

RESULTS OF DETAILED MONITORING OF ONE OF THE ENERGY RESOURCE CENTER'S MULTIFAMILY SHARED SAVINGS BUILDINGS

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INTRODUCTION

The St. Paul Energy Resource Center, thru its multifamily shared savings program, has installed small, high-efficiency boilers to operate with existing larger, less efficient boilers in St. Paul apartment buildings. Domestic hot water (DHW) heating is also usually provided by the new boiler. These new boilers, known as "front-end" or "base-load" boilers, have been installed as part of a larger package of retrofits, making it impossible to evaluate their energy savings. This paper reports a study undertaken to determine the operating characteristics and to isolate the energy savings for a base-load boiler at 894 St. Clair in St. Paul. Energy savings for both DHW and space heating and DHW are presented, as well as the efficiencies of the new and old DHW heating systems, and DHW use characteristics of the building.

PRE-RETROFIT BUILDING AND MECHANICAL SYSTEM DESCRIPTION

894 St. Clair is a well-maintained, three-story, 33 unit, masonry apartment building built around 1910. The one-bedroom and efficiency units were occupied during the study by approximately 41 persons. There were a few retired persons and no children. Most units had showers.

The building was heated with a modern cast iron steam boiler with a steady-state efficiency of 78 percent. The input of the gas power burner was 1.73 million Btu/hr. A two-pipe steam distribution system provided steam to the large cast iron radiators located in most rooms. The boiler was controlled by a single thermostat in a storage closet of a first floor laundry room. An insulated steam pipe near the room's ceiling was the only source of heat near the thermostat. Much of the building was overheated as evidenced by many open windows.

The DHW system consisted of a separate natural draft tankless gas water heater used to heat water in an uninsulated 350 gallon, horizontally mounted cylindrical storage tank. Most building owners believe that this type of system is among the most efficient, due to its low off-cycle losses. The burner and pump that circulates water from the bottom of the storage tank thru the heater was controlled by an aquastat located in the middle of one end of the storage tank. The heater input was 240,000 Btu/hr and the steady-state efficiency, about 74 percent. A pump and an uninsulated recirculation line next to the horizontal main DHW distribution pipe and near the basement ceiling ensured that the water in this main was always kept hot.

RETROFIT DESCRIPTION

Changes made to the building envelope included a few single-glazed windows located in a heated garage and some insulated storage rooms. The heating system was converted from steam to hot water. Each radiator had its steam trap removed

and an air-bleeder valve installed. A circulation pump and expansion tank were added, and a new pressure relief valve and high limit aquastat were added to the boiler. A new two-stage, remote-sensing thermostat was installed, with the sensor located in a first floor north-facing apartment.

A 167,000 Btu/hr condensing base-load boiler was installed with two zone valves for space or DHW heating. When heating space, water is pumped from the main building return line, thru the base-load boiler, and back into the return line downstream from where it was removed. The thermometer's first stage controls the base load boiler and it's second stage controls the old boiler. An outdoor temperature switch turns off the space heating equipment, including the circulation pump, whenever the outside temperature rises above the set temperature. When heating DHW, base-load boiler water is pumped thru one side of a water-to-water heat exchanger as water from the storage tank is pumped thru the other side. When the building thermostat and DHW aquastat are both demanding heat, the base load boiler output goes to DHW. Insulation was added to the old boiler, the DHW storage tank, all uninsulated pipes in the boiler room, and the DHW recirculation and main distribution pipes. The retrofit allowed the new base-load boiler to be turned off, leaving the old boiler to heat space and the old water heater to heat DHW. Annual savings for the entire retrofit package amounted to 920 million Btu for a retrofit cost of \$22,350. (Nevitt, 1986).

INSTRUMENTATION AND MONITORING

A data acquisition system was installed to monitor relevant temperatures, gallons of domestic hot water usage, and run times of the burners for the two space heating and two water heating systems. Sensors included AD-590 temperature sensors, relays in parallel with gas and zone valves, and a 10-gallon-on/ 10-gallon-off contactor on a turbine-type water meter. An analog to digital converter connected the sensors to a lap-top computer, which was connected to a printer for data storage. Software was written to use the printer as a strip chart recorder to give continuous recordings of about 10 channels. Daily averages or totals of all variables were printed out at midnight each day. The base-load boiler was turned on and off every two weeks during the study. Results presented here are based on daily values for Jan. 19 thru May 26, 1986.

RESULTS

Figure 1 graphs daily gas used for DHW heating (millions of Btu) vs. the energy needed to raise the DHW consumption from the cold water inlet temperature to the temperature of the water leaving the boiler room. This was calculated by using the flow meter and temperature sensors at the cold water inlet and at the DHW pipe leaving the boiler room. Each time 10 gallons of DHW were used, the computer calculated the energy required to raise the water temperature from the inlet temperature to that of the water leaving the boiler room. This was summed for each 10 gallons of water used throughout the day. The lines drawn through the two data sets were determined through linear regressions. The Y intercept of these lines may be interpreted as the stand-by gas use of the DHW systems (the amount of gas used if no water were drawn from the system). The inverse of the slope of the lines may be interpreted as the marginal efficiency of the systems (the additional delivered hot water energy for an additional Btu of gas consumption).

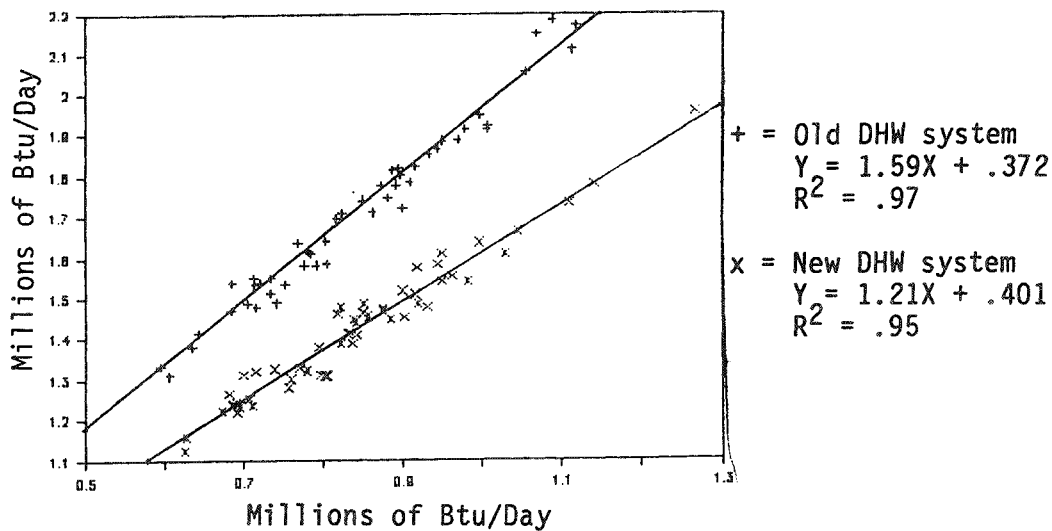


Figure 1: Daily DWH gas consumption vs. energy needed to raise the daily DWH consumption from the inlet to the outlet temperature.

Based on the regression analysis, stand-by gas use of the old system was found to be 372,000 (+/- 36,000) Btu/day and, of the new system, 401,000 (+/- 36,000) Btu/day. The marginal efficiency of the old system was 63 (+/- 1.5) percent, and that of the new system was 82 (+/- 2.5) percent. The operating efficiency of the two systems for the study period (including stand-by losses) was found by dividing the average daily energy delivered to the DWH (841,000 Btu/day for both systems) by the respective average daily gas consumptions (1.71 million Btu/day for the old system and 1.42 million Btu/day for the new system) yielding 49 percent for the old system and 59 percent for the new system. The average daily gas savings for the new system over the old system amounted to .29 million Btu/day. Average daily hot water consumption for the building was 975 gal/day (24 gal/day/person or 30 gal/day/apt.).

The daily energy used for space heating was plotted against the temperature difference between inside and outside the building. Linear regression found no significant differences between the two systems. The oversize of the old boiler caused the interior temperature to overshoot and turn off the base-load boiler. This caused the base-load boiler to operate only about 60 percent of the time it was available for space heating. Because all water for space heating flows thru the old boiler, its off-cycle losses are present even when only the new boiler is operating. It also is suspected that the old boiler has a higher seasonal efficiency than was expected.

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REFERENCES

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