Pipes on March 27, 2016 on construction costs and types of piping that OSU uses.

- multi-thermal 750 piping system
- return line is half the diameter of steam pipe
- shallow trench-concrete box-“coffin trench”
- walk through tunnels
  - long life span
- direct bury system
  - less expensive
- new system pipes with old system pipes causes corrosion and “Band-Aid” problem
  - one OSU project supposed to be $35,000 but turned out to be $100,000 because of this
- across the river pipes=more expensive, 25-30% of total cost
- 10” diameter steam pipes are $400/ft.
- steam elbows are $3,000
- 5” diameter condensate return pipes are $390/ft.
- condensate elbows are $3,800
- installation is about 1.5-2x materials costs
- excavation is large cost

OSU has unique system: 600lbs