FOURTEEN BASIC ENERGY CONSERVATION MEASURES

TO

REDUCE ENERGY COSTS

By: Henry Manczyk, CPE, CEM
Director of Facilities Management
Monroe County, New York

Fourteen Basic Energy Conservation Measures

Fourteen Basic Energy Conservation Measures

Introduction

By Henry Manczyk, CPE, CEM
Director of Facilities Management
Monroe County, New York

Energy Conservation is important for several reasons: Economic, Environmental and Social. Economically, it makes sense since energy is a commodity which we cannot afford to waste. Environmentally, it's makes sense as well. It has been universally recognized that the more efficiently we utilize energy, much less carbon dioxide will be released into the atmosphere, thus preserving our environment and avoiding as much as possible the unpredictable changes in our climate. The other benefit that results in the overall objectives of energy conservation is the social factor which creates a significant amount of jobs in the manufacturing and installation of energy efficient equipment.

An effective building energy management system is essential to ensure that energy savings are realized while providing a work environment that maximizes the comfort and performance of the building's occupants.

A successful energy management program requires full commitment by the owners and building occupants as well as by a professional energy manager with a holistic view of energy management who can capture the savings the program has produced.

Well-planned energy management programs systematically set energy use goals and explore ways to achieve them, such as an installation of energy efficient equipment and a revised standard of operation and maintenance procedures.

In any effective energy management conservation program, the first step is to perform an energy audit of the facility. A thorough evaluation will establish the load profile, identify all energy consuming systems as well as evaluate the condition of the systems, and analyze the impact of improvements to those systems.

The energy audit and survey will generate a report that clearly identifies and defines potential energy conservation opportunities. The report should recommend strategies and equipment modification based on economic analysis to reduce building energy consumption.

Normally, most of the recommended energy conservation measures can be achieved with little or no cost. Others, however, require investment to get implemented if the project is to be cost effective.

This article identifies 14 case studies of energy conservation measures. Each example presents its desired values and return on investment.

References:

- "Energy Management of Commercial Buildings", By: "Caddet", Coded Analysis Series 19, May 1996
  http://www.aceee.org/pubs/cad19.htm

- "Good Energy Management Begins with an Energy Audit", By: "Energy User News" Posted on July 10, 2000 on the internet.
  http://www.energyusernews.com/eun/cda/article_information/fundamentals_item/0,2637,6421,00.html

- "Why We Should Conserve Energy" By: The Association for the Conservation of Energy 2000 (ACE)
  www.ukace.org/encons.htm

Issued: August 13, 2002

Definitions and Equations

(1) Equation for heat loss from a building

$$Q = H.L.M. \times \Delta T$$

Where

Q = Btu/Hr

H.L.M. = Heat loss multiplier = U-factor x Area = $\frac{BTU}{Hr - {}^{o}F}$

ΔT = Temperature difference

= Indoor temperature – outdoor temperature

(2) Equation for total heat loss for a heating season using the Bin Hour method.

$$Q = H.L.M. \times \Delta T \times Hour$$

Where

Q = Btu

H.L.M. = Heat loss multiplier = U-factor x Area = BTU/Hr - ^{o}F

ΔT = Temperature difference

= Indoor temperature – outdoor temperature

Hour = Bin Hour

NOTE: The bin hours are the length of time that the outside air temperature is between a given temperature range. The Bin temperature used in these calculations are the mid-point of the given temperature range.

The total heat loss for a season with a constant indoor temperature of 70 ^oF is:

$$Q = H.L.M. \; x \; (T_2 - T_1) \; x \; Hours$$

This can be written mathematically:

$$Total\ Heat\ Loss = H.L.M. \; x \; \sum \Delta T \; (Bin\ Hours)$$

Where,

$\Sigma\Delta T$ (Bin Hour) is the summation of each ΔT times the corresponding bin hours for the heating season.

At 70 ^oF the $\Sigma\Delta T$ (Bin Hour) is:

(70 - 57) x	364 Hour	=	4,732	^oF-Hr
(70 - 52) x	439	=	7,902	
(70 - 47) x	503	=	11,569	
(70 - 42) x	566	=	15,848	
(70 - 37) x	745	=	24,585	
(70 - 32) x	928	=	35,264	
(70 - 27) x	625	=	26,875	
(70 - 22) x	402	=	19,296	
(70 - 17) x	247	=	13,091	
(70 - 12) x	172	=	9,976	
(70 - 7) x	72	=	4,536	
(70 - 2) x	23	=	1,564	
			175,238	^oF-Hr

Note: The above bin hours were derived from Niagara Falls, N.Y. climatological data.

Niagara Falls, N.Y. Region

Total Bin Hours in the Range of 0^oF - 59^oF

		SHIFTS			
RANGE	MID-POINT	00:30 - 08:30	08:30 - 16:30	16:30 - 00:30	TOTAL HOURS
59-55	57^oF	96	143	125	364
54-50	52^oF	137	143	159	439
49-45	47^oF	167	157	179	503
44-60	42^oF	197	181	188	566
39-35	37^oF	254	238	253	745
34-30	32^oF	345	276	307	928
29-25	27^oF	227	185	213	625
24-20	22^oF	152	117	133	402
19-15	17^oF	106	60	81	247
14-10	12^oF	74	39	59	172
9-5	7^oF	39	13	20	72
4-0	2^oF	12	5	6	23
				Total Hours in the Range of 0^oF - 59^oF	5,086

NOTE! It is assumed that, with the building improvements, energy is not consumed at an outside air temperature of 60^oF or above.

TOTAL AVAILABLE HOURS DURING HEATING SEASON FROM

SEPTEMBER 1 TO MAY 1

MONTH	DAYS	HOURS
September	30	720
October	31	744
November	30	720
December	31	744
January	31	744
February	28	672
March	31	744
April	30	720
TOTAL AVAILABLE HOURS =		5,808

1) Equation: Heat Saved

$Q = A \times \Delta U \times W \times 10^{-6}$

Where

Q = Energy Saved = MMBtu's

A = Area of Glass = 1,062 Ft^2

ΔU = Change in U-Factor = (1.1 - .5) = .6

W = Weather Multiplier = 75° ⟶ 200,711 Hr-°F

10^{-6} = MMBtu/Btu

$Q = (1{,}062)(.6)(200{,}711)(10^{-6}) = 127.9$ MMBtu's

2) Equation: Infiltration Savings

$Q = L \times \Delta C \times F \times S \times 1.08 \times W \times 10^{-6}$

Where

Q = Energy saved = MMBtu's

L = Length of crack on wall with most windows = 420 Ft

ΔC = Change in crack = (.001-.001) = .004 Ft

F = Wind correction factor = .43

S = Speed of wind = 440 Fpm

1.08 = Conversion Factor

W = Weather Multiplier = 75°F ⟶ 200,711 Hr-°F

10^{-6} = MMBtu/Btu

$Q = (420)(.004)(.43)(440)(1.08)(200{,}711)(10^{-6})$

= 68.9 MMBtu's

Total Energy Savings

Heat:	127.9 MMBtu's
Infiltration:	68.9 MMBtu's
	196.8 MMBtu's

Cost: 196.8 MMBtu's x $6.37/MMBtu = $1,253.62

Equipment Cost: Cost supplied by a window installer includes labor

Office Window System = $6,000

Garage Fixed Window = $6,000 (See Note)

$12,000

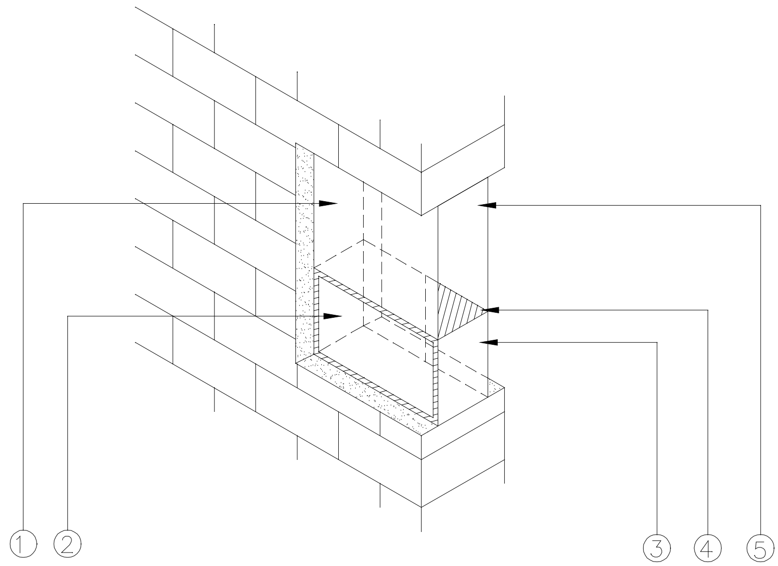
Note: The fixed windows are the windows that are in the garage area and not the same as the window system for the office area. These fixed windows would have a fixed interior second pane of glass.

Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Savings}} \quad \frac{\$12,000}{1,253.62} = 9.6 \text{ years}$$

ENERGY CONSERVATION MEASURE #1

WINDOWS REPLACEMENT



① EXISTING FIXED WINDOW
② OPERABLE PART OF EXISTING WINDOW WHICH OPENS OUTWARD
③ NEW SLIDING WINDOW FOR EASY ACCESS TO EXISTING OPERABLE WINDOW
④ AIR BREAK TO STOP AIR MOVEMENT INTO THE SPACE BETWEEN THE FIXED WINDOWS
⑤ NEW INTERIOR FIXED WINDOW

Equation:

$$Q = A \times \Delta U \times W \times 10^{-6} \times C$$

Where

Q = Energy Saved = $

A = Area = 2520 Ft^2

ΔU = Change in U-Factor = (.171 - .042) = .129

W = Weather Multiplier = 175,276 °F – Hr

10^{-6} = MMBtu/Btu

C = Cost of Gas = $6.37

$$Q = (2520)(.129)(175{,}276)(10^{-6})(6.37) = \$363$$

Equipment Cost

$1,320

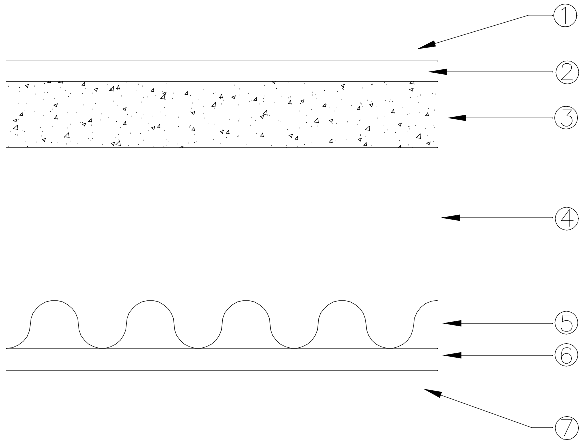
Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Savings}} = \frac{\$1{,}320}{\$363} = \underline{3.6\ \text{years}}$$

ENERGY CONSERVATION MEASURE #2

ADDING ADDITIONAL INSULATION IN THE CEILING

ROOF SECTION



ITEM	PRESENT	PROPOSED
① OUTSIDE AIR FILM	.17	.17
② BUILT- ROOFING	.33	.33
③ 3" CONCRETE	3.33	3.33
④ AIR SPACE	.93	
⑤ INSULATION		19.00
⑥ TILE	.47	.47
⑦ INSIDE AIR FILM	.61	.61
	5.84	23.91
U-FACTOR= 1/R=	.171	.042

Equation:

$$Q = A \times \Delta U \times W \times 10^{-6}$$

Where

Q = Energy saved = MMBtu's

A = Area of wall = 520 Ft^2

ΔU = Change in U-factors = (.322 - .107) = .215

W= Weather multiplier = 70° ⟶ 175,276 Hr-°F

10^{-6} = MMBtu/Btu

$$Q = (520\ Ft^2)(.215)(175{,}276)(10^{-6}) = 19.6\ MMBtu's$$

Cost

$$19.6\ MMBtu \times \frac{\$6.37}{MMBtu} = \$125/year$$

Equipment cost: 1985 "Means: Construction Cost Data"

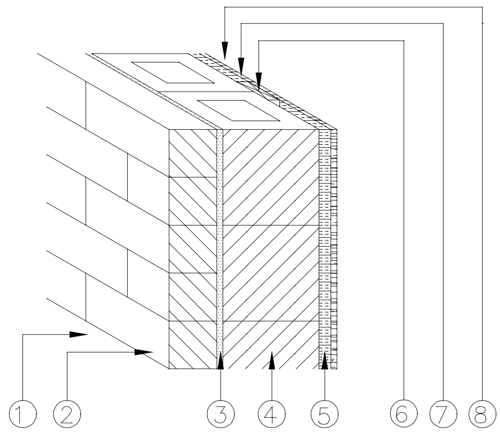
Urethane 1" R-5.8	520 Ft^2 x \$.72/Ft^2	= \$374
Gypsum wallboard 12"	520 Ft^2 x \$.75/Ft^2	= \$390
Furring attach to masonary	60 x 8 Ft x .57/Ft	= \$274
		\$1,038

Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Saving}} = \frac{\$1{,}038}{\$125} = \underline{8.3\ years}$$

ENERGY CONSERVATION MEASURE #3

ADDING ADDITIONAL INSULATION TO THE INTERIOR OF A HOUSE



ITEM	R-VALUES EXISTING	R-VALUES PROPOSED
① OUTSIDE AIR FILM	.17	.17
② 4" FACE BRICK	.44	.44
③ 1/2" MORTAR	.10	.10
④ 8" BLOCK	1.72	1.72
⑤ RIDGE INSULATION		5.8
⑥ 1"x3" VERTICAL FURRING		
⑦ 1/2" GYPSUM WALLBOARD		.45
⑧ INSIDE AIR SPACE	.68	.68
	3.11	9.36

Existing: U-FACTOR= 1/R = 1/3.11 = .322 BTU/HR-FT2-F

Proposed: U-FACTOR= 1/R = 1/9.36 = .107 BTU/HR-FT2-F

Equation: $Q = A \times \Delta U \times W \times 10^{-6} \times C$

Where

Q = Energy saved = $

A = Area of roof with rigid insulation = 6,495

ΔU = Change in U-factors

Case 1 = (.051 - .046) = .005

Case 2 = (.051 - .040) = .011

Case 3 = (.051 - .033) = .018

W = Weather multiplier with night setback = 139,996 H-°F

10^{-6} = MMBtu/Btu

C = Cost of Gas = $6.37/MMBtu

Case 1: $(6{,}495)(.005)(139{,}996)(10^{-6})(6.37) = \$29$

Case 2: $(6{,}495)(.011)(139{,}996)(10^{-6})(6.37) = \$64$

Case 3: $(6{,}495)(.018)(139{,}996)(10^{-6})(6.37) = \$104$

<u>Equipment Cost</u>

Case 1 = 6,495 Ft^2 x $.67/$Ft^2$ = $4,352

Case 2 = 6,495 Ft^2 x $.78/$Ft^2$ = $5,066

Case 3 = 6,495 Ft^2 x $.92/$Ft^2$ = $5,975

<u>Simple Payback</u>

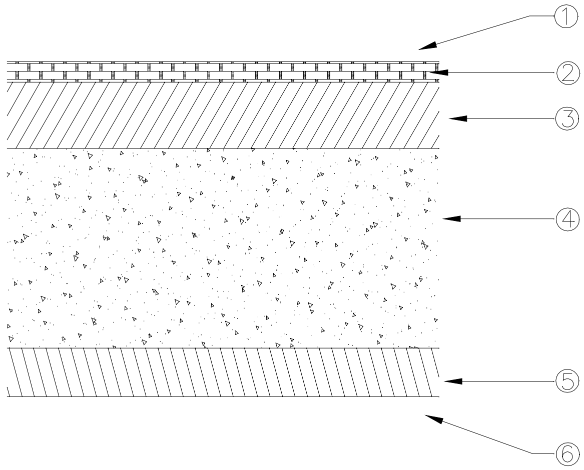
Case 1: $\dfrac{\text{Equipment Cost}}{\text{Saving}} = \dfrac{\$4{,}352}{29} = 150$ years

Case 2: $= \dfrac{\$5{,}066}{64} = 79$ years

Case 3: $= \dfrac{\$5{,}975}{104} = 57$ years

ENERGY CONSERVATION MEASURE #4 — REPLACEMENT OF ROOF INSULATION

ROOF SECTION



ITEM	EXISTING	CASES 1	CASES 2	CASES 3
① OUTSIDE AIR FILM	.17			
② BUILT-UP ROOFING	.33			
③ INSULATION	14.58	16.67	20.00	25.00
④ 2" CONCRETE	3.33			
⑤ TILE	.47			
⑥ INSIDE AIR FILM	.61			
R =	19.49	21.58	24.91	29.91
U-FACTOR= 1/R=	.051	.046	.040	.033

Formula

$Q = Sa \times (1/R_1 - 1/R_2) \times \Delta T \times D \times 10^{-6} \times C$

Where

Q = Energy Saved = $

Sa = Surface area of tank = 33.3 FT^2

$$R_1 = \left[\frac{.917LN\left(\frac{11}{10}\right)}{.03} + .61 \right] = 3.52$$

$$R_2 = \left[\frac{1.125LN\left(\frac{13.5}{10}\right)}{.03} + \frac{1.125LN\left(\frac{13.5}{11}\right)}{.03} + .61 \right] = 19.56$$

ΔT = Temperature difference = (120 – 60) = 60°F

D = Length of Year = 8760 Hr.

10^{-6} = MMBtu/Btu

C = Cost of Gas = $6.37

Q = (33.3)(1/3.52 – 1/1956)(10^{-6})(60)(8760)(6.37) = $32

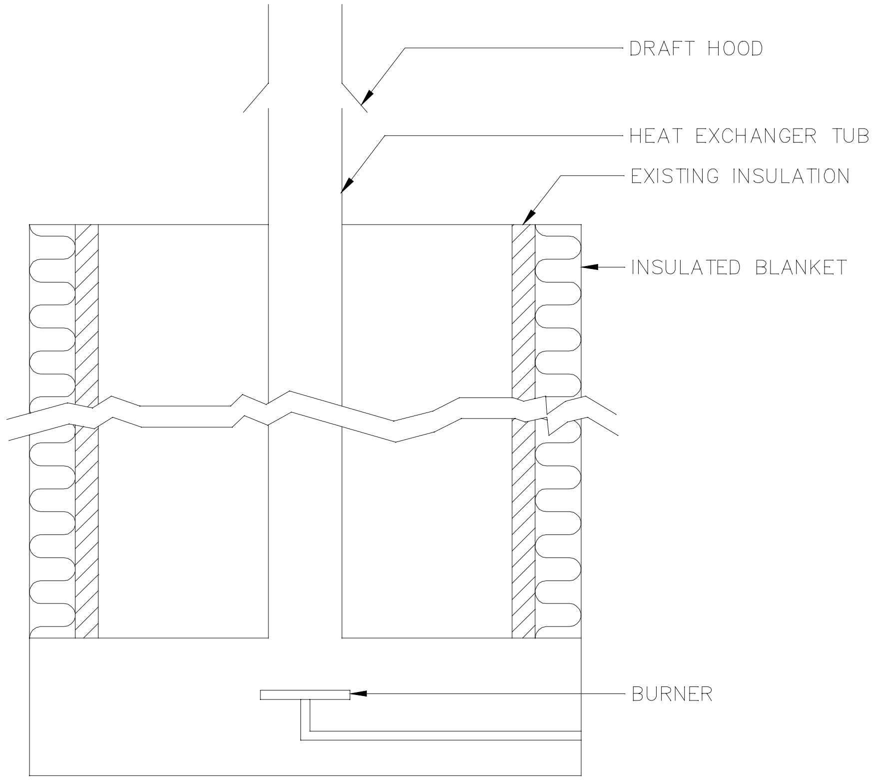
Equipment Cost: $55

<u>Simple payback</u>

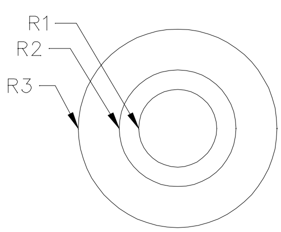
$$\frac{\text{Equipment Cost}}{\text{Savings}} = \frac{\$55}{32} = \underline{\underline{1.72 \text{ years}}}$$

ENERGY CONSERVATION MEASURE #5

INSULATED BLANKET FOR A DOMESTIC HOT WATER HEATER



RESISTANCE FOR A CYLINDER



$$\text{PRESENT} = \left[\frac{R2 \ \text{LN} \left(\frac{R2}{R1} \right)}{K1} + H \right]$$

$$\text{PROPOSED} = \left[\frac{R3 \ \text{LN} \left(\frac{R2}{R1} \right)}{K1} + \frac{R3 \ \text{LN} \left(\frac{R3}{R2} \right)}{K2} + H \right]$$

Equation: Heat Saved

$$Q = A \times \Delta U \times W \times 10^{-6} \times C$$

Where

Q = Energy saved = \$

A = Area of Doors = 984 Ft^2

ΔU = Change in U-Factor = (.721 - .077) = .644

W = Weather multiplier = 140,314 °F-Hr

10^{-6} = MMBtu/Btu

C = Cost of Gas = \$6.37

$Q = (984)(.644)(140,314)(10^{-6})(6.37) = \$566$

Equation: Infiltration

$$Q = P \times \Delta S \times 204.34 \times W \times 10^{-6} \times C$$

Where

Q = Energy Saved = \$

P = Perimeter of Doors = 332 Ft.

ΔS = Change in crack = (.01-.001) = .009

204.34 = Conversion factor = (440 x .43 x 1.08 = 204.34)

W = Weather multiplier = 140,314 °F-Hr

10^{-6} = MMBtu/Btu

C = Cost of Gas = \$6.37

$Q = (332)(.009)(204.34)(140,314)(10^{-6})(6.37) = \$546$

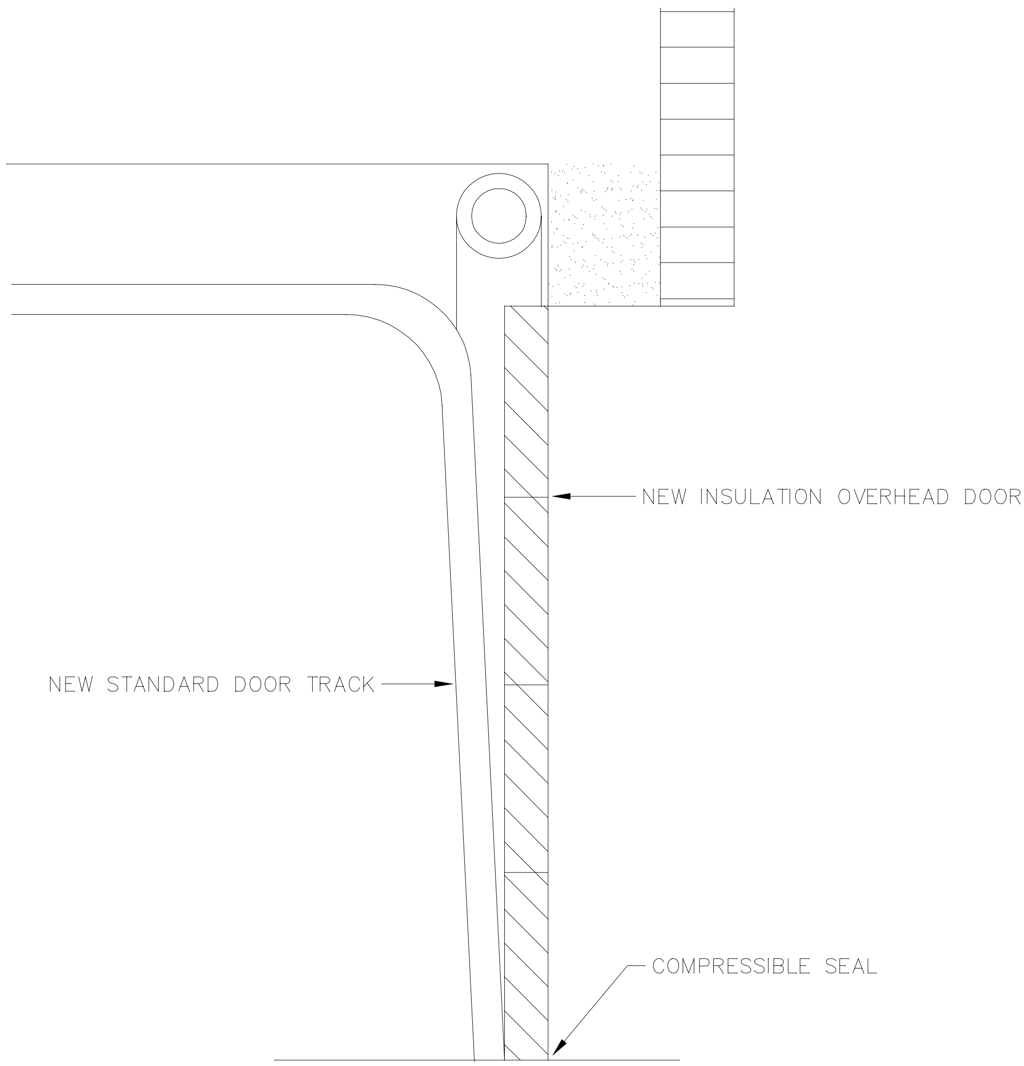
Equipment Cost: \$11,958

Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Savings}} = \frac{\$11,958}{546+566} = \underline{10.8 \text{ Years}}$$

ENERGY CONSERVATION MEASURE #6

NEW OVERHEAD DOORS



Formula: Heat Saved

$$Q = H.L.M. \times \Delta T \times H \times 10^{-6} \times C$$

Where

Q = Energy saved = $

H.L.M. = Heat loss multiplier = 4,534 Btu/Hr-°F

ΔT = Temperature change = 68 – 62 = 6°F

H = Hours

10^{-6} = MMBtu/Btu

C = Cost of oil = $6.83

$Q = (4{,}534)(6)(284)(10^{-6})(6.83) = \$53$

Formula: Electric Saved

$$Q = Hp \times .746 \times H \times C$$

Where

Q = Electric saved = $

Hp = Horsepower = .25

.746 = Conversion factor

H = Hours = 2,869

C = Cost of electric = $.07

$Q = (.25)(.746)(2{,}869)(.07) = \$37$

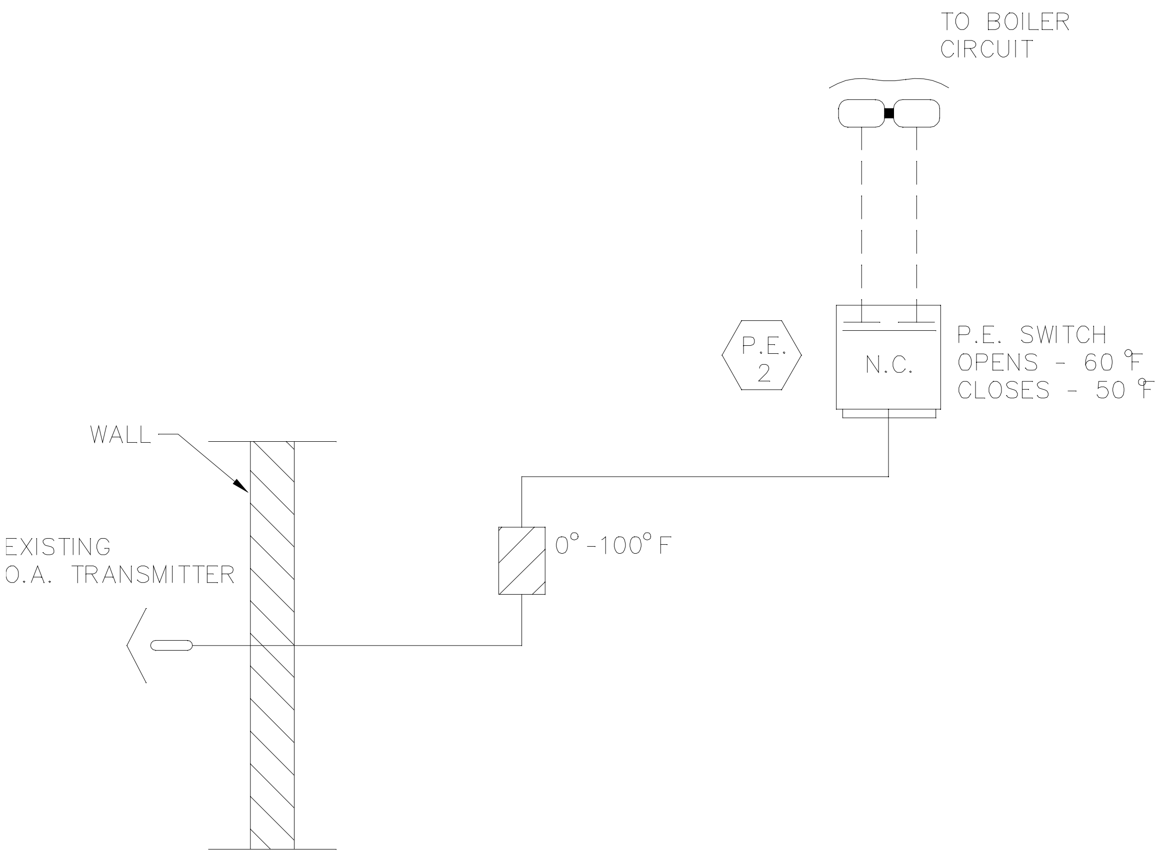
Equipment Cost: $240

Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Savings}} = \frac{\$240}{37+53} = 2.66 \text{ years}$$

ENERGY CONSERVATION MEASURE #7

BOILER OUTDOOR LOCKOUT CONTROLLER



Equation:

$$Q = 1{,}872 \times A \times R \times (1/T_2) \times (dTa/T_1).5 \times dTa \times M \times D \times 10^{-6} \times C$$

Where

Q = Energy saved = $

1,872 = Conversion Factor = ((104,000/60) x 1.08 = 1,872)

A = Area of vent = π(4)2/4 = 12.6 In^2

R = Resistance factor = 2.236

T_2 = Average absolute gas vent temperature = 575°R

dTa = Average difference in gas and outside air

= 115 – 34 = 81°F

T_1 = Absolute outside air temperature = 494°R

M = Time heater is on standby = 22 hours

D = Length of heating season = 212 days

10^{-6} = MMBtu/Btu

C = Cost of gas = $6.37

$$Q = (1{,}872)(12.6)(2.236)(1/575)(81/494)^{.5}(81)(22)(212)(10^{-6})(6.37)$$

= $89

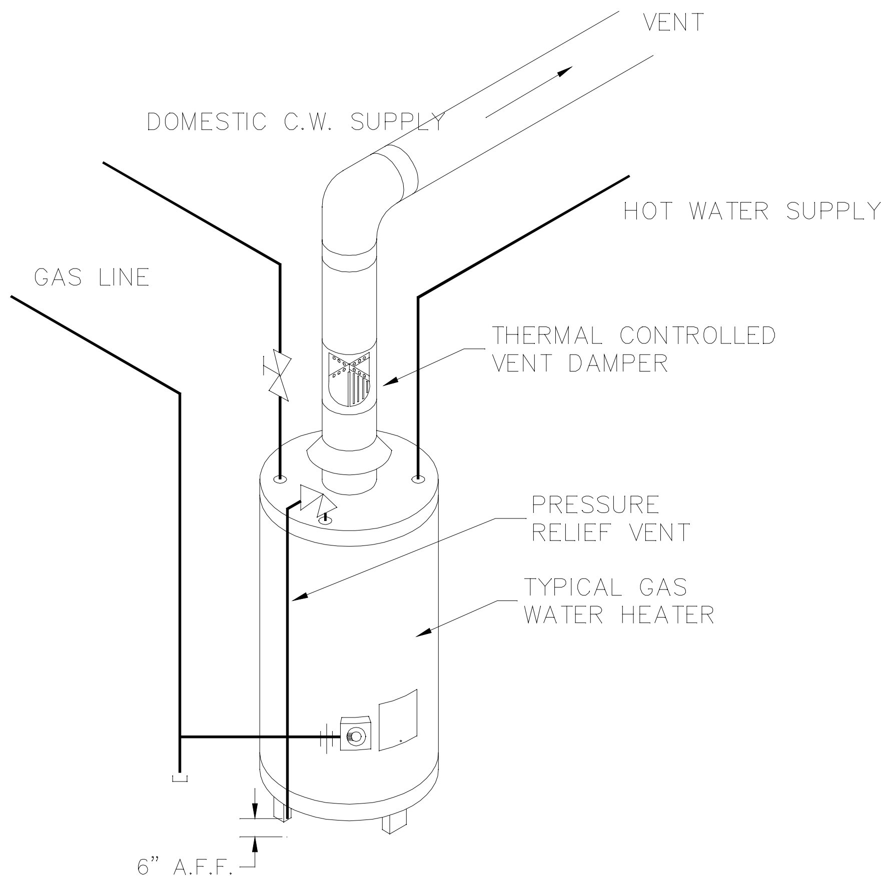
Equipment Cost: $50

Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Savings}} = \frac{\$50}{89} = 0.6 \text{ years}$$

ENERGY CONSERVATION
MEASURE #8

THERMO FLUE VENT DAMPER
FOR DOMESTIC HOT WATER HEATER



Equation:

$Q = M \times 8.33 \times C \times \Delta T \times L \times 10^{-6} \times 6.37$

Where

Q = Energy saved = $

M = Make-up water = 100 gallons/day

8.33 = Conversion factor

C = Specific heat = 1 Btu/Lb - °F

ΔT = Change in temperature = 190-50 = 140°F

L = Length of season = 212 days

10^{-6} = MMBtu/Btu

C = Cost of Gas = $6.37

$Q = (100)(8.33)(1)(140)(212)(10^{-6})(6.37)=\$157$

Equipment: $1,200

Simple Payback

$\frac{\text{Equipment Cost}}{\text{Savings}} = \frac{\$1,200}{157} = \underline{\underline{7.6 \text{ years}}}$

Equation

$$Q = Sa \times (1/R_1 - 1/R_2) \times \Delta T \times L \times 10^{-6} \times C$$

Where

Q = Energy saved = $

Sa = Surface area of pipes

= 150 Ft. x (π(1.5/12)) = 58.9 Ft^2

$$\left[R_1 = \frac{0.063 Ln\left(\frac{.755}{.75}\right)}{25} + .61 \right] = .61002$$

$$\left[R_2 = \frac{.146 Ln\left(\frac{1.755}{.75}\right)}{.03} + \frac{.146 Ln\left(\frac{1.755}{.755}\right)}{25} + .61 \right] = 4.75$$

ΔT = Change in temperature = 140 - 60°F = 80°F

L = Length of heating season = 5,808 Hours

10^{-6} = MMBtu/Btu

C = Cost of Gas = 6.37

$Q = (58.9)(1/.61002 - 1/4.75)(80)(5,808)(10^{-6})(6.37)$

= 249

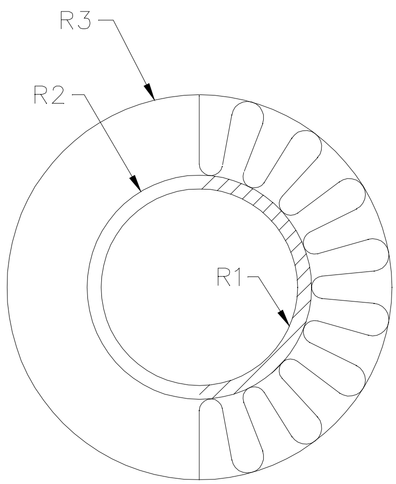
Equipment Cost: Means "CONSTRUCTION COST" includes labor

150 Ft x $3.14 = $471

Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Saving}} = \frac{\$471}{249} = \underline{1.9 \text{ years}}$$

INSULATED PIPE SECTION



R3: RADIUS TO EXTERIOR OF INSULATION
R2: RADIUS TO EXTERIOR OF PIPE
R1: RADIUS TO INTERIOR OF PIPE

BARE PIPE

$$\text{RESISTANCE} = \left[\frac{R2 \ \mathrm{LN}\left(\frac{R2}{R1}\right)}{K1} + H \right]$$

INSULATED PIPES

$$\text{RESISTANCE} = \left[\frac{R3 \ \mathrm{LN}\left(\frac{R2}{R1}\right)}{K1} + \frac{R3 \ \mathrm{LN}\left(\frac{R3}{R2}\right)}{K2} + H \right]$$

Equation

$$Q = CFM \times 1.08 \times T \times W \times 10^{-6} \times C$$

Where

Q = Energy Saved

CFM = Exhaust air = 200 CFM

1.08 = Conversion Factor

T = % Exhaust is off = 71% or .71

W = Weather multiplier = 149,841 H-°F

10^{-6} = MMBtu/Btu

C = Cost of Gas = $6.37

$$Q = (200)(1.08)(.71)(149{,}841)(10^{-6})(6.37) = \$146$$

Equipment Cost:

$70

Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Savings}} = \frac{\$70}{146} = 0.48 \text{ years}$$

Equation

$$Q = P \times \Delta H \times 59.2 \times W \times 10^{-6} \times C$$

Where

Q = Energy saved = $

P = Perimeter of windows = 1,030 Ft.

ΔH = Change in crack = (.01-.001) = .009

59.2 = Conversion factor = (220 x .25 x 1.08 = 59.4)

W = Weather multiplier = 175,276 Hr-°F

10^{-6} = MMBtu/Btu

C = Cost of Gas = $6.37

$$Q = (1{,}030)(.009)(59.2)(175{,}276)(10^{-6})(6.37)$$

$$= \$613$$

Equipment Cost with Labor:

$409

Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Savings}} = \frac{\$409}{613} = 0.67 \text{ years}$$

Equation

$$Q = N \times M \times L \times G \times \Delta T \times S \times 10^{-6} \times C$$

Where

Q = Energy saved = $

N = Number of showers = 120 showers/day

M = Minute per shower = 5 min./shower

L = Length of school season = 180 days

G = Flow rate = 16.7 Lb/Min.

ΔT = Temperature saved = 160-120 = 40°F

S = Specific heat of water = 1 Btu/Lb-°F

10^{-6} = MMBtu/Btu

C = Cost of Gas = 6.37

$Q = (120)(5)(180)(16.7)(40)(1)(10^{-6})(6.37)$

= $459

Equation $Q = H.L.M. \times \Delta T \times H \times 10^{-6} \times C$

Where

Q = Energy saved = $

H.L.M. = Heat Loss Multiplier = 2,300 Btu/Hr-°F

ΔT = Temperature saved = 4°F

H = Hour of season = 5,808 Hr.

10^{-6} = MMBtu/Btu

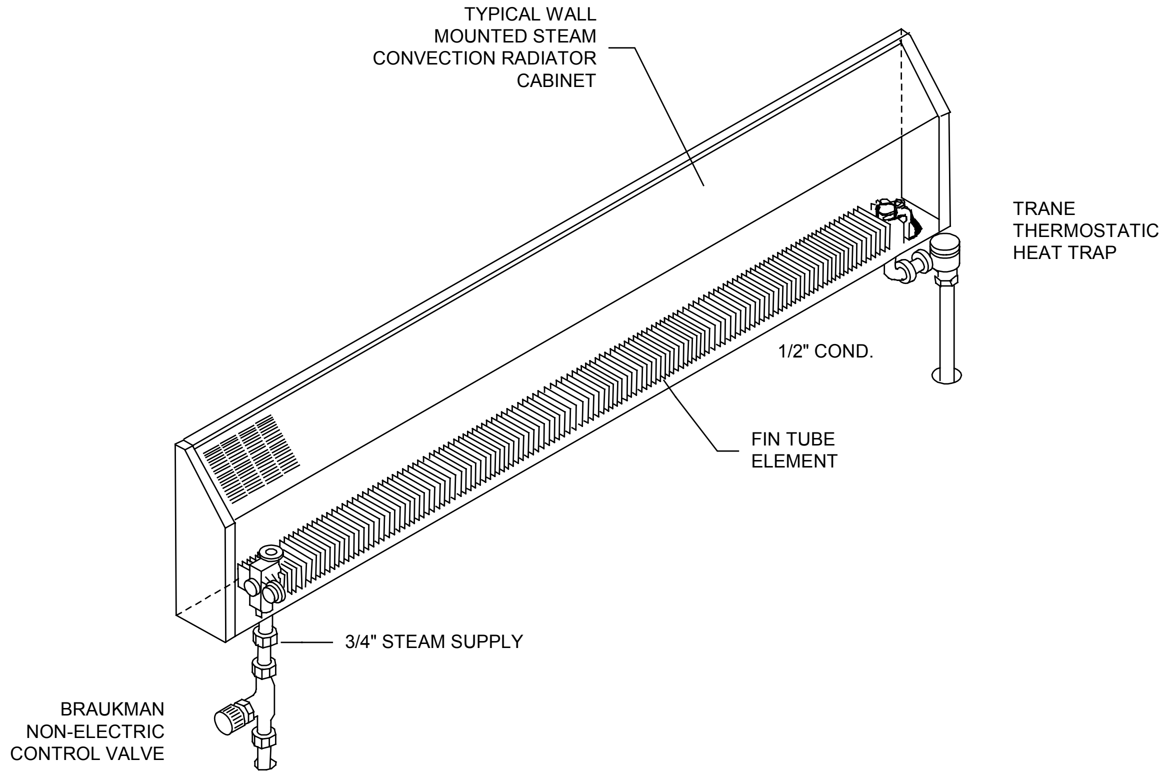
C = Cost of Gas = $6.37

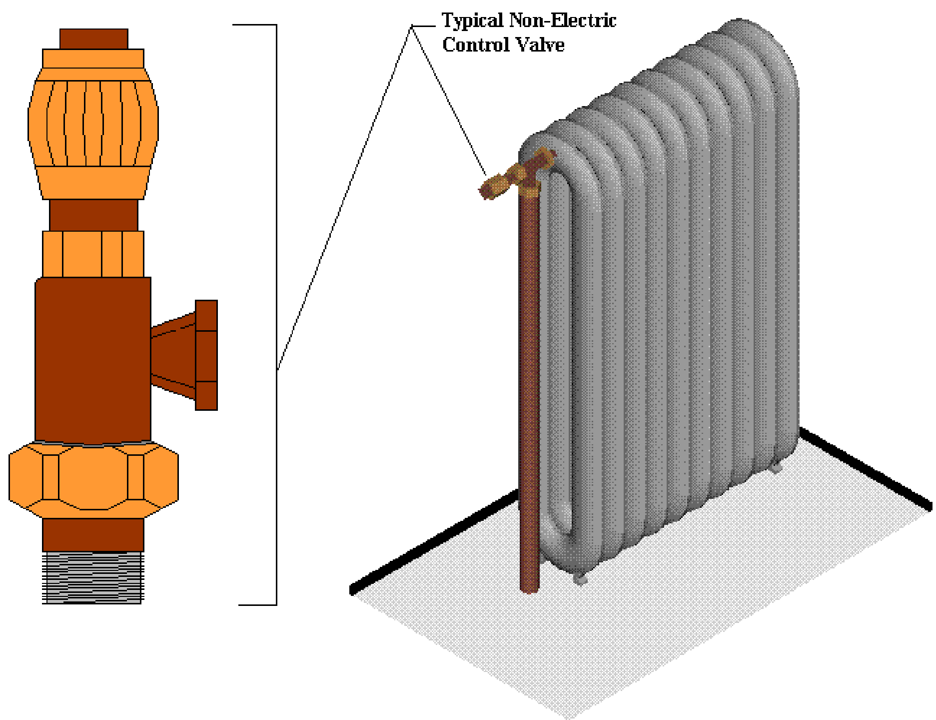
$Q = (2,300)(4)(5,808)(10^{-6})(6.37) = \$340$

Equipment Cost: $500

Simple Payback

$$\frac{\text{Equipment Cost}}{\text{Savings}} = \frac{\$500}{340} = 1.5 \text{ years}$$


TYPICAL WALL
MOUNTED STEAM
CONVECTION RADIATOR
CABINET
TRANE
THERMOSTATIC
HEAT TRAP
1/2" COND.
FIN TUBE
ELEMENT
3/4" STEAM SUPPLY
BRAUKMAN
NON-ELECTRIC
CONTROL VALVE


Typical Non-Electric
Control Valve