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RESOURCE CONSERVATION AND POLLUTION PREVENTION THROUGH PROCESS
OPTIMIZATION AT SANDIA NATIONAL LABORATORIES' STEAM PLANT

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1. INTRODUCTION

The Steam Plant at Sandia National Laboratories/New Mexico (SNL/NM) supplies on average 680,000 kg/day (1.5×10^6 lb/day) of saturated steam for space heating and laboratory processes for SNL/NM, Technical Area 1, the eastern portion of Kirtland Air Force base, the Department of Energy's Albuquerque Office, and the KAFB Coronado Club. The primary fuel is natural gas (740 mscf/yr); the secondary fuel in the event of a natural gas interruption is diesel fuel. Two storage tanks provide a diesel fuel reserve of 1.5 million gallons. The Steam Plant has been in continuous operation since 1949, and some of the boilers are past their design life. Table 1, below, provides a summary of the operational data for each of the five boilers. Each of the boilers is controlled through a central Digital Control System (DCS). The DCS design is based on the stoichiometric equation, where the O_2 stack concentration and load rate are set points and the combustion air and gas flow are adjusted based on the equation. The DCS was installed and programmed in 1992, but has not been updated since.

Table 1. Summary of Boiler Operational Data

Boiler #	Year of Installation	Steam Production (lb/hr)	Installed Boiler Efficiency Equipment for Heat Recovery	Fuel Type
1	1949	50,000	none	Natural Gas/Diesel
2	1949	50,000	none	Natural Gas/Diesel
3	1949	50,000	none	Natural Gas/Diesel
5	1967	100,000	Air Preheater	Natural Gas/Diesel
6	1972	150,000	Economizer	Natural Gas/Diesel

Long range studies are being conducted to determine the fate of the steam plant, but implementation of any of these options is at least 5 years in the future. Because it is a major source of air emissions, water and chemical use, and waste water at SNL/NM, the steam plant pursued immediate solutions to reduce

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costs and pollutant releases, while still providing uninterrupted, quality service to its customers. This paper will summarize the ongoing efforts to conserve water, and reduce air and wastewater discharges at the SNL/NM Steam Plant. These improvements were identified through a Pollution Prevention Opportunity Assessment, an Emissions Reduction Study,

2. RESULTS

A. BACKGROUND

Figure 1, a process flow diagram of the Steam Plant, identifies all major inputs and outputs. Figure 1 represents the configuration of the Steam Plant prior 1995, when recent improvements were implemented.

Before the source water (primarily well water) is converted to steam, it must be treated to remove minerals and alkalinity. The source water is processed through a water softener to remove calcium and magnesium salts, and a dealkalizer to remove carbonate alkalinity and adjust the pH. The treated source water is then mixed with returning condensate. Condensate is a valuable commodity to the steam plant. With its high temperature (up to 175 F), it requires less energy to produce steam. Additionally, condensate has already been treated and softened. This combined feed (make-up water) is de-aerated and treated with various chemicals to prevent solids from precipitating out of solution. The make-up water is periodically monitored by an onsite laboratory to determine the proper chemical dosage.

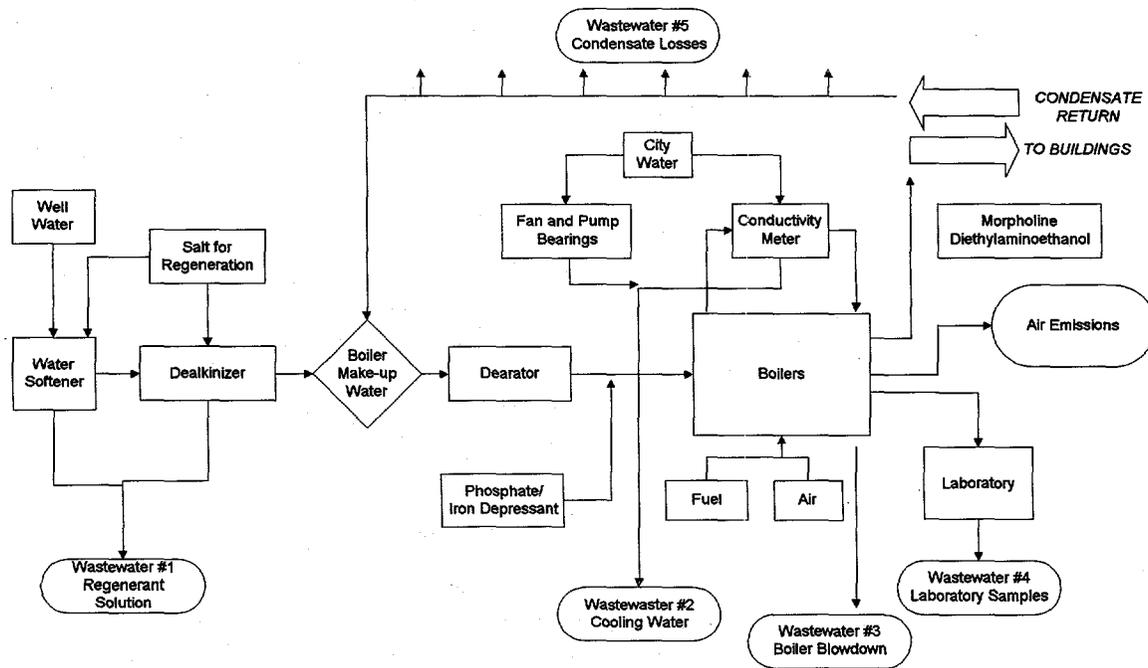


Figure 1. Process Flow Diagram of Steam Plant (Prior to Water Conservation Measures)

Once the water has been properly treated it is sent to one of the five operational boilers for conversion to steam. The steam is then distributed and returned to the plant through an underground network of 46 miles of piping to its users. The steam leaves the plant through three main lines at a pressure of 120 psi. It then enters steam pits, which act as transformers, reducing the pressure to 15 psi, and distributing it to individual buildings. When the desired amount of heat has been released, the steam is discharged to a steam trap, which separates the steam from the condensate. The condensate is sent back to the steam

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plant through condensate return lines using steam powered pumps. Figure 2 presents a schematic of the Steam Distribution Network. Approximately 30% of the steam produced is sold to KAFB.

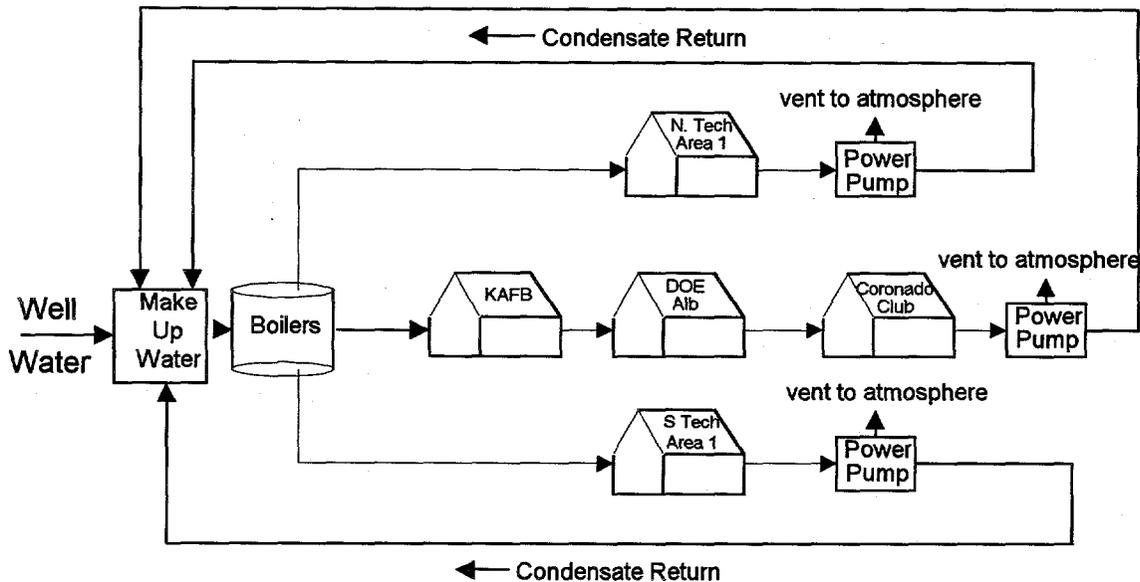


Figure 2. Steam Distribution Network at Sandia National Laboratories

Five major waste water streams (refer to figure 1) were generated during the production of steam. Each of these waste streams was combined for discharge into the City of Albuquerque sanitary sewer.

- 1) Water Softener and Dealkalizer Waste Water. Both of these units contain synthetic resins that remove impurities as the source water passes through. Periodically the resins are recharged with a salt (NaCl) solution. This recharge, or backwash water was estimated at 4 million gallons/year.
- 2) Cooling water. Two major sources contributed to this waste water stream. 1) The steam plant uses conductivity meters to monitor the quality of water processed into steam. To prevent the meters from overheating the steam plant uses a cold water line as a heat exchanger. The cold water, potable water from the City of Albuquerque, passed over the meter and was discharged to the sewer. This process generated approximately 2.6 million gallons per year. 2) To provide the necessary temperature for operation pump and fan bearing were cooled by continuously flushing with City water. This is a once through cooling system, which generated approximately 4 million gallons per year.
- 3) Boiler Blowdown. During the steam making process, residual minerals in the process water and added water treatment chemicals are not fully vaporized into steam and remain inside the boiler. With time the concentration of these materials increases. To prevent scale build-up inside the boiler, the concentrated solution is periodically removed. The contents are evacuated using the internal pressure of the boiler in a process known as blow-down. There are two types of blowdown, continuous and bottom. In continuous blowdown, a small percentage of the liquid in the boiler is bled off. In bottom blowdown, a more concentrated solution is removed from the bottom of the boiler. The continuous blowdown is used to pre-heat the make-up water, reducing the fuel necessary to heat it, while also lowering the temperature of blowdown prior to sewer discharge. The bottom blowdown is discharged directly to the sewer. The annual waste water produced by blow-down was approximately 5.7 million gallons per year.
- 4) Lab Waste Water. Each boiler is connected to the laboratory by a dedicated line which flows continuously when the boiler is operating. Inside the laboratory the sample stream flows through an open faucet. Periodically, the laboratory technician will collect a sample for water chemistry analysis.

Waste Water # 1.

The three dealkinizers were replaced with newer, more efficient models and an improved synthetic resin. The resin is a mixed bed type, with both cation and anion exchangers. The anion exchanger removes bicarbonate alkalinity, while the cation exchanger removes dissolved silica. (The old resin only removed bicarbonate alkalinity). This enabled 43% more water to be processed (an increase from 35,000 to 50,000 gallons), prior to regeneration, increasing resin life, reducing salt usage, and decreasing the volume of recharge waste water by 1.2 million gallons per year. To regenerate the mixed bed resin a hot caustic solution is pumped through the resin prior to regeneration with NaCl. Silica concentration in the feedwater was lowered from 24 to 7 ppm. The more efficient removal of bicarbonate alkalinity, reduced the need to add amine (which neutralizes the acid) to the boiler make-up water. The overall reduction in chemical use (amine and salt) was 80%.

Waste Water # 2 and # 3.

The discharges of conductivity meter cooling water and laboratory sample water has been eliminated. Both waste streams are now recycled back to the make-up water. Additionally the two waste water streams are collected in steam powered pumps which transfer the liquid to the condensate tank. This has eliminated the need for electric transfer pumps, and reduced electrical costs. Water consumption and waste water generation was reduced by 7.6 MG/year

The discharge of cooling water for the pump and fan bearing has been significantly reduced. Approximately 50% of the fans and bearing are now cooled with treated water (processed through the dealkinizers). Once this water is used to cool the bearings, it is use as make-up water for the boiler. This retrofit reduced water consumption and waste water generation by 4 million gallons per year.

Waste Water # 4.

Reduced silica and bicarbonate alkalinity concentrations in the make-up water has resulted in increased boiler cycles from 13 to 26. The boiler cycle is equal to the ratio of the solids in the boiler to the solids in the feedwater. By lowering the concentration of solids in the feedwater, the cycle is increased.. This effectively increases the amount of time between blowdowns, and reduces the yearly volume of blowdown waste water, and the volume of make-up water required to replace the blowdown by 2.7 million gallons per year.

Waste Water # 5.

Through inspecting the condensate return line and interfacing with steam users, SNL/NM identified and repaired leaks, increasing the average returned condensate from 52% to 68%. This is equivalent to 12 million gallons year of water savings due to a decrease in the amount of well water that needs to be treated and supplied to the boiler. Additionally, chemical costs are reduced by not having to treat the water, and fuel is saved, because the condensate is at a higher initial temperature.

Upgrade of laboratory. A chemical distribution system was installed at the steam plant. Chemicals are now purchased in bulk, stored in large tanks and distributed to the needed processes by metering pumps through dedicated piping. Previously, chemicals were purchased in small containers, and added manually to the system. This has improved worker safety, reduced the potential for spills, and reduced chemical usage by an estimated 30%.

B. AIR EMISSIONS

Near-term studies have concentrated on efforts to increase efficiency and decrease emissions from the boilers. Recommendations from these evaluations include: boiler tuning, low NO_x burners, and flue gas recirculation. Installation of low NO_x burners (LNB) and a flue gas recirculation (FGR) system can be highly effective at reducing emissions, however, they may require significant retrofits depending on the

configuration of the boiler. To determine the best course of action, funding (\$60,000) was obtained to implement the following two items.

1. Boiler Tuning and Optimization

Conducted by a boiler professional, this process concentrates on making operational changes to optimize boiler operation. The goals of this process include: minimize excess air and flue gas temperature, measure efficiency, minimize steam pressure, minimize blowdown, and provide accountability of losses. On natural gas fired boilers, NO_x emissions can be reduced by 10-20%. Additionally, tuning improves fuel efficiency from 1 - 3%. As part of the optimization, boiler professionals will determine if other measures (i.e., LNB and FGR) are a cost effective solution for additional emissions reduction

2. Rewrite boiler control program for DCS

Since the installation of the DCS, manufactured by Asea, Brown and Bovari (ABB), upgrades have been made to the operating software and to the steam plant (i.e., more accurate flow meters). Because the original installation and programming for the DCS was conducted by a subcontractor, steam plant personnel do not feel that the system is performing to its full potential. ABB will be hired to reprogram the DCS, working with plant personnel to identify the key control parameters to maximize efficiency and increase operational flexibility. ABB indicates that up to a 4% increase in efficiency is achievable.

The first of these tasks has been completed. Each of the five boilers were tested individually over a limited load range. The effluent of each boiler was analyzed for oxygen (O₂), CO and NO_x concentrations using a portable gas analyzer. Each of the units was tested in the "as found" condition before any changes to the operation were made. Following this baseline testing parameters affecting combustion (excess air and the air register position) were manipulated to determine if operating conditions could be improved to increase steam generator efficiency and decrease CO and NO_x emissions. During the testing period, the steam requirement of the plant was limited to loads between 40,000 and 50,000 lbs/hr. This is a typical summer loading. For the larger boiler, #5 and #6, higher loading conditions were simulated by reducing the steam pressure in the main steam header, creating a higher boiler load. Although this procedure allowed operating data to be recorded at several load points, there was not sufficient at a high load to enable manipulation of parameters which affect the combustion process.

The preliminary test results indicate that Units 5 and 6 operate in the 84% to 86% efficiency range and produce steam at a fuel cost of approximately \$3.54 to \$3.66 per thousand pounds. Units 1, 2, and 3 operate in an efficiency range of 78% to 83 % and produce steam at a fuel cost of \$3.67 to \$3.90 per thousand pounds of steam. Combustion tuning resulted in improvements to the efficiency of up to 2% and reduction of fuel costs of 2.5% for units 1, 2, and 3. The improvement to the performance of unit 5 was less pronounced, with boiler efficiency increasing by 0.67% and the cost of steam reducing by approximately 0.84%. Unit 6 was not able to be tuned due to load restrictions.

The results of testing indicate that the most cost-effective manner to operate the steam plant, in its present condition and configuration, is as follows:

- Operate only unit 5 for system loads from minimum load to 90,000 lbs/hr.
- Operate only unit 6 for system loads between 75,000 lbs/hr and 140,000 lbs/hr
- Units 5 and 6 should be operated together for system demands between 140,000 lbs/hr and 230,000 lbs/hr
- Above a system demand of 230,000 lbs/hr, unit 2 should be put into service, followed by units 1 and 3.

If high steam load demands are anticipated in the future, then it is recommended that units 1, 2, and 3 be retrofitted with economizers. However, if frequent steam loads greater than 230,000 lbs/hr are not anticipated, then the retrofit of economizers is not economical. Completion of this task will include the

analysis of retrofitting one or more of the boilers with low NO_x burners or a flue gas recirculation system to further increase efficiency and lower emissions. Because the boiler tuning was conducted in a summer month when steam demands are low, it is recommended that the procedure be repeated for boilers 5 and 6 during a high demand period.

The preliminary results from this effort are promising. The results from the boiler tuning will be used to reprogram the DCS to further maximize efficiency and increase operational flexibility.

3. CONCLUSIONS

A. Summary of Results

Through simple retrofits, such as the modification of plant plumbing to permit recycling and reuse of process and cooling water, and optimization of operational process, the SNL/NM steam plant has realized significant reductions in waster usage, waste water production, fuel and chemical use. Because air emissions are directly related to fuel use, these improvement resulted in lowered emissions. This reduction is emissions has not been quantified for water saving projects. These efforts have reduced the overall operating cost of the steam plant. Ongoing efforts to increase operational efficiency and reduce air emissions through boiler tuning and upgrade of the DCS computer code will produce additional economic and environmental benefits.

An additional benefit of implementing these projects has been to obtain better operating data, and to increase pollution prevention and resource conservation awareness. The information gathered as a result of these projects has improved the quality of the steam plant operational data, and identified areas of improvement.

Additional pollution prevention/resource conservation activities planned at the steam plant include:

- Retrofit of remaining fan and bearing cooling systems. The fans and bearing still cooled by once through City water will be retrofitted to use treated water which will be recycled as boiler make-up. It is anticipated that this will save an additional 4 million gallons in water use per year.
- Hire one full time employee (FTE) for FY 1998 to investigate, monitor and increase the amount of condensate returned to the steam plant. Although condensate return has been increased by 16 % in the last two years, much of the condensate is still lost to leaks in piping, and leaking or disconnected steam traps. It is anticipated that costs savings related to increased condensate return will pay for the cost of employing and additional FTE.
- Implementation of cost effective results from the Boiler Tuning and DCS Reprogramming effort
- Implementing cost effective water conservation opportunities identified as part of the site-wide Water Conservation audit. These include: further reduction in chemical use through process control and monitoring, specifically use of boiler feed chemicals such as amines and possible reuse of steam plant effluent as cooling tower feed waster.