CONVERTING STEAM HEATED BUILDINGS TO HOT WATER: PRACTICES, SAVINGS AND OTHER BENEFITS

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ABSTRACT

As part of an effort to gather reliable information on conservation measures for multifamily buildings, the conversion of steam heating systems in older buildings to hot water heating systems was investigated. The purpose was to determine how common conversions are in Minneapolis, what modifications are typical, how much it costs, and how much energy is saved. The study is based on interviews, site visits and PRISM analysis of monthly gas data.

In all the conversions studied, the boiler was replaced. Other work done depended on the building's existing system. In two pipe steam (TPS) systems, the existing distribution system was retained. In single pipe steam (SPS) systems new piping and radiation was installed and other changes were made to allow the buildings to be zoned. These changes make SPS systems more expensive and difficult to convert. As a result, SPS buildings are converted less often, even though SPS systems are much more common than TPS systems in Minneapolis.

The final sample was ten buildings, four SPS conversions and six TPS conversions. They include seven multifamily buildings, one commercial building, one church rectory, and one duplex. The SPS buildings showed savings of 13% to 27% of total weather normalized gas use and the TPS buildings had savings of 17% to 39%

In addition to energy savings, other benefits help to make conversion attractive. These benefits include more even heating, fewer tenant complaints, reduced maintenance and increased building values.

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INTRODUCTION

The Minneapolis Energy Office (MEO) began its multifamily energy conservation program in 1981. An early discovery was that firm data on energy savings from specific conservation measures was virtually nonexistent. Since owners were understandably reluctant to invest in retrofits without reliable information on expected savings, MEO and the local gas utility launched a joint Multifamily Testing Program in 1982. Measures that have been field tested through this program include high efficiency tune-ups for conversion boilers (Peterson, 1983), a control system to eliminate uneven heating in steam heated apartment buildings (Peterson, 1984), and outdoor reset and cutout control for modern, hot water heated apartment buildings (Hewett, Peterson 1984). Another such study testing vent dampers in multifamily buildings is currently in progress. It is not possible within time and budget constraints to install and field test every conservation measure of interest. This report is the first in a series of research projects which use as a data base buildings in which a particular owner installed retrofit was looked at rather than buildings in which installation of the equipment was controlled and the building's operation and gas use was monitored weekly or daily.

Steam to hot water conversion is the practice of replacing the steam heating system in an older building with a modern, hot water heating system. The purpose of this study was to determine how common conversions are in the Minneapolis-St. Paul area, what specific modifications are part of the typical conversion, how much it costs and how much energy is saved. This research was conducted jointly by the Minneapolis Energy Office and the Self-Reliance Center, a Minneapolis community based nonprofit corporation.

BACKGROUND: MULTIFAMILY BUILDING TYPES AND ENERGY USE

Most buildings of five or more units in Minneapolis are two or three story walk-ups with fifty units or less. Nearly all have gas central heating and domestic hot water. The two predominant types are steam heated buildings built before 1940 and hot water heated buildings built after 1950.

The typical steam heated apartment building in Minneapolis has a single thermostat which controls the operation of the boiler. When the thermostat calls for heat, the boiler comes on and begins to generate steam. Once the thermostat is satisfied, the boiler shuts off. In such a "single zone" system, there is no way to control the supply of heat to individual apartments. Because of short boiler cycles and large differences in steam travel time to different apartments, the amount of heat delivered to various apartments varies considerably and uneven temperatures are common.

Steam heated buildings can be subdivided into single pipe steam (SPS) systems and two pipe steam (TPS) systems. In SPS systems, each radiator is connected to a single pipe which both supplies steam and carries away condensate (Figure 1). In TPS systems, there are separate steam supply and condensate return pipes for each radiator (Figure 2). TPS systems are generally found in somewhat newer buildings and are far less common. Of 169 steam buildings audited by MEO through June 1985, only 40 were TPS.

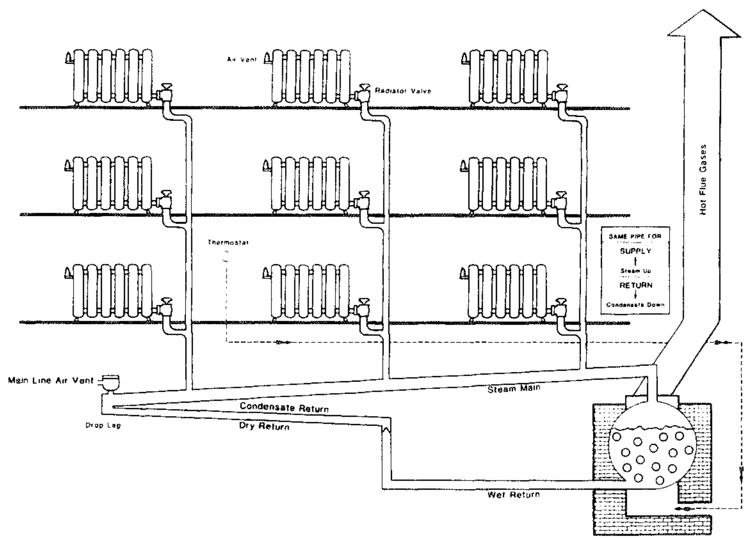

Figure 1. Schematic of a single pipe steam system.

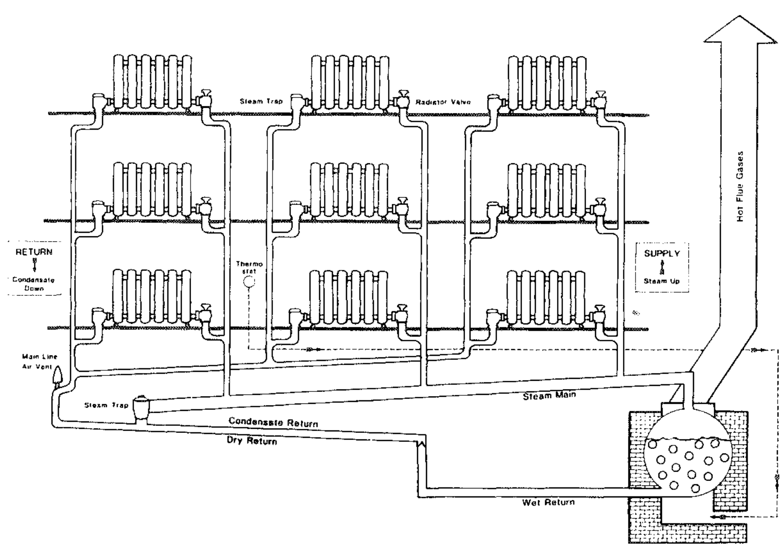

Figure 2. Schematic of a two pipe steam system.

In addition to these differences in the distribution systems, two different types of radiators are found in steam heated buildings. One type is a "steam only" radiator and is found mostly in SPS buildings. The sections of this type of radiator are only connected at the bottom. Consequently, these radiators will not work for hot water. The "steam/hot water" radiator has sections that are connected at both the top and bottom. This radiator type was a more recent development and is more common in TPS systems.

Based on a preliminary baseline study done on 124 hot water and 50 steam heated multifamily buildings audited in Minneapolis through May of 1984, the median total gas use of Minneapolis steam heated buildings is about 99,000 Btu/sq. ft.-yr. compared with 87,000 Btu/sq. ft.-yr. for hot water heated buildings (Hewett, et al 1984). Several factors may be responsible for this difference, including differences in the heating system itself, differences in the building envelope and differences in maintenance in occupancy between steam and hot water heated buildings. Converting the heating system from steam to hot water is expected to lessen uneven heating, reduce pipe losses and boiler jacket losses and is one option for narrowing the gap in energy use between steam and hot water heated buildings.

METHODOLOGY

Criteria for Inclusion in the Study

The study was initially confined to multifamily buildings that had six or more units, were no larger than three stories, and were located in the Minneapolis-St. Paul metro area. Buildings that had undergone major renovation or in which other major conservation measures had been done within a year before or after the conversion were not considered to be appropriate for the study, since savings due to conversion alone could not be isolated. Due to limited access to gas company records , buildings had to have been converted within the past three years, unless the owner kept good records of the building's fuel consumption. Finally, if possible, buildings in which fuel switching had occurred were not to be included in the study.

Over the course of the project, 41 buildings that had undergone a steam to hot water conversion were identified. Of these, 19 were the wrong building type, 8 had undergone other retrofits at the same time as the conversion work, 7 had fuel consumption records which were too poor to use and 2 were too recent a retrofit to be included in this analysis.

It became clear as this process was underway that our sample would be very small if the original criteria were strictly adhered to. As a result, the criteria were relaxed to include other building types and buildings in which other retrofits had been done. A church rectory (#1201) and a duplex (#2823) were added, as well as a commercial building (#230) and an apartment building which had both switched from dual fuel to gas only (#3219). Another building (#24) in which attic insulation was installed within the retrofit period was also included.

Sources of Information

Information used in this study was gathered from five sources-- the cities' departments of heating inspections, contractors who are involved in conversion projects, owners who had buildings in which conversion of the heating plant had taken place, the gas companies and the city assessor's offices. Additional information on the buildings themselves was gathered through site visits.

At the start of the study, heating inspectors and supervisors from the departments of heating inspections of both Minneapolis and St. Paul were interviewed to determine the frequency of conversions taking place in the metro area and to obtain the names of contractors involved in conversion work.

Contractors in the Twin City area who do steam to hot water conversions were interviewed briefly to determine what their involvement in conversion work is and to invite their participation in the study. Participating contractors provided MEO with the specific addresses of buildings which could be used in the study, and were surveyed at length about each of the buildings they had converted. The survey asked questions relating to the mechanical details of the conversion, the contractor's perceptions of why the owner converted and characteristics of the building. The buildings used in this study represent the work of five contractors.

A third source of information was building owners. Most owners were found through contractors, but a few came by other means. The Minnesota Multi-Housing Association also helped generate owner leads. Owners released their building's fuel records and answered questions about the conversion. The owner survey was geared less to technical data and more to such things as reasons for conversion, other conservation measures implemented, and so on.

Minnegasco and Northern States Power, the two utilities in the metro area, provided monthly gas data on the buildings in their respective service areas. The city assessor's offices provided data on total building area and age. Finally, field vists were made to most of the buildings to gather additional information that surveys did not or could not reveal.

Method of Analysis of Gas Data

Gas consumption before and after the conversion was normalized for weather using the Princeton Scorekeeping Method (PRISM)(Fels, 1955; Goldberg, 1982) This state of the art computer program is considered highly accurate in estimating weather normalized annual consumption (NAC).

CONVERSION PRACTICES IN MINNEAPOLIS-ST. PAUL

Number of Conversions Taking Place

According to information gathered from heating inspectors, the number of conversions taking place in the Twin City area is small. On average 6200 inspections occur per year. Of this total approximately four to five are steam to hot water conversion work.

When initially interviewed, contractors felt that many conversions were going on in the Twin Cities. But in follow-up conversations these contractors were unable to produce very many usable cases. Many of the jobs had been done years ago, involved commercial rather than multifamily buildings or were outside the metropolitan area. Some contractors may have elected not to tell us about conversions that they didn't view as successes. Others may have thought there were many because a single conversion represents a large amount of work for a small contractor.

There is some evidence that interest in conversion is growing. The Minneapolis heating inspections department, for example, states that conversions are on the increase, especially in residential applications. Also energy auditors have reported increasing owner interest in conversion.

Conversion Specifics

One of the goals of the research was to determine what modifications are made as part of a typical conversion. The work done in converting from steam to hot water depended primarily on the building's existing piping system. In two pipe steam (TPS) systems the existing distribution system and radiation was nearly always retained, which made conversion relatively easy and inexpensive. In single pipe steam (SPS) systems a considerable amount of new piping and new radiation was needed. Since SPS conversion was so extensive anyway, other changes were made to allow the building to be zoned. All of these changes make SPS systems much more expensive and difficult to convert. This is reflected in the number of conversions. Of the ten buildings included in the study, six were TPS and only four were SPS, in contrast to the fact that in the Twin Cities housing stock as a whole only about a fifth of the steam buildings are TPS. Specific details of the conversion of both types of systems are discussed below, and can be found summarized in Table I.

In all cases studied, the boiler was replaced. In two cases, there was some mechanical reason why the old boiler needed to be replaced. In two other cases, the owner felt the old boiler was inefficient or worried about it breaking down. The contractors interviewed stated that while boiler replacement is not always necessary as part of the conversion process they usually recommend it if the owner has the money available. In general, contractors felt that the old steam boilers were inefficient, oversized and had a limited life expectancy. In addition, the boiler is probably the item on which the contractor has the highest profit. The type of boiler installed depended primarily on contractor preference and/or availability of equipment. In only one case studied (#1201) did the owner specify a particular high efficiency boiler.

Table I. Building characteristics and conversion specifics.

		Single Pipe Steam				Two Pipe Steam					
BUILDING NUMBER		438	24	3219	624	1871	1001	580	2823	1201	230
NUMBER OF UNITS	APT.			25	26	16	18	10	2		
	CONDO	17	6								
	OTHER									Church Rectory	Commercial
NEW BOILER	MODEL (# OF UNITS)	Triad (5) G3000	Weil-Mc HE-5 (3)	Slant-Fin GG375 (3)	Hydrotherm MR900B (3)	Weil-Mc EG-H125	Slant Fin GG375P	Weil-Mc MGB-5	Burnam XG200G	Hydro-Pulse (2)	Triad (6) G300J
	BTU/HR TOTAL	1,500,000	399,000	1,125,000	900,000	500,000	750,000	680,000	165,000	200,000	2,400,000
	OTHER	Modular	Hi-Eff		Modular					Hi-Eff	Modular
PIPES	SAME					X	X	X	X	X	
	NEW	X	X	X	X						X
RADIATION	SAME					X	X	X	X	X	
	NEW	X	X	X	X						X
ZONING	PRE	SINGLE	SINGLE	SINGLE	SINGLE	SINGLE	SINGLE	SINGLE	SINGLE	Multi 3-Zone	SINGLE
	POST	Multi non-elec	Multi electric	Multi non-elec	Multi non-elec	SINGLE	SINGLE	Multi TRV's	SINGLE	Multi 3-Zone	Multi
FUEL	PRE	GAS	GAS	GAS/OIL	GAS	GAS	GAS	GAS	GAS	GAS	GAS/OIL
	POST	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS
YEAR BLDG WAS BUILT		1900	1920's	1920	1916	1938	1929	1890's	1917	1936	1890's
CONVERSION DATE		2/83	10/83	8/82	8/81	10/81	10/83	2/81	8/83	10/82	7/83

Two Pipe Steam Conversion. In the conversions of TPS systems, the existing distribution system was kept basically intact. With a TPS system the piping can be reused because each radiator is already connected to a supply pipe and a return pipe. However, the condition of the piping must be checked for evidence of corrosion and replacement made when necessary. This is particularly true of horizontal lines which are most susceptible to deposits. In most of the cases in this study, piping systems were generally in good condition and the only changes that occurred were changes in the first few feet of pipe from the boiler.

All but one of the TPS systems studied had radiators that were compatible with hot water (i.e., the columns were connected at both the bottom and the top), so the radiators were kept and used in the new system with a few simple changes. An air bleeder had to be installed at the top of each radiator and the trap in the return side piping of the radiator had to be removed or drilled out. The hand valves on the supply side of the radiator were replaced in some cases. While replacement is advisable to assure proper working condition of the valves, it is not necessary. Only one TPS building in the study had new radiation installed. This building (#230), was a commercial property in which the original radiation consisted of a series of pipes running through the spaces to be heated. In this case, new baseboard radiation was installed.

Another issue that comes into play regarding the reuse of old steam radiators is the possibility that once the hot water system is in place, the old radiators, originally sized for steam, will now be undersized. Steam heated radiators supply 240 Btu/sq. ft.-hr. at an average temperature of 220°F whereas hot water provides only 150 Btu/sq. ft.-hr. at an average temperature of 170°F. Most contractors felt that this would not be a problem due to gross oversizing in the old system, and the subsequent addition of conservation measures which lower the heat loss. However, it may be a problem if a lot of radiators have been removed from the old system. The buildings in this study had no problems with under radiation after the conversion.

Since so much of the distribution system remained intact and since the typical steam piping layout does not lend itself readily to zone control, most of the buildings which underwent TPS conversion retained the same zoning system they had prior to conversion. A typical TPS apartment building in Minneapolis has two to four supply mains running through the basement from which risers feed steam to individual radiators or to a column of radiators with one radiator per floor. In order to zone the heat in such a piping system, individual thermostatic radiator valves (TRV's) must be installed on each radiator. This is generally not done since TRV's, at about $45 each plus installation, add considerably to the cost of the project. As a result, in four of the six TPS cases in this study the building retained its original zoning configuration even after conversion. In three cases this meant the buildings remained a single zone, and in one case (#1201) it meant the building remained three zones. The two odd cases were in building #580 in which TRV's were installed on each radiator at the specific request of the owner, and in building #230 in which the extra effort was made to zone the system since all the radiation and a lot of the piping had to be replaced anyway.

Prior to the conversion, all of the TPS buildings that operated as single zone systems had a central thermostat that controlled the boiler, except the commercial building, which had a timer. In the one TPS building that was zoned, a timer and a pressuretrol controlled the boiler.

The post conversion control system for the TPS buildings depended on whether the building was zoned as part of the conversion. All of the TPS buildings that remained single zone systems retained a central thermostat to control the boiler. In some cases, the thermostat was combined with a reset, which adjusts the temperature of the water in the distribution loop in response to outdoor temperature, and a cutout, which shuts the circulating pump and burners off whenever the outdoor temperature is high enough that no heat is needed. In the two zoned TPS conversions, the boilers are now controlled only by resets. Thermostatic valves control the flow of hot water into individual zones.

Single Pipe Steam Conversion. Specifics of SPS conversion differ from those of TPS conversion. First of all, much of the distribution system must be repiped. There is the obvious need to add a separate return pipe which is nonexistent in a SPS system. The steam mains and risers that are already in place are sometimes replaced and sometimes used as supply lines in the new system depending on their condition and how oversized they are.

None of the SPS conversion cases studied had radiators that were compatible with hot water (i.e., the columns were connected only at the bottom). As a result, these had to be replaced. In all four cases studied the radiators were replaced with modern copper fin tube baseboard radiation.

In contrast to the situation in TPS conversion, all the SPS conversions ended up as multi-zone buildings. Since most of the piping and radiation is being replaced anyway, it is relatively easy to redesign the pipe layout so that each apartment has its own distribution loop, with a single inlet and outlet. A thermostatically controlled zone valve can then be installed on the inlet to allow individual control of the apartment temperature. In the SPS conversions studied, three had self-contained control devices and one had a conventional zone valve wired to a remote thermostat. Of these two options, the latter is more expensive to install, but may be regulated more accurately by the tenant.

Prior to conversion, three of the systems in the SPS buildings were controlled by a central thermostat and one was controlled by a timer. In two of three cases, this primary control was combined with an aquastat that shut the boiler off when the condensate temperature rose enough to indicate that heat had reached the entire building. After conversion, all four buildings were controlled by a reset.

Reasons for Converting

One purpose of the study was to find out why owners choose to convert, and what benefits owners perceive conversion to have.

As part of the survey, the owners of each building were asked to give their main reasons for converting. The two reasons that came up most often were the hope of saving money and the desire to correct the uneven heating problems of steam (Table II). Two other reasons that came up less often but were still common were eliminating the maintenance problems of a steam system, and correcting a particular problem with the current boiler (e.g., the boiler was leaking). Contractors were also asked to give their perspective on why a particular owner converted. Saving money was the reason they stated most frequently, followed by correcting uneven heating and solving a particular boiler problem. Interestingly, no contractor mentioned maintenance problems as a reason owners converted, although this was fairly high on the owners' list of reasons.

Table II. Reasons for converting.

CONTRACTORS		OWNERS
38%	Save Money	26%
28%	Correct Uneven Heat	26%
0%	Reduce Maintenance	18%
14%	Problems With Boiler	18%
5%	Financing Available	4%
15%	Other	8%

Owners of the buildings felt they had received most of the benefits from the conversion they anticipated. Overwhelmingly, the owners and/or building managers reported a reduction in complaints from tenants regarding overheating or underheating of particular apartments. Tenant comfort appears to have been improved. Owners also felt there was less worry with the newly installed heating system. In addition, most of the building owners in this study appeared to be interested in long-term ownership and perceived the conversion as improving the value of their buildings and upgrading building equipment.

When surveyed, eight out of ten owners described themselves as being very satisfied with the retrofit. One owner was very satisfied with the conversion itself, but unhappy with the service of the contractor. The tenth owner was generally satisfied, but felt the retrofit was too recent to gauge his absolute satisfaction. This strong positive response was in spite of the fact that none of the owners had any idea how much money the conversion had actually saved them.

ENERGY SAVINGS FROM CONVERSIONS

The median savings overall is 24%. For apartment buildings only, it is 20%. Savings figures for individual buildings are shown in Table III.

Table III. Costs, savings and payback for conversions.

		Single Pipe Steam				Two Pipe Steam					
Bldg. I.D. Number		438	24	3219	624	1871	1001	580	2823	1201	230
Bldg. Sq. Ft. (Gross)		32,500	14,400	19,400	13,300	13,300	17,500	9,100	2,700	5,000	91,000
COST	Total	$64,000	$21,000	$37,000	$40,000	$ 8,000	$16,000	$ 8,400	$ 4,000	$13,000	$126,000
	Per Unit	$ 3,765	$ 3,500	$ 1,480	$ 1,538	$ 500	$ 889	$ 840	$ 2,000	NA	NA
	Per Sq. Ft.	$ 1.97	$ 1.46	$ 1.91	$ 3.01	$ .60	$ .91	$ .92	$ 1.48	$ 2.60	$ 1.38
Pre NAC, CCF		34,670	11,896	21,043	17,389	12,639	14,005	9,191	4,481	7,497	59,986
Post NAC, CCF		25,190	10,232*	16,850	15,100	8,924	9,653	7,577	3,741	4,581	43,907
Δ NAC, CCF		9,480	1,664*	4,193	2,289	3,715	4,352	1,614	740	2,916	16,079
% Δ NAC, CCF		27%	14%	20%	13%	29%	31%	18%	17%	39%	27%
First Yr. Savings		$ 5,546	$ 975	$ - 388**	$ 1,339	$ 2,173	$ 2,546	$ 944	$ 433	$ 1,706	$ 1,308**
Payback (Years)		11.5	21.5	No Payback**	29.9	3.7	6.3	8.9	9.2	7.6	96.3**
Alt. FY Savings***				$ 1,887							$ 7,236
Alt. Payback Yrs.***				19.6							17.4
Pre NAC, BTU/sq. ft.-yr.		106,700	82,600	108,500	130,700	95,000	80,000	101,000	166,000	149,900	65,900
Post NAC, BTU/sq. ft.-yr.		77,500	71,100	86,900	113,500	67,100	55,200	83,300	138,600	91,600	48,300
Change, BTU/sq. ft.-yr.		29,200	11,600	21,600	17,200	27,900	24,900	17,700	27,400	58,300	17,700

* Post retrofit consumption for building 24 was adjusted to compensate for attic insulation done at the same time as the conversion. See text for details.
** Based on fuel switch from interruptible gas at $.45/CCF (prior to conversion) to firm gas at $.585/CCF (after conversion).
*** Alternative FYS and payback if owner remained on interruptible service after conversion.

All four SPS conversions looked at in the study (#438, #24, #3219, #624) were apartment buildings. Savings were 27%, 14%, 20% and 13% of the total weather normalized gas use. This corresponds to a respective change in consumption of 29,200, 20,300, 21,600 and 17,200 Btu/sq. ft.-yr.

Three of the TPS conversions (#1871, #1001, #580) were apartment buildings. These buildings showed savings of 29%, 31% and 18% or 27,900, 24,900, and 17,700 Btu/sq. ft.-yr. The remaining three TPS conversions were a duplex (#2823), a church rectory (#1201), and a commercial building (#230) which saved 17%, 39%, and 27% respectively. Corresponding changes in consumption were 27,400, 58,300 and 17,700 Btu/sq.ft.-yr.

Figure 3 shows the pre and post net annual consumption in Btu/sq. ft.-yr. for the seven multifamily buildings in comparison to typical consumption ranges for steam and hot water buildings. Except in one case, the apartment buildings in the study did not differ significantly in pre retrofit gas use per square foot from a pool of fifty steam heated buildings audited by the Minneapolis Energy Office, nor did they appear to be different in other respects, based on the site visits. Thus it is likely that savings achieved are representative of what might be expected for steam to hot water conversion in other multifamily buildings. The one exceptional case is building #624 which showed an unusually high consumption per square foot both before and after the retrofit. This building was also the building in the study which showed the least savings overall.

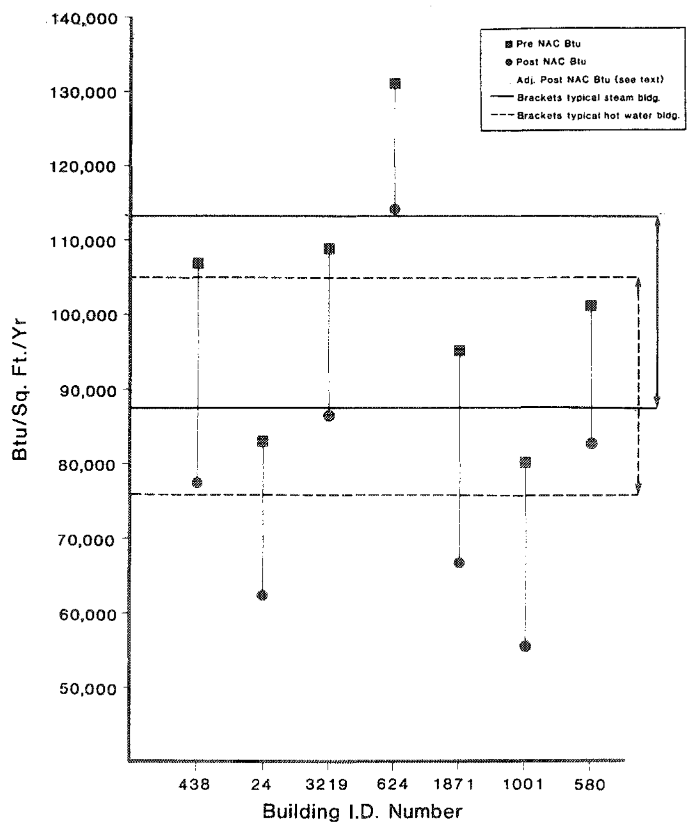

Figure 3. Comparison of pre and post Btu/sq.ft consumption

It should be noted that the savings percentage and the post retrofit consumption for building #24 have been adjusted to compensate for attic insulation done at the same time as the conversion. Savings due to attic insulation were assumed to be approximately two thirds of RCS predicted savings. This assumption is based on research done by Hirst and Goeltz in St. Paul and by Hewett in Minneapolis which showed average measured savings to be considerably lower than predicted RCS calculations (Hirst, Goeltz, 1983) (Hewett, et al 1984). Total savings for building #24 was 24.5% or 2,917 CCF of gas per year (one CCF equals 100 cubic cubic feet equals 1 Therm equals 100,000 Btu's). Of this approximately 10.5% or 1253 CCF per year was attributed to attic insulation and 14% or 1,664 CCF per year to the conversion.

COSTS

A TPS conversion generally costs much less than a SPS conversion due to the labor and materials involved in the change over of a SPS system. For the multifamily buildings over six units, the cost of TPS conversions ranged from $.60 to $.92 per square foot. In contrast, the SPS conversions ranged from $1.91 to $3.01 per square foot. Per unit costs for this work can be compared with similar results. TPS conversions cost from $500 to $900 per unit, whereas SPS conversions cost from $1,500 to $3,800 per unit (Table III). The three other buildings in the study were a duplex, a church rectory and a commercial building. The duplex conversion has a cost of $1.49 per square foot or $2,000 per unit. The somewhat higher cost compared to other TPS buildings is not surprising, since the boiler is usually one of the higher cost items in any conversion and this cost varies only moderately with building size. The church rectory also had a higher cost per square foot of $2.60. Like the duplex, it had a smaller area over which to spread the cost of the boiler. In addition, this particular conversion used state of the art high efficiency boilers which cost substantially more than conventional boilers. The cost for the conversion of the commercial building was $1.39 per square foot.

The contractors were not able to provide a formula or rules of thumb that they use to bid a conversion job. They did mention four basic factors that affect the cost of conversion. These are whether the building's current system is SPS or TPS, whether the boiler is to be replaced or retained, whether the radiators are reusable/compatible with hot water and the condition and accessibility of the pipes

In buildings in which the old steam boiler needs replacement anyway, a steam to hot water conversion may be a very attractive option for an owner. This was the case for two of the buildings studied (#3219 and #1001). Here, the contractor bid a steam boiler replacement as well as the steam conversion. For one building, boiler replacement cost would have been $20,000 compared with $37,000 for conversion; for the other it would have been $9,500 compared to $16,000.

All the buildings in this study had the boiler replaced as part of the conversion. From interviews with the owners and contractors this was not a necessity in all cases. In buildings where the old steam boiler is in good shape, retrofit to the existing boiler rather than replacement may be a way to reduce the cost of a conversion.

Since this study looked at buildings in which the conversion had already been installed by the owner, there was no control over the specifications or quality of the installations. Therefore, there may be great variance in the costs of these installations for the product delivered. As an example, a recent conversion in St. Paul received a high bid of $24,000 and a low bid of $10,200 from two different contractors for the same work. Both the St. Paul Energy Resource Center (Nelson, 1985) and Citizens Conversation Corporation of Boston (Rowse, 1985) have been able to do conversions at a lower cost by carefully controlling the bidding and specification process.

SIMPLE PAYBACKS

Three of the four SPS buildings in the study showed simple paybacks of 12, 22 and 30 years for steam to hot water conversions. The fourth SPS building had no payback. Three of the six TPS buildings had paybacks of 4, 6, and 8 years, two had paybacks of 9 years and one had a payback of 96 years (Table III).

The SPS building with no payback (#3219) switched from interruptible gas at .45/CCF prior to conversion to firm gas at .585/CCF after the conversion. This switch resulted in an increase in annual space heating cost of $388 despite a decrease in consumption. An alternative calculation for this building shows a payback of 20 years if the building had remained on interruptible service. The TPS conversion with the longest payback was the commercial building (#230) at 96.4 years. This building also switched gas rate classes from interruptible to firm at the time of the conversion. An adjusted payback of 17 years is obtained if the option of remaining on interruptible service after the conversion is considered. Converting from steam to hot water does not necessitate converting to firm gas. Even when boilers are replaced, interruptible burners can still be installed. A disadvantage is that interruptible burners can add an additional 30% to 40% to the cost of a new boiler. Considering these two cases, it would appear that it may be worth the added expense. An even less expensive option would be to retain the original boiler and interruptible burner when conversion takes place.

CONCLUSIONS

Steam to hot water conversions are rather uncommon at present in the Twin Cities. The cost of SPS conversions is much higher than TPS because new piping and radiation systems are almost always needed and therefore TPS conversions represent a disproportionately higher number of all steam to hot water conversions.

The SPS conversions studied produced energy savings on the order of 13% to 30% of the total annual gas use, with paybacks of 12 to 30 years for buildings that stayed in the same gas rate class. TPS conversions saved 17% to 40% with paybacks of 4 to 9 years for buildings that stayed in the same rate class.

The two buildings that switched from interruptible to firm gas had energy savings of 20% and 27%, but showed no or a poor payback. Considerably better paybacks could have been achieved in these two cases if the owners had chosen to remain on interruptible service.

If the effect of fuel switching is eliminated, the SPS buildings show a median pay back of 21 years and the TPS buildings a median payback of 8 years. While many multifamily building owners generally prefer paybacks of 2 to 3 years on energy investments, a payback in the 8 year range may be acceptable for this retrofit, particularly in light of the other benefits of steam to hot water conversion. These benefits include correcting uneven heat and reducing maintenance problems. The owners in this study were very satisfied with the conversions even though they had no measure of the savings at the time we initially contacted them.

An individual owner needs to weigh the payback, his/her tenure strategy and other possible benefits in deciding whether to implement steam to hot water conversion. S/he should also consider whether other retrofits, like a better steam control system, might produce many of the benefits at a significantly lower cost.

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