BUILDING ENERGY MANAGEMENT AND REDESIGN RETROFIT (BEMARR)

HEATING

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1. GENERAL

1.01 One of the major contributors to rising energy costs is the wasted energy in building heating. Three possible energy-saving methods for building heating are discussed in this section:

(a) Shutting down boilers, when required, for domestic hot water only

(b) Eliminating dead legs in heating systems

(c) Installing a stack vent damper.

The material used in this section has been extracted from the *Building Energy Management and Redesign Retrofit (BEMARR) Manual* issued with GL 76-10077 (EL-4857) dated October 7, 1976.

1.02 Whenever this section is reissued, the reason(s) for reissue will be given in this paragraph.

1.03 ***Abbreviations and Acronyms:*** Refer to Table A for a list of abbreviations and acronyms used in this section.

2. SHUTTING DOWN BOILERS, WHEN REQUIRED, FOR DOMESTIC HOT WATER ONLY

2.01 In many locations, hot-water or steam boilers are operated during summer months to provide domestic hot water. Depending upon the occupancy and use of the building, this can be inefficient and energy consuming. Such locations should be examined to determine whether an electric, a small oil-fired, or gas-fired hot-water heater can be substituted. In addition to oil or gas savings, labor costs for boiler inspections are saved when the boiler is shut down.

2.02 Two items are needed to determine whether it is worthwhile to install a small domestic hot-water heater to replace a boiler. These are the cost of fuel for the existing operation and the estimated operating cost of the hot-water heater.

A. Cost of Current Operation

2.03 Fuel oil or gas bills for the months when heating is not required should provide the necessary data for calculating the operating cost of a hot-water heater. However, many locations burning fuel oil have a minimum delivery schedule which may not allow simple identification of the energy usage for domestic hot water in the summers. At these build-

TABLE A

ABBREVIATIONS AND ACRONYMS

ABBREVIATION	TERM
BTU	British Thermal Unit
BTU/hr	British Thermal Units per Hour
F	Fahrenheit
ft	Foot
gal	Gallon
hr	Hour
HVAC	Heating, Ventilating, Air Conditioning
kWh	Kilowatt-Hour
MBH	BTU/hr × 1000
T	Temperature (°F)

ings, estimates can be developed by monitoring fuel gauges or by installing portable running time meters on burner controls. Knowing the gallons per hour burned and the number of hours the boiler operates in a 1- or 2-week period should enable a fairly accurate estimate of seasonal consumption. Sample buildings should be selected for garages, suburban switching offices, etc. Studies on these buildings should provide sufficient information for determining the feasibility at other similar locations.

B. Cost for Operating an Electric Hot-Water Heater

2.04 The following six definitions are required to understand the procedure for determining operating costs:

(a) ***Effective Storage Capacity:*** The portion of the tank capacity which can be drawn off before an excessive drop below required water temperature occurs. It is generally accepted that effective storage capacity is 70 percent of the nominal tank capacity. Manufacturers should be consulted for specific information.

(b) ***Recovery Capacity:*** The quantity of water that a system can heat from the supply water temperature to the required water temperature in 1 hour.

(c) ***System Efficiency:*** The ratio of the energy in the form of heated hot water delivered by the fixture to the energy supplied to the water heater. Generally, efficiencies of 80 percent can be expected with small, well-insulated storage tanks, insulated piping, and a limited circulating system.

(d) ***Overall Seasonal System Efficiency:*** The system efficiency for an annual period. Generally, overall seasonal system efficiencies for recirculating systems with insulated piping and storage tanks are about 70 percent.

(e) ***Generation Efficiency:*** The ratio of the heater to the gross energy input to the device heating the water. Generation efficiency will be close to 100 percent for an electric unit and 60 to 80 percent for a fuel-fired heater.

(f) ***Overall Seasonal Generation Efficiency:*** The generation efficiency for an annual period. This will be close to 100 percent for an electric unit, but will be less than the generation efficiency for fuel systems due to variations in system loading.

2.05 There are many different combinations of storage and recovery capacity that will satisfy any given building. Because of this, it will be necessary to limit either the storage or recovery capacity. Consider a switching building which has eight people occupying the building 5 days a week. Design conditions are:

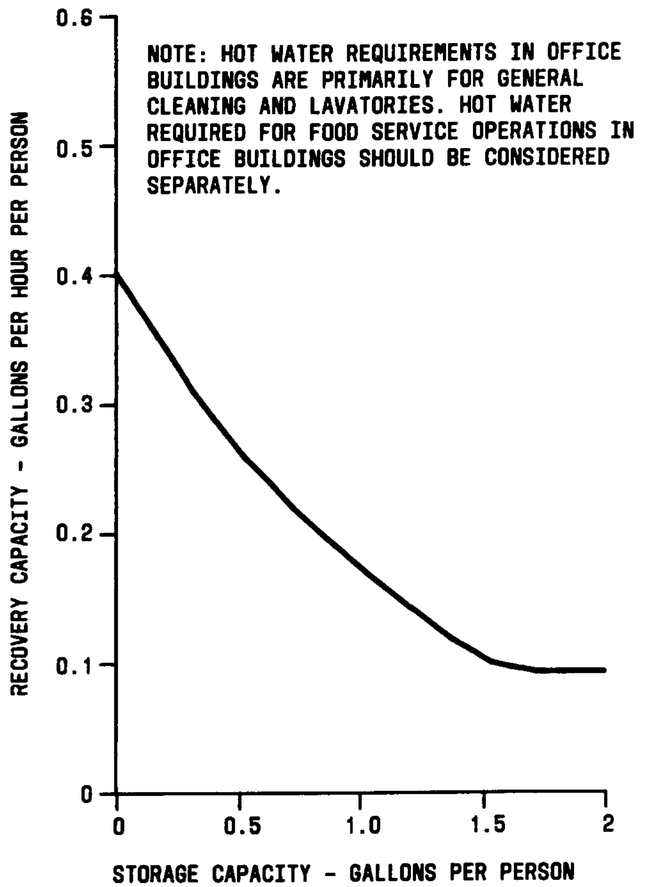
- Sixty degrees Fahrenheit supply water temperature
- Eighty percent system efficiency
- One hundred and ten degrees Fahrenheit required water temperature
- One hundred percent generation efficiency
- Seventy percent effective storage
- Seventy percent overall seasonal system efficiency
- One hundred percent overall seasonal generation efficiency.

Figure 1 shows that the minimum recovery rate is 0.1 gallon per hour per person.

Recovery Required = Number of people × recovery per person

= 8 × 0.1

= 0.8 gallon per hour.



MAXIMUM HOUR GALLONS/OCCUPANT	MAXIMUM DAY GALLONS/OCCUPANT	AVERAGE DAY GALLONS/OCCUPANT
0.4	2.0	1.0

Fig. 1—Office Buildings—Recovery Versus Storage

2.06 Figure 1 also shows that at 0.1 gallon per hour per person, 1.6 gallons per person effective storage will be required.

Effective Storage = Number of people × storage per person

= 8 × 1.6

= 12.8 gallons.

Now calculate the tank capacity, which is:

Tank Capacity (gallons)

$$= \frac{\text{Effective Storage (gallons)}}{\text{Percent Effective Storage/100}}$$

With an effective storage of 70 percent, then,

$$\text{Tank Capacity} = \frac{12.8}{0.7} = 18.3 \text{ gallons.}$$

If a commercially available unit at 20 gallons is selected, the effective storage of this unit is:

Tank Capacity (gals) × Effective Storage (%)

or 20 × 0.7 = 14 gallons.

2.07 Effective storage per person is 14 gallons divided by eight people or 1.75 gallons per person. Checking Fig. 1, the recovery capacity for this storage remains at 0.1 gallon per hour per person. Therefore, the recovery required is at 0.8 gallon per hour. If the effective storage were lower, the recovery required would have to be recalculated before proceeding.

2.08 The recovery capacity is calculated using the following formula:

$$\text{Recovery Capacity kW (Input)} = \frac{R \times 8.33 \times (T_r - T_s)}{3{,}413 \times E_s \times E_g}$$

where,

R = Recovery required, gallons per hour

T_r = Required water temperature, °F

T_s = Supply water temperature, °F

E_s = System efficiency, %/100

E_g = Generation Efficiency, %/100.

In this case,

$$\text{Recovery Capacity} = \frac{0.8 \times 8.33 \times (110\text{-}60)}{3413 \times 0.8 \times 1.0}$$

$$= 0.12 \text{ kW.}$$

2.09 A tank capacity of 20 gallons and a heater with at least 120 watts is needed. For this example, assume that a commercial unit is available at 150 watts. Now calculate the cost for operating this unit. To compute the monthly electrical energy usage, use the following equation:

$$\text{Energy Consumption (kWh)} = \frac{H \times 8.33\,(T_r - T_s)}{3{,}413 \times E_o \times E_{og}}$$

where,

H = Hot water usage, gallons

E_o = Overall seasonal system efficiency, %/100

E_{og} = Overall seasonal generation efficiency, %/100

T_r and T_s are required and supply temperatures.

Hot water usage is calculated as follows:

H = Number of days per month × use per day

where use per day is the average day gallons per occupant (Fig. 1) times the number of occupants. In this case,

$$H = 30 \times (8 \times 1.0)$$

$$= 240 \text{ gallons}$$

Therefore, energy consumption is:

$$= \frac{240 \times 8.33 \times (110\text{-}60)}{3413 \times 0.7 \times 1.0}$$

$$= 42 \text{ kWh per month.}$$

If electricity costs are 5 cents/kWh, then the unit can be operated at $2.10 per month. If the unit is off on weekends and operates only 20 days per month, the monthly costs are only $1.40.

C. Economic Analysis

2.10 The last item needed for an economic analysis is the cost of installing the unit. Generally, it can be said (and most boiler manufacturers agree) that in smaller buildings, domestic hot-water heaters should be provided. The energy savings will warrant the cost of installation.

Example: A particular location is spending $100 per season for fuel oil for hot water during the nonheating season, which is 5 months. At $2 per month, $10 is spent to operate the electric hot-water heater for the season and $90 is saved per year. It will cost $250 to purchase and install the hot-water heater. Therefore, it is feasible to install the unit in this building.

3. DEAD LEG ELIMINATION IN HEATING SYSTEMS

3.01 In many steam distribution systems that have been modified over the years, lines and radiators no longer in use have been abandoned, thereby creating dead legs. However, it is the nature of steam that these dead legs, unless filled with condensate, function as radiating surfaces and thereby waste energy. Similarly, flow through unused branches in hot-water systems wastes energy.

3.02 Such dead legs should be eliminated by shutting them off at the beginning of the leg. In steam systems, inactive mains and branches should be sectioned off to minimize radiation losses. The flow in unused branches of hot-water heating systems should be stopped by closing isolation or zone valves. If such valves do not presently exist in hot-water or steam systems, they should be installed.

3.03 Take a multistoried building with steam heating, for instance. The following information was determined during a site visit:

• Heating system efficiency:		50%
• Steam temperature:		220°F
• Room temperature:		65°F
• Dead legs for:	3-inch pipe*:	100 ft
	2-inch pipe:	150 ft
	1-inch pipe:	200 ft

How much energy is wasted? Table B tabulates the BTU/hr per linear foot of insulated pipe. Since the temperature difference is 155, use the 150° column. The heat loss for the pipes is:

Heat loss = BTU/hr/ft × feet of pipe

for 3-inch pipe:

Heat loss = 24.8 BTU/hr/ft × 100 ft

= 2480 BTU/hr

*Three-inch pipe had 2 inches of insulation, and 1- and 2-inch pipe had 1-inch insulation.

for 2-inch pipe:

Heat loss = 31.5 BTU/hr/ft × 150 ft

= 4725 BTU/hr

for 1-inch pipe:

Heat loss = 17.5 BTU/hr/ft × 200 ft

= 3500 BTU/hr

for a total loss of 10,705 BTU/hr.

TABLE B

HEAT LOSS PER FOOT IN BTU/HR FOR INSULATED PIPE

	PIPE SIZE (INCHES)	TEMPERATURE DIFFERENCE BETWEEN THE FLUID AND SURROUNDING AIR			
		50	100	150	200
BASED ON 1-INCH THICK INSULATION	1/2	3.7	7.5	11.3	15.1
	3/4	4.7	9.35	14.0	18.7
	1	5.8	11.7	17.5	23.4
	1-1/4	7.4	14.8	22.2	29.6
	1-1/2	8.4	16.9	25.3	33.8
	2	10.6	21.0	31.5	42.0
	2-1/2	12.8	25.6	38.4	51.2
BASED ON 2-INCH THICK INSULATION	3	8.2	16.5	24.8	33.0
	3-1/2	9.4	18.8	28.2	37.6
	4	10.6	21.2	31.8	42.4
	4-1/2	11.8	23.6	35.4	47.2
	5	13.1	26.2	39.3	52.4
	6	15.6	31.2	46.8	62.4
	7	18.0	35.9	53.8	71.8
	8	20.3	40.6	60.9	81.2
	9	22.7	45.4	68.1	90.8
	10	25.3	50.7	76.05	101.4
	12	30.0	60.1	90.2	120.2
	14	33.0	66.0	99.0	132

3.04 Also assume that the boiler is on the line for 4000 hours, and the gas costs 45 cents per therm; then:

$$\text{Annual cost of heat loss} = \frac{\text{Total heat loss}}{\text{efficiency}} \times \frac{\text{hours}}{} \times \frac{\$0.45}{\text{therm}} \times \frac{1\text{ therm}}{100{,}000\text{ BTU}}$$

$$= \frac{10{,}705\text{ BTU/hr}}{0.5} \times \frac{4000\text{ hours}}{} \times \frac{\$0.45}{\text{therm}} \times \frac{1\text{ therm}}{100{,}000\text{ BTU}}$$

$$= \$385.38$$

Given the savings figure and the cost of isolating the pipes, Life Cycle costing can determine the feasibility of this change.

4. FLUE STACK VENT DAMPER INSTALLATION

4.01 Vent dampers are devices installed in the flue stacks of natural gas and oil-fired furnaces or boilers equipped with barometric dampers or draft hoods. These devices automatically close the furnace or boiler flue stack to prevent the loss of heated air up the stack during the heating equipment off cycle.

4.02 All manufacturers call for their dampers to be installed by a prequalified service agency. Also, a prequalified service agency is required to conduct an annual inspection of the flue stack, the vent system, and the damper device for deterioration from corrosion and for safe operation by performing checkout procedures set forth by the manufacturer. Additionally, frequent inspections by the building operations forces for corrosion and safe operation of the damper device in accordance with the manufacturer's recommendations would be required.

4.03 Based on manufacturers' data, energy savings for gas-fired systems range from 9 to 37 percent. Savings are expected to be higher for boilers, due to the larger mass of the heat transfer surfaces, than for furnaces. Savings will also be higher for installations which draw combustion air from inside the building. All telephone company installations should have combustion air supply direct from the exterior of the building into the boiler or furnace room and, therefore, the higher savings would not be applicable.

4.04 Vent dampers for use with natural gas-fired equipment are tested and certified under the American National Standards Institute (ANSI) and must carry the American Gas Association (AGA) symbol. Those for use with oil-fired heating equipment are tested and certified by the Underwriters Laboratories (UL) and must carry the UL symbol. The ANSI Standard is only applicable to vent dampers 12 inches in diameter or smaller. For some companies with many small heating plants, installing vent dampers may lead to substantial energy savings. However, the general feeling is that the energy saving potential of the dampers is small, and safety considerations would lead to recommending against their use. Companies that decide to use vent dampers must ensure that they are installed as recommended by the manufacturer, train their maintenance forces on proper maintenance of these dampers, and ensure that the maintenance is actually performed.

5. REFERENCES

5.01 The information in this section is based on the following references:

- *American Society of Heating, Refrigeration, and Air Conditioning Engineers Handbook of Fundamentals, 1972,* 1791 Tullie Circle, NE, Atlanta, Georgia 30329

- *American Society of Heating, Refrigeration, and Air Conditioning Engineers Application, 1974,* 1791 Tullie Circle, NE, Atlanta, Georgia 30329.