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Steam Condensate Leakage

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Abstract:

Argonne National Laboratory (ANL) is a multi-program research and development center owned by the United States Department of Energy and operated by the University of Chicago. ANL's primary facilities are located on a 1,700 acre site 27 miles southwest of Chicago. Over 70 buildings house approximately 4,500 employees at this site.

The majority of the buildings on site use steam for heating and other purposes. Steam is generated from liquid water at the site's central boiler house and distributed around the site by means of large pipes both above and below the ground. Steam comes into each building where it is converted to liquid condensate, giving off heat which can be used by the building. The condensate is then pumped back to the boiler house where it will be reheated to steam again.

The process is continual but is not perfectly efficient. A substantial amount of condensate is being lost somewhere on site (instead of being returned to the boiler house.) The lost condensate has both economic and environmental significance. To compensate for lost condensate, makeup water must be added to the returned condensate at the boiler house. The water cost itself will become significant in the future when ANL begins purchasing Lake Michigan water. In addition to the water cost, there is also the cost of chemically treating the water to remove impurities, and there is the cost of energy required to heat the water, as it enters the boiler house 100° F colder than the condensate return.

It has been estimated that only approximately 60% of ANL's steam is being returned as condensate, thus 40% is being wasted. This is quite costly to ANL and will become significantly more costly in the future when ANL begins purchasing water from Lake Michigan.

This study locates where condensate loss is occurring and shows how much money would be saved by repairing the areas of loss. Shortly after completion of the study, one of the major areas of loss was repaired. This paper discusses the basis for the study, the areas where losses are occurring, the potential savings of

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repairing the losses, and a hypothesis as to where the unaccounted for loss is occurring.

I. BACKGROUND

The majority of the buildings at ANL use steam for heating and other purposes. Steam is generated from liquid water at the site's central boiler house and distributed around the site by means of large pipes both above and below the ground. The Central boiler house contains five boilers manufactured by Wickes Boiler Co. during 1950-1965. Boilers 1-4 each have an operating capacity of 85,000 lbs steam/hr. and boiler 5 has a capacity of 170,000 lbs. steam/hr. All of the boilers operate at a pressure of 200 psig with saturated steam conditions.

Steam generated at the boiler house is distributed to each building on site by means of large insulated pipes. The steam comes into each building and goes through a heat exchanger, giving off heat as it condenses to liquid condensate. The condensate flows to a condensate receiver, from where it is pumped out of the building and returns to the boiler house. There it is reconverted to steam and used over again, a continual process. The process is not perfectly efficient, as a substantial amount of condensate is not being returned to the boiler house. Makeup water must be added at the boiler house to compensate for the lost condensate. This water must be chemically treated and heated, both of which have a cost to the laboratory. The lost condensate is also of great concern because ANL will soon begin to purchase water from Lake Michigan at a cost of $4 per 1000 gallons. It was estimated that 40% of ANL's steam was being wasted, and a study was done to locate the areas of loss so that they may be repaired.

II. OBJECTIVES

The main objectives of this study were to:

1. Locate and document areas where steam or condensate loss is occurring.

2. Determine the quantity of steam or condensate being lost.

3. Assign a dollar amount to the losses, showing how much money would be saved by repairing the areas of loss.

III. PROCEDURE

Two main areas were targeted for study, individual buildings and outdoor steam distribution pipes.

A preliminary list of buildings known to be losing condensate was acquired from the boiler house. Appointments were made to visit the buildings and observe where and how the loss was occurring.

The first building examined was Building 213, the ANL cafeteria. This building uses a large amount of steam, mainly for the purpose of cooking and washing dishes. No losses were apparent upon inspection, so building maintenance was consulted. It was learned from building maintenance that the building's condensate return system was damaged. All condensate was being dumped directly into the sewer, returning nothing to the boiler house. An experiment was set up to measure the amount of condensate being lost. Using a one gallon graduated container to collect the condensate and a watch, the duration of time needed for the condensate to fill the container half-full was measured. This procedure was repeated several times and at different times of the day, and all data was recorded. A total of 200 trials were performed, and calculations were made based upon the data, giving an experimental estimate of the amount of condensate being lost at building 213.

Buildings in the 300 area were then visited. Buildings 302, 308, 311, 330, and 335 were found to be dumping condensate because of damaged condensate return systems. Rather than using experiments to determine the amount of condensate being lost, steam consumption data were acquired from the boiler house. Steam consumptions for each building and for the site as a whole for the past year were obtained. The data provided figures for total steam generated, total steam distributed to site, auxiliary steam used in the boiler house, condensate returned, as well as steam consumed at each building. Since all condensate from these buildings was being wasted, the measure of the steam consumed at the buildings could be used as an accurate measure of the amount of condensate being wasted. It was also found that buildings 206 and 208 were dumping all condensate into the sewer. In all, eight buildings were found to have damaged condensate return systems and were dumping all condensate into the sewer.

Several small condensate leaks were observed in the piping inside the individual buildings, but the losses were very small. Many of the encountered leaks were only a slow drip. The amounts of steam or condensate lost in these leaks was small and difficult to measure.

The outdoor steam distribution pipes were then examined in order to determine if they were contributing to the loss. Pipes were surveyed over the entire site, and several leaks were observed and documented. The location of the leak, the relative size, and the type of leak were recorded. A total of about 15 leaks were found on the pipes, ranging in size from very small with minimal loss to larger leaks with a substantial amount of loss. As with the small leaks observed in the piping inside the buildings, the amount being lost at these leaks was difficult to measure.

IV. RESULTS

Since buildings 206, 208, 213, 302, 308, 311, 330, and 335 return no condensate to the boiler house, the amount of condensate lost by each building is the amount of steam consumed. The data acquired from the boiler house contained the steam consumptions for each of these buildings, and these figures are used as the figures for the amount of condensate being lost. The steam consumption data are used rather than the experimental data from building 213 because the consumption data come from a constant meter and are more accurate. Data was put into spreadsheet form and calculations were made until results and conclusions were obtained. Table 1 displays the amount of condensate lost by each building.

Table 1: Condensate Lost at Each Building (in lbs.)

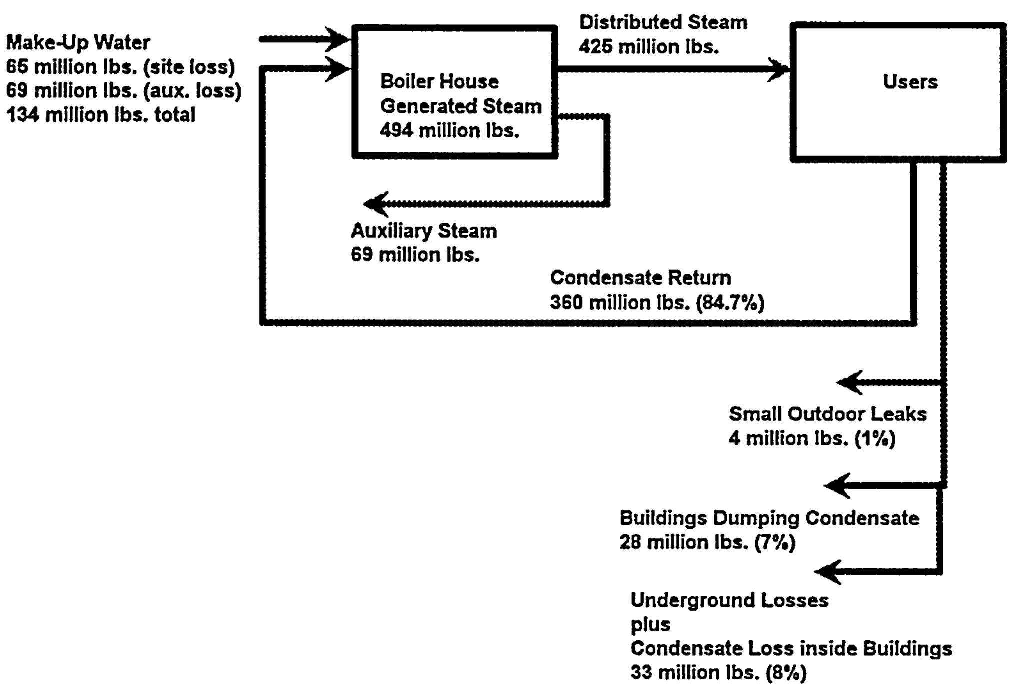
Building	Summer Sub-Total	Winter Sub-Total	Total
206 & 208	1,685,000	5,214,576	12,981,518
213	1,775,082	3,611,651	8,664,254
302	70,000	612,262	1,404,746
308	1,290,134	2,177,060	7,393,839
311	150,000	390,211	1,047,082
330	500,000	2,516,615	5,805,614
335	30,000	511,472	910,001
Total	5,500,216	15,033,847	38,207,054

* Some figures have been interpolated where data unavailable
Summer Sub-Total represents July through September 1994
Winter Sub-Total represents January through March 1995

It had been estimated that only 60% of ANL's steam was being returned to the boiler house as condensate; however, this is not an accurate estimate. The data acquired from the boiler house show that the amount of condensate that is unaccounted for is significantly less than 40%. Data was received for July 1994 through June 1995, (with the exception of January and April 1995, for which data was not readily available). During the ten month period, there has been a total of 494 million lbs. of steam generated at the boiler house. Over 69 million lbs. of steam were used at the boiler house as auxiliary steam, and 425 million lbs. of steam were distributed to site. The amount of condensate returned to the boiler house was 360 million lbs., yielding an average return rate of 84.7% (360/425). This is the percentage of distributed steam that is returned as condensate. The condensate return as a percentage of generated steam is significantly lower, at just under 73% (360/494), indicating a substantial steam loss at the boiler house. The reason for this difference is because approximately 14% of the generated steam is used as auxiliary steam which is used by the boiler house and never gets distributed to site. Auxiliary steam is used to energize steam turbines that drive feedwater pumps, forced draft fans, and induced draft fans. Exhaust steam is then used to preheat feedwater prior to injection into the deaerator. If the exhaust steam from the turbines is not sufficient to preheat the feedwater in the deaerator, then auxiliary steam is used directly to provide supplementary heat in the deaerator. Additionally, boiler blowdown is necessary to remove impurities that build up Inside the boiler. When dealing with condensate return rates, the distinction must be made between percentage of distributed steam versus percentage of generated steam. The amount of condensate being lost on-site is about 15.3% of the total distributed steam. Figure 1 graphically shows the steam-condensate process and accounts for all generated steam.

Figure 1

Steam Consumptions July 94-June 95



Buildings 206, 208, 213, 302, 308, 311, 330, and 335 dump all condensate into the sewer, returning nothing to the boiler house. Since all condensate is dumped, steam consumption data for the buildings can be used to determine the amount being wasted. During the past year (excluding January and April) these eight buildings have dumped over 28 million lbs. of condensate. This is 7% of the steam distributed to site and accounts for 44% of the total distributed condensate loss of 65 million lbs. Repairing the condensate return systems in these buildings would result in this 7% being saved and bring the condensate return rate to over 91% of the distributed steam.

The amount of condensate wasted by these eight buildings during the past 12 months (including January & April) is greater than 38 million lbs. These 38 million lbs. had to be replaced with makeup water at the boiler house. The two most prominent costs associated with this are chemical treatment and energy. The makeup water comes in at 50° F and is about 100° F colder than the condensate return. To heat the makeup water to the temperature of the condensate return requires the input of additional heat energy. The makeup water must also be chemically treated to remove impurities. For simplicity, a rough estimate of \$0.4/1000 lbs. H_2O for chemical treatment costs and \$0.4/1000 lbs. H_2O in energy costs is used, yielding a total cost of roughly \$0.8/1000 lbs. H_2O. Dumping 38 million lbs. of condensate requires 38 million lbs. of makeup water. Using \$0.8/1000 lbs. H_2O results in a cost of over \$30,400 per year. Repairing the condensate return systems at these buildings would result in a cost savings of over \$30,400 per year to ANL. This cost will be significantly greater in the future when ANL begins purchasing Lake Michigan water. As early as this fall, the water will be purchased at a cost of \$4/1000 gallons. Using a conversion factor of 8.34 pounds/gallon H_2O, 38 million lbs. corresponds to 4.6 million gallons H_2O per year. This makeup will cost ANL approximately \$19,000 per year if the systems are not repaired. Combining the current cost with the future cost, repairing the condensate return systems at these buildings will save ANL approximately \$50,000 per year.

After taking into account the eight buildings previously mentioned, an additional 9% of the distributed steam is still unaccounted for. This loss is occurring in three possible areas. 1) Some of the loss is due to leaks in the outdoor steam piping system, in the form of steam and condensate leaks, but the amount being lost here is difficult to measure. The pipes were examined during the summer, and all leaks were documented. An accurate picture cannot be gained because the leaks observed during the summer may be more significant during the winter, when steam consumption is higher. The amount of loss from the outdoor pipes above the ground is probably of the order of 1% of the steam distributed to site. More leaks would be observed if the pipes were examined during the winter months. 2) The outdoor steam distribution and condensate return pipes also run underground. Loss may be occurring underground where it cannot be observed. This is probably where the majority of the unaccounted for loss is occurring. 3) Some loss also occurs from small leaks inside the buildings, but the amount lost in this manner is very small.

Several leaks were observed in the outdoor steam distribution pipes. The quantity of steam or condensate leaking is difficult to accurately determine, and so an estimate of 1% is used. A table was created listing the location, size, and type of leaks found.

Shortly after this study was concluded, building 213's condensate return system was repaired. The project began with excavating the land adjacent to the building where the pipes enter the building. The condensate return pipes were observed to be damaged and were removed. The pipes were replaced as were the steam distribution pipes near the building as they too were observed to be damaged.

The other buildings reported above which were dumping all condensate into the sewer have similar problems as building 213. These buildings have damaged condensate return systems, also in the areas where the pipes enter the buildings. To repair these buildings would require similar procedures as building 213.

V. CONCLUSION

While believed to be about 60%, ANL's condensate return rate is actually closer to 85%. Approximately 15% of the total steam distributed to site is lost on site and is never returned as condensate. Buildings 206, 208, 213, 302, 308, 311, 330, and 335 all have damaged condensate return systems so they are dumping all condensate. The amount of condensate being dumped by these buildings is about 7% of the steam distributed to site. This is roughly 44% of the wasted condensate. The condensate return combined with the condensate loss accounted for at these eight buildings accounts for over 91% of the steam distributed to site. Nearly 9% of the distributed steam still remains unaccounted for. Repairing of the condensate return systems of these buildings would result in a cost savings of more than $30,400 per year. As early as this fall, ANL will begin purchasing water from Lake Michigan at a cost of $4 per 1000 gallons of water. An additional $19,000 will be saved each year in water costs if the systems are repaired. This brings the total savings to approximately $50,000 per year. Several leaks were found in the outdoor steam distribution pipes as well as inside the buildings, but the quantity of loss occurring was small and not easily determined.

It is likely that much of the 9% unaccounted for loss is occurring in the underground piping around the site. This is likely because the majority of the loss that is accounted for is occurring underground where the steam and condensate pipes enter the buildings. These underground pipes were observed to be damaged and corroded, thus giving reason to hypothesize that much of the unaccounted for loss is also occurring underground in a similar manner.