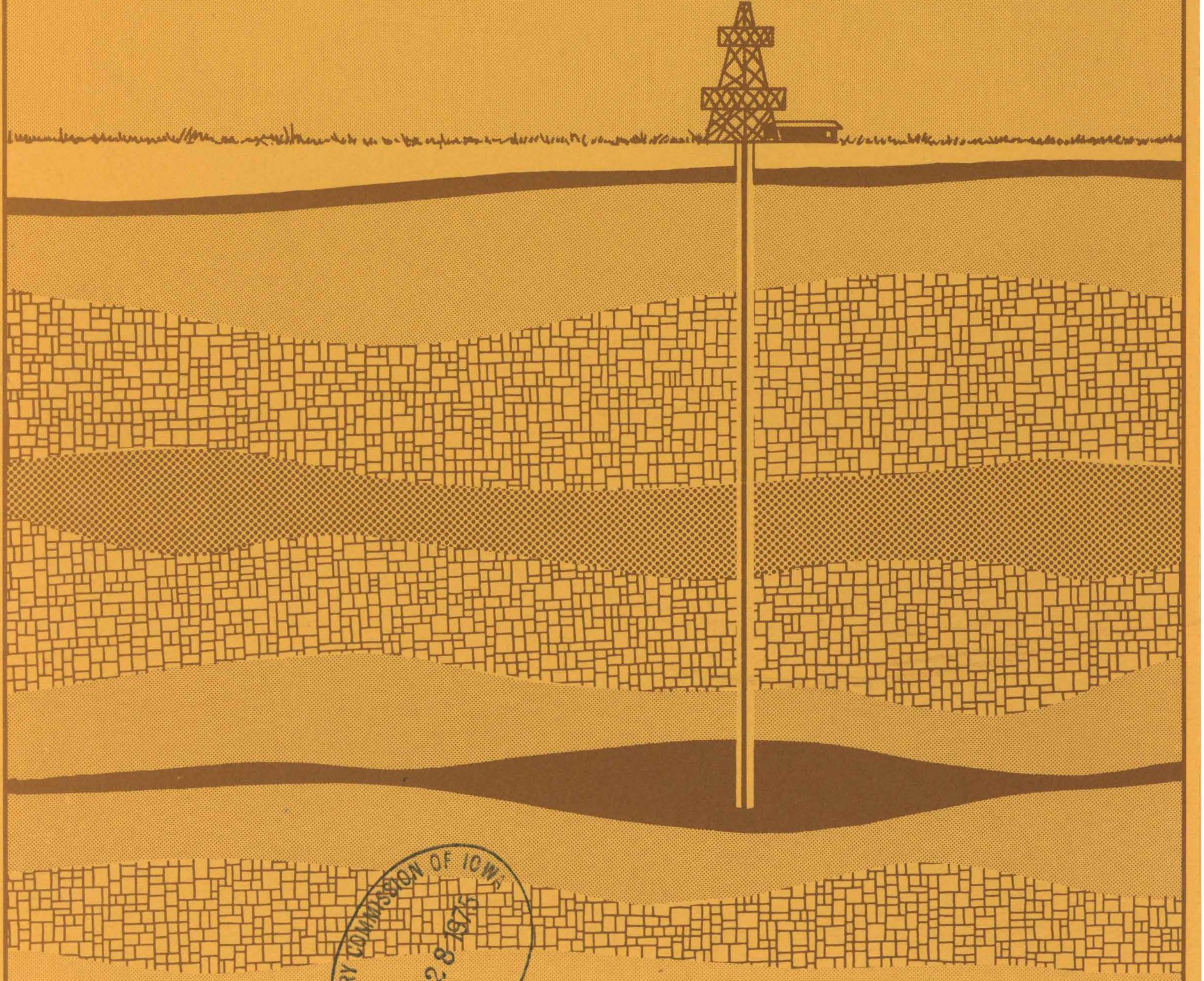
ENERGY CONSERVATION in Industrial Plants

by **Donald McKeown A.I.A.**
Professor of Architecture



IOWA STATE UNIVERSITY of Science and Technology
Center for Industrial Research and Service
A Function of Iowa State University Extension
Ames, Iowa December, 1973 CIRAS-5

$1.15

CONTENTS

INTRODUCTION 3

ENERGY CONSERVATION IN INDUSTRY 3
Present Industrial Practices 3
Higher Fuel Costs 3
Future Demands for Fuel 4
Use of Energy in the United States 4

LOSS OF ENERGY IN BUILDINGS 4
Effects of Insulation in an Industrial Plant 5
    Amount of fuel used yearly 6
    Yearly heating costs 6
    Cost of insulating this plant 6
    Fuels and their heat values 6
    Heating and air conditioning comparisons 7
    Heat gain 7
    Humidity control 7
    Insulated window glass 9
Effects of Solar Transmission on Buildings 9
    Buildings are heat traps 10
    Intercepting solar rays 11
    Shade trees protect against heat gain 12
    Summary: Controlling solar heat gain 12
Controlling the Introduction of Outdoor Air 12
    Air for odor reduction 12
    Heat loss from chimneys 13
Individual-Clustered Building Arrangements 13
Selection of Electric Lamps 13
    Fluorescent lamp life compared 13

MORE ENERGY CONSERVATION METHODS 14
Efficiency of Unit Air Conditioners 14
    Costs comparing three different units 15
Zoning and Weekend Operations 15
Regular Maintenance of Equipment 15
    Fuel burner care 16
Reorganize and Improve Processes 16
Consolidate Auto Trips 16
Modifying Existing Buildings 16

gift, [redacted], 8/28/75 copy 1

INTRODUCTION

Energy can and must be conserved to a much greater degree than is now practiced in business and industry. Quite simply, our rates of consumption are increasing at a faster pace than fuel is being supplied. Regardless of all the current claims that fuel-producing giants are creating monopolies for themselves, no one can deny that our fossil fuels are becoming more difficult to tap.

The newer forms of energy production are being developed but not at a fast enough rate to satisfy our present and near-future rates of consumption. Simply, we must buy time in order to research and develop the means necessary to produce our required demands for energy. The real crisis is not necessarily insufficient quantities of available energy but rather more of a human type of crisis. We must be more cognizant of ways in which we can save energy by recycling processes.

Energy has become almost an end in itself. On short trips we ride too often instead of walking. We exhaust hot gases directly to the atmosphere in great quantities when these could be reused within most industrial plants to supply energy. We ask computers and other types of machines to think for us, talk for us, brush our teeth, scratch our backs, and do thousands of other tasks. We are truly a plugged-in society that seldom asks where the energy is coming from to supply this ever increasing array of machines.

Perhaps we need to concentrate on becoming a world where we use energy to amplify our more human aspects rather than one where energy replaces our humanness to such a degree.

This material points out ways in which various forms of energy may be used more efficiently. These ideas can directly and immediately conserve energy, thereby reducing the current rate of fossil fuel consumption. Some of these practices must be employed if we are to buy the time needed to develop cleaner and more effective ways to generate our needed energy supplies.

ENERGY CONSERVATION IN INDUSTRY

Present Industrial Practices

During a recent series of visits to several Iowa industrial plants, many examples were observed where considerable energy was being wasted during industrial processes. These wasteful practices centered around furnaces where heat treating processes were involved. In all instances, high-temperature heat from these furnaces was being discharged directly outdoors without recovering this energy. Further, no serious plans were being considered to remedy the situation in the near future.

As expected, the wasteful practices were known only too well by the personnel in charge of plant operations. They were also known by the chief executive officers of the corporations. Yet, these practices were being condoned as being the best possible solutions to the problem because of the low costs of fuels, principally natural gas.

When questioned about why steps were not being taken to recycle such waste energy, the executives answered something like the following: "As long as we can procure this natural gas for about 40 cents per thousand cubic feet, it is economically unsound at present to spend the money necessary for recycling changes in the operation."

This was followed by the usual comment "I must make a certain level of profit to attract and satisfy stockholders. These shareowners can go to their bank and get at least 6 percent interest on a time certificate. This is less risky than purchasing stock in a corporation such as mine."

Consequently, the high rate of consumption of precious fossil fuels continues. There is little mention of the basic problem. Who is to say that there is an unending supply of natural gas and other petroleum products? Some executives do not feel that the supply of fuel could stop. Instead, there is the confident acceptance of a possible rise in the cost of natural gas and other fuels. However, this causes no great alarm because a rise in price can be passed along to consumers in the purchase price of the product. In summary, there is little movement toward conserving the limited resources of fuel.

Higher Fuel Costs

Without question, energy prices are on their way to higher levels. The national energy policy of maintaining low-cost energy cannot be sustained. Already oil companies are complaining that the Federal Power Commission has held natural gas at artificially low prices. It should be priced as a premium fuel. The low prices have stimulated gas demand, but curbed incentives for exploration. It also has curbed incentives for nonwasteful use of the fuel. If natural gas prices were allowed to seek a free market level, perhaps the cost would rise to $1 per thousand cubic feet at the gas-well.

The FPC has currently set 26 cents per thousand cubic feet as the highest price that natural gas can be sold to interstate pipelines from major producing states. *Forbes Magazine,* Oct. 1, 1972, pointed out that FPC is approving imports of liquefied natural gas from Algeria. These supplies of Algerian gas land on the East Coast at a price of 91 cents per thousand cubic feet. Even in Algeria, the price is 46 cents.

FPC's pricing authority does not extend into the intrastate market. Recently the price of new intrastate gas along the Gulf Coast leaped from 20 cents per thousand cubic feet to about 45 cents per thousand cubic feet. Some short-term and small-volume sales have cost up to 60 cents per thousand cubic feet at the gas-well.

A few people are counting on a natural gas price close to 75 cents per thousand cubic feet in the mid 1970's. They expect this to rise to around 85 cents or even $1 by 1980 or shortly thereafter.

Future Demands for Fuel

According to an article in *Chemical Week* of Sept. 20, 1972, "The United States met 87.6 percent of its needs for energy in 1970, but this is expected to drop to only 70.3 percent in 1985. Domestic oil is projected to supply only 43.4 percent of the United States demand in 1985. Gas is even more critically projected—it is expected to be short about 17.4 trillion cubic feet in 1985."

The extravagant heating and air-conditioning methods of Americans will change only if fuel price levels or fuel shortages greatly affect us. Then builders, architects, owners, and engineers will call for increased insulation in all buildings rather than skimp on its use.

As energy becomes higher priced, more attention will be given to fuel savings practices in day-to-day operations such as using low-pressure steam in place of high-pressure steam, providing better maintenance to stop steam leaks, and turning off condensers while they are not needed. Specific energy consumption patterns will need to be examined to obtain reductions. DuPont is using a program of this type and has cut power costs from 7 to 15 percent.

Some forward-thinking industrial planners are now designing processes to be less energy-intensive. In general, the concept is to work up an energy flow plan first, and then design a material flowsheet around it. Energy savings of more than 20 percent have been realized using this approach. One chief project manager points to several areas in plant design where energy can be reduced. He looks for more heat exchange within and between process units, with efficiencies of from 80 to 90 percent.

Use of Energy in the United States

A Stanford Research Institute study found that energy is consumed in our country as follows:

Residential and Commercial Buildings	**Industrial Use of Energy**
20% for space heating	14% for heating
4% for water heating	17% for process steam
2½% for air conditioning	8% for electric drives and illumination
2.4% for illumination	
Total of about 29%	Total of 39%

Transportation uses 25%
Chemical and animal feed stocks 6%
Miscellaneous 1%

"Reducing the demand for energy is immediately more effective than increasing the supply," points out Fred S. Dubin, president, Dubin-Mindell-Bloome Associates, consulting engineers and planners of New York City. Dubin is one of the leading engineers in the development and design of energy conservation systems.

About 40 percent of U.S. energy is used in residential, commercial and industrial heating, cooling, domestic hot water, and process steam. Dubin comments that current know-how is available to save more than 20 percent of this amount.

Another review of energy consumption figures suggests that 68 percent of U.S. consumption is in the hands of architects, engineers, and building operators. This includes the 29 percent by residential and commercial buildings plus 39 percent from industrial use. Considerable savings could be made through minimizing energy lost in buildings.

LOSS OF ENERGY IN BUILDINGS

Here are 12 areas outlined by Dubin where energy is lost in buildings:

1. Heat losses and cooling loads due to transmission through walls, ceilings and floors are greater with lightweight panel construction and lack of adequate insulation. They are affected by color, orientation, shape, and angle of incidence to sun's rays.

2. Solar transmission is greatest through glass, but may also be a significant factor on flat roofs. Sixty square feet of glass on the west side of a building will require a ton of refrigeration for cooling and consume 1,000 watts per hour.

3. Outdoor air (formerly called "fresh air") for ventilation, as well as infiltration, results in tremendous energy consumption during summer and winter. The use of better filtration and odor control devices permits reducing the use of outdoor air.

4. Air exhausted from buildings contains heat energy in the winter and cooling energy in the summer. With proper heat recovery equipment, this lost energy could be transferred to incoming outdoor air.

5. Chimneys, fireplaces, exhaust hoods, and combustion devices in kitchens, laboratories, restrooms, and laundry rooms allow much energy to be lost.

6. Individual small buildings, as opposed to high-density residential development, increase energy consumption because the skin-area to building-volume ratio is very great.

7. Single-purpose buildings with short occupancy and lack of diversity are very inefficient in energy use.

8. Lighting levels are often at unrealistically high intensities rather than at levels for the seeing task required. A light bulb is an inefficient energy converter; only 10 to 14 percent of the energy consumed results in useful lighting, while the rest goes into heat.

9. Sloppy calculations, excess safety factors, and failure to account for people and appliance loads result in oversized equipment and inefficient operation.

10. The stack effect in buildings introduces outdoor air when building design is inadequate to prevent it.

11. The lack of energy storage systems results in a loss of energy which otherwise could be stored and used.

12. Improper zoning within buildings and ventilation of unoccupied areas result in wasted energy.

In the following pages, these 12 ways in which energy is lost and wasted in buildings will be examined and applied to industrial buildings. Examples will be used to show how savings could come about in industry.

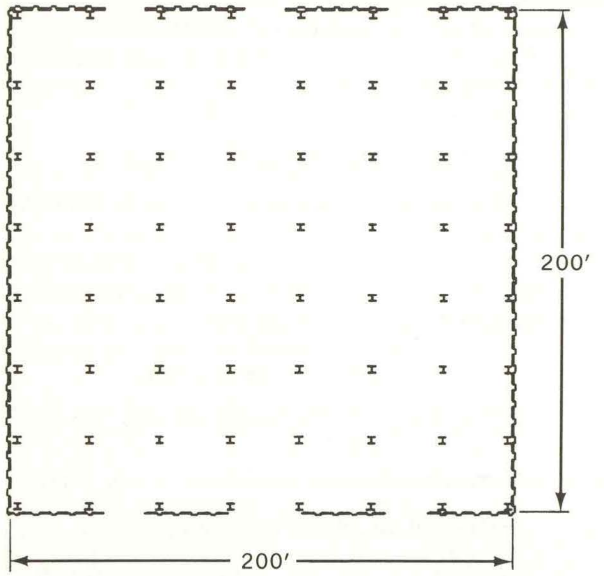


Fig. 1. Plan of 40,000-square-foot industrial plant.

Effects of Insulation in an Industrial Plant

Let us begin by looking into the first item, namely: What effect does the use of insulation have in slowing the heat loss through the ceilings, walls, cracks, windows, and floors?

For example, we will analyze an industrial building constructed of steel walls with a roof supported on a rigid steel frame. This building is 200 by 200 feet in outside dimension as shown in figures 1 and 2. The walls are 20 feet high, and its roof height at the center ridge is 25 feet. This building is placed on a concrete slab which rests directly on 6 inches of coarse gravel, plus a vapor barrier that rests directly on the ground.

The first step will be to compare the costs of placing varying thicknesses of insulation on the inside of the metal walls and roof. We will also examine several types of masonry construction used for walls and compare their relative merits as contrasted with the metal walls.

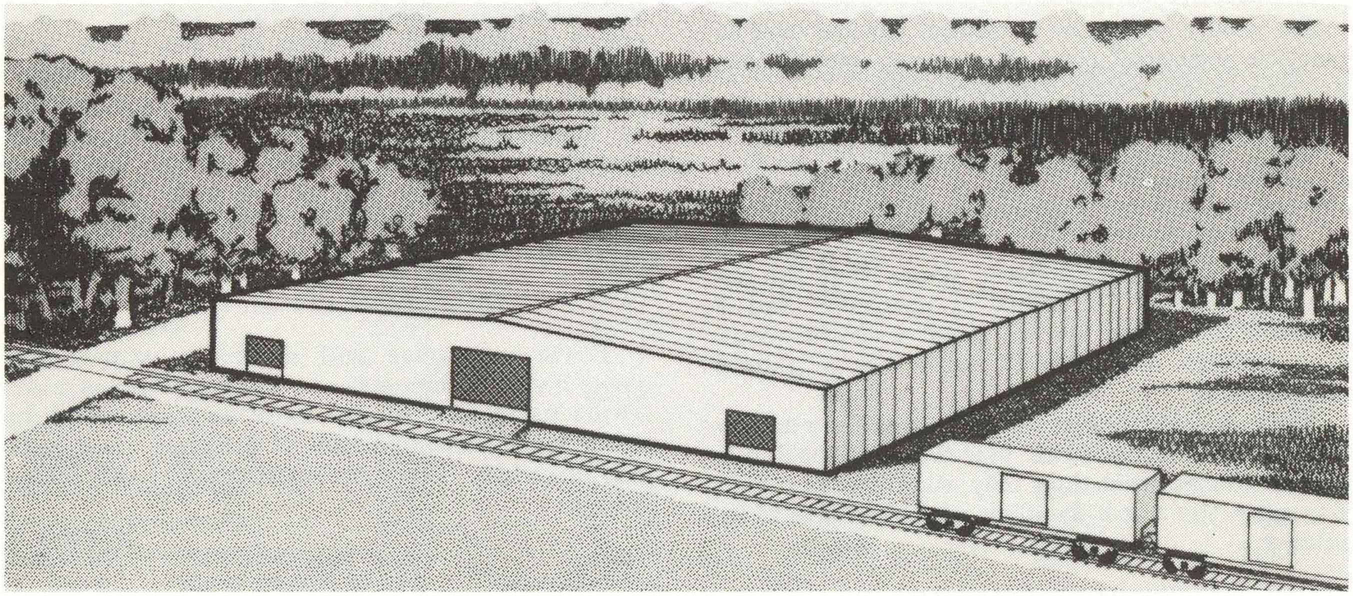


Fig. 2. View of industrial plant.

The building is set in Iowa, where the critical design temperature is 20 degrees below zero. An interior design temperature of 70 degrees Fahrenheit is used. This means a 90-degree indoor-outdoor temperature difference at times during the winter months. The average winter temperature is 32 degrees. For infiltration losses through cracks and loosely fitted construction, one-half air change per hour was assumed.

After computations, the following heat losses were derived for the metal-clad industrial plant: (BTUH is British thermal unit per hour.)

1½" insulation, fiberglass	1,693,600 BTUH
2" insulation, fiberglass	1,542,400 BTUH
2½" insulation, fiberglass	1,391,200 BTUH
3" insulation, fiberglass	1,290,400 BTUH

After computations, the following heat losses were derived for the masonry walled plant:

4" brick + 2" air space + 4" brick	1,664,800 BTUH
4" brick + 2" insulated air space + 4" brick	1,332,800 BTUH
8" concrete block wall (no insulation)	2,026,000 BTUH
10" concrete block wall (no insulation)	1,966,400 BTUH
12" concrete block wall (no insulation)	1,836,800 BTUH

The preceding comparisons show that unless a masonry wall is insulated, the heat loss through it can be extremely high. The extra thickness of the concrete block wall makes little difference in the quantity and rate of heat that transfers through the wall.

Amount of Fuel Used Yearly

The yearly quantities of natural gas fuel used to heat the industrial plant made of metal-clad construction (3-inch ceiling insulation) are:

1½" insulation, fiberglass	4,611,286 cu. ft.
2" insulation, fiberglass	4,199,603 cu. ft.
2½" insulation, fiberglass	3,787,920 cu. ft.
3" insulation, fiberglass	3,513,464 cu. ft.

The yearly quantities of natural gas fuel used to heat the industrial plant of masonry walled construction (3-inch ceiling insulation) are:

4" brick + 2" air space + 4" brick	4,532,785 cu. ft.
4" brick + 2" insulation + 4" brick	3,628,909 cu. ft.
8" concrete block wall	5,516,334 cu. ft.
10" concrete block wall	5,354,057 cu. ft.
12" concrete block wall	5,001,186 cu. ft.

The previous figures have shown that the difference between 1½ inches of insulation and 3 inches of insulation on the metal wall will result in a savings of 1,097,822 cubic feet of natural gas per year.

The preceding figures also show that the masonry wall using 4 inches brick plus 2 inches insulation plus 4 inches brick has only slightly more heat loss than the metal building with 3 inches of insulation.

Yearly Heating Costs

The relative yearly cost of heating fuel using natural gas would be as follows if the natural gas cost is assumed to be 45 cents per thousand cubic feet:

Metal-Clad Industrial Plant

1½" insulation	$2,075
2" insulation	$1,890
2½" insulation	$1,705
3" insulation	$1,581

Masonry Walled Industrial Plant

4" brick + 2" air space + 4" brick	$2,040
4" brick + 2" insulation + 4" brick	$1,633
8" concrete block wall	$2,482
10" concrete block wall	$2,409
12" concrete block wall	$2,250

The preceding figures show that it would cost approximately $494 less to heat the metal-clad building with 3 inches of insulation than to heat the one with 1½ inches of insulation. However, this refers only to heat loss; we have not considered air conditioning.

Cost of Insulating This Plant

The next comparison examines the approximate cost of insulation for this building including costs of both material and labor for the completed job. The cost used is as follows: (Use current local costs when obtaining estimates.)

Insulation Cost per Square Foot

1½" nonrigid, fiberglass blankets	10¢ sq. ft.
2" nonrigid, fiberglass blankets	12¢ sq. ft.
2½" nonrigid, fiberglass blankets	14¢ sq. ft.
3" nonrigid, fiberglass blankets	16¢ sq. ft.

Metal-Clad Industrial Plant: Insulation Cost

1½" insulation	$5,600
2" insulation	$6,720
2½" insulation	$7,840
3" insulation	$8,960

Vapor barriers should be installed along with the insulation. Without the vapor barrier, considerable damage can be done to walls, roofs, and floors. Walls lacking the barrier can become soggy and allow a faster transfer of heat from a building by means of conduction. This is also true of roofs and floors. The barrier should always be placed toward the warmer side of the wall. This means it is best placed behind the finished wall or ceiling material.

Fuels and Their Heat Values

Power companies that distribute natural gas place nearly all industries on interruptible contracts. Firms using natural gas must at times switch to other fuels. A comparison of principal fossil fuels and electricity with their approximate heat values follows:

Fuel	Heat Value	Efficiency in Percent
Anthracite coal	14,600 BTU per pound	65-75
No. 2 fuel oil	141,000 BTU per gallon	70-80
Natural gas	1,052 BTU per cu. ft.	70-80
Electricity	1 watt = 3.41 BTUH	95-100

The preceding efficiencies represent coal as burned in a coal furnace; No. 2 fuel oil combusted in an oil burner; natural gas used in a gas burner; and electrical energy used in an electric heater with wire coils.

With the above information, we can compare the equivalent quantity of each fuel necessary to provide heat for a building of 200,000 BTUH heat loss. The solution would be as follows:

$$\text{Gas} \quad \frac{200{,}000}{1052 \times 0.75} = 253.4 \text{ cu. ft. per hour}$$

$$\text{Oil} \quad \frac{200{,}000}{141{,}000 \times 0.75} = 1.89 \text{ gallons per hour}$$

$$\text{Coal} \quad \frac{200{,}000}{14{,}600 \times 0.70} = 19.5 \text{ pounds per hour}$$

$$\text{Electricity} \quad \frac{200{,}000}{3.41 \times 1.00} = 58{,}651 \text{ watts } (58.65 \text{ kilowatts})$$

For just one hour's time, the equivalent costs at the following rates would be as follows:

Gas at 45¢ per 1,000 cubic feet = 11.4¢
Oil at 20¢ per gallon = 37.8¢
Coal at $28.50 per ton = 27.3¢
Electricity at 1.5¢ per kilowatt hour = 88.0¢

Heating and Air Conditioning Comparisons

Table 1 gives yearly estimated cost comparisons for both heating and air conditioning the same 40,000 sq. ft. industrial plant. Figures 3, 4, 5, 6, 7, 8, 9, and 10 compare the relative merits of each of the wall systems discussed previously. Note that the figures list an index termed the U coefficient of heat transmission. This is defined as the number of British thermal units per hour (BTUH) of heat that passes through one square foot of wall, roof, or floor when the temperature difference between both sides is one degree Fahrenheit.

Heat Gain

The heat gain has been calculated for this building on the basis of 75 degrees F. indoor and 95 degrees outdoor temperature. Following are the totals gained from computations of heat gain for this industrial plant using the various wall combinations previously discussed.

Totals of Heat Gain From Different Building Systems

Metal-clad buildings:

1½" insulation	361,200 BTUH
2" insulation	323,200 BTUH
2½" insulation	289,600 BTUH
3" insulation	267,200 BTUH

Masonry buildings:

4" brick + 2" air space + 4" brick	273,600 BTUH
4" brick + 2" insulation + 4" brick	200,000 BTUH
8" concrete block	331,200 BTUH
10" concrete block	324,800 BTUH
12" concrete block	318,400 BTUH

Humidity Control

To have a feeling of body comfort during warm **summer weather,** we adjust the thermostat on the air conditioning system to about 75 degrees, providing the relative humidity is being reduced by the system to 40-50 percent.

However, to experience body comfort in **winter weather,** we must add more moisture to the indoor air through means of a humidifier. You may have noticed that when your thermostat was set at 75 degrees with a low humidity content, you still felt cold. The suggested thermostat setting is about 70 degrees in winter plus providing additional moisture to about the maximum relative humidity levels listed on page 9. Thus energy will be conserved,

Table 1. Yearly Estimated Costs for Heating and Cooling a 40,000-Square-Foot Industrial Plant in Iowa.

Building type	Initial cost Heating	 Air Conditioning	Yearly heating cost	Yearly air conditioning cost	Total yearly cost
Metal: 1 1/2" Insulation	$3,500	$30,000	$2,075	$2,385	$4,460
Metal: 2" Insulation	$3,200	$27,000	$1,890	$2,115	$4,005
Metal: 2 1/2" Insulation	$3,000	$24,000	$1,705	$1,913	$3,618
Metal: 3" Insulation	$2,700	$22,000	$1,581	$1,785	$3,366
Masonry 4" Brick + 2" Air Space + 4" Brick	$2,800	$23,000	$2,040	$1,800	$3,840
Masonry: 4" Brick + 2" Insulation + 4" Brick	$2,000	$17,000	$1,633	$1,320	$2,953
Masonry: 8" Concrete Block	$3,300	$28,000	$2,482	$2,190	$4,672
Masonry: 10" Concrete Block	$3,250	$27,000	$2,409	$2,145	$4,554
Masonry: 12" Concrete Block	$3,150	$26,000	$2,250	$2,100	$4,350

Note: Initial cost of heating based on gas-fired space heaters at $500 per 50,000 BTUH rating.
Initial cost of air conditioning based on $1000.00 per ton; rooftop type units.
Cost of operating air conditioning units based on 1.5¢ per kilowatt hour. 3.41 watts = 1 BTU

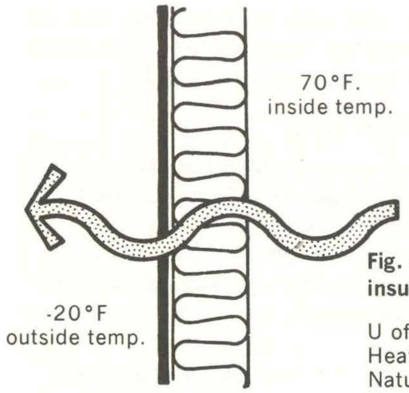


Fig. 3. Metal building with 1½ inches insulation.

U of heat transfer—0.17
Heat loss—1,693,600 BTUH
Natural gas used yearly—4,611,286 cu. ft.
Yearly cost of natural gas—$2,075
Heat gain—361,200 BTUH
Required cooling—30 tons
Yearly cost of heating and cooling—$4,460

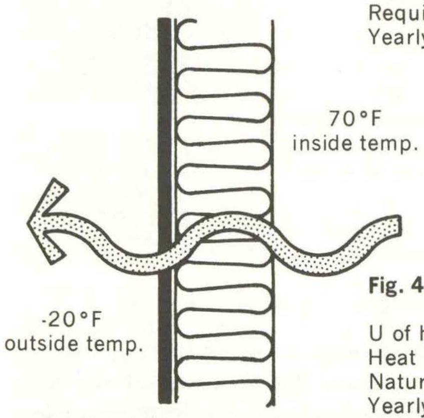


Fig. 4. Metal building with 2 inches insulation.

U of heat transfer—0.14
Heat loss—1,542,400 BTUH
Natural gas used yearly—4,199,603 cu. ft.
Yearly cost of natural gas—$1,890
Heat gain—323,200 BTUH
Required cooling—27 tons
Yearly cost of heating and cooling—$4,005

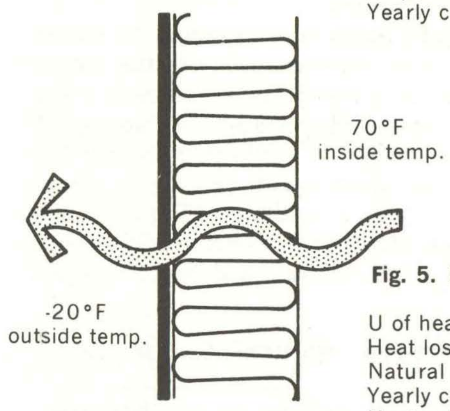


Fig. 5. Metal building with 2½ inches insulation.

U of heat transfer—0.11
Heat loss—1,391,200 BTUH
Natural gas used yearly—3,787,920 cu. ft.
Yearly cost of natural gas—$1,705
Heat gain—289,600 BTUH
Required cooling—24 tons
Yearly cost of heating and cooling—$3,618

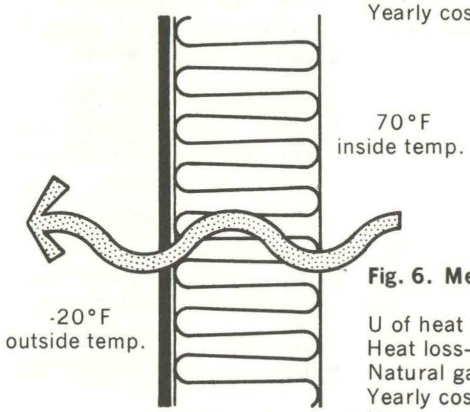


Fig. 6. Metal building with 3 inches insulation.

U of heat transfer—0.09
Heat loss—1,290,400 BTUH
Natural gas used yearly—3,513,464 cu. ft.
Yearly cost of natural gas—$1,581
Heat gain—267,200 BTUH
Required cooling—22 tons
Yearly cost of heating and cooling—$3,366

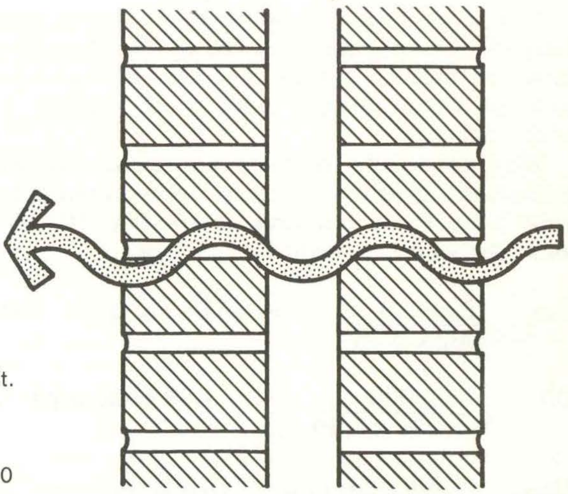


Fig. 7. Masonry building with 2 wythes of 4-inch brick plus 2-inch air space.

U of heat transfer—0.35
Heat loss—1,664,800
Natural gas used yearly—4,532,785 cu. ft.
Yearly cost of natural gas—$2,040
Heat gain—273,600 BTUH
Required cooling—23 tons
Yearly cost of heating and cooling—$3,840

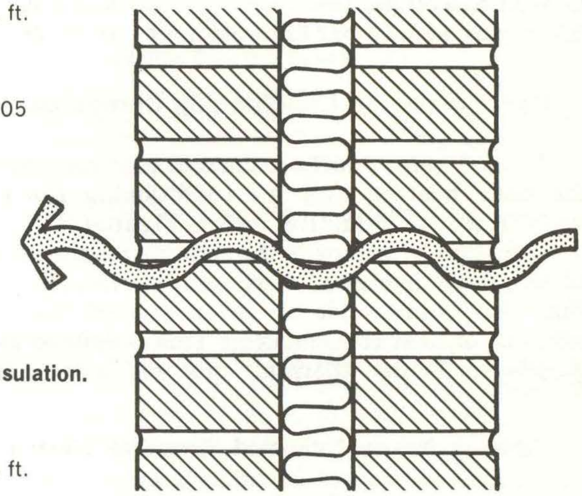


Fig. 8. Masonry wall with 2 wythes of 4-inch brick plus 2-inch rigid or loose insulation.

U of heat transfer—0.12
Heat loss—1,332,800 BTUH
Natural gas used yearly—3,628,909 cu. ft.
Yearly cost of natural gas—$1,633
Heat gain—200,000 BTUH
Required cooling—17 tons
Yearly cost of heating and cooling—$2,953

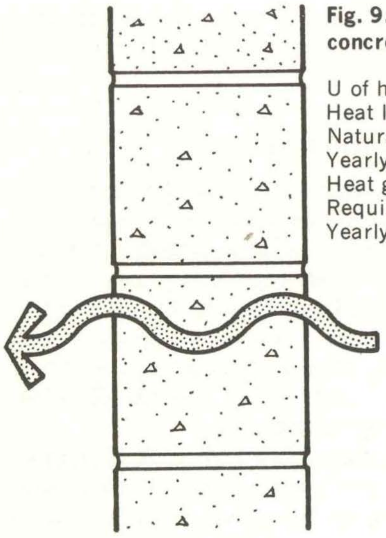


Fig. 9. Masonry building with 8-inch concrete block (no insulation).

U of heat transfer—0.53
Heat loss—2,026,000 BTUH
Natural gas used yearly—5,516,334 cu. ft.
Yearly cost of natural gas—$2,482
Heat gain—331,200 BTUH
Required cooling—28 tons
Yearly cost of heating and cooling—$4,672

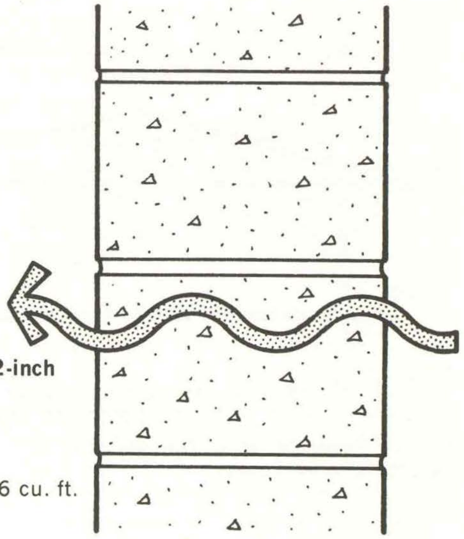


Fig. 10. Masonry building with 12-inch concrete block (no insulation).

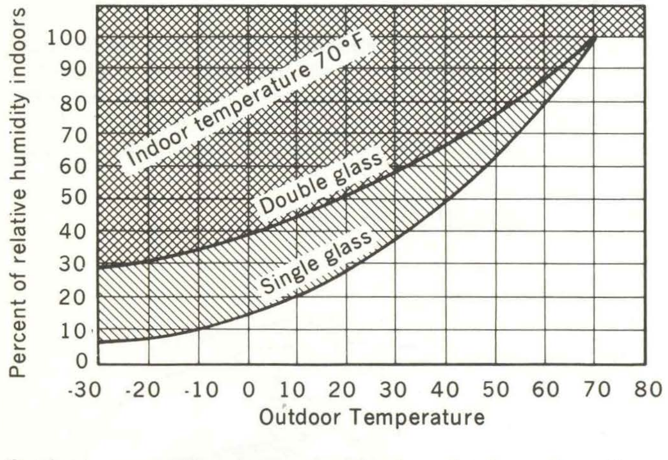
U of heat loss—0.49
Heat loss—1,836,800 BTUH
Natural gas used yearly—5,001,186 cu. ft.
Yearly cost of natural gas—$2,250
Heat gain—318,400 BTUH
Required cooling—26 tons
Yearly cost of heating and cooling—$4,350

money will be saved and employees will feel more comfortable.

Outdoor air temperature degrees Fahrenheit	Maximum indoor relative humidity in percent
Below -20 degrees	15
-10 to -20 degrees	20
-10 to 0 degrees	25
0 to +10 degrees	35
+10 to all above temperatures	40

Insulated Window Glass

Condensation on windows relates to the relative humidity indoors, the outdoor temperature, and the quality of the window glass. Figure 11 shows this relationship.



Outdoor temperature	When to use double glass due to condensation forming on single glass:
-20°F	Use double glass above 8% relative humidity
0	Use double glass above 15% relative humidity
20	Use double glass above 30% relative humidity
40	Use double glass above 51% relative humidity

Fig. 11. Relationship between outdoor temperature, indoor relative humidity, and condensation forming on glass.

When additional moisture is added, use of insulated glass is recommended for windows because of condensation problems. The glass has an additional benefit of reducing heat loss.

Two thicknesses of insulated glass are available. See Figure 12. Sealed double glass allows about half the BTUH heat loss of a single thickness of glass. Sealed triple glass allows about one-third the BTUH heat loss of a single thickness of glass.

Effects of Solar Transmission on Buildings

Energy loss and gain from solar transmission was the second major item listed by Dubin (see page 4). It stated that solar transmission was greatest through glass, but that it was a significant factor on flat roofs. Figure 13 shows how it operates. First, the solar rays begin heating the roof. After a time, the roof becomes completely heated and is like a large hot plate. The heat from the heated roof radiates off the underside of the roof into the attic. If there is not sufficient provision to exhaust this heat in the attic, the attic temperature can increase up to 150 degrees F.

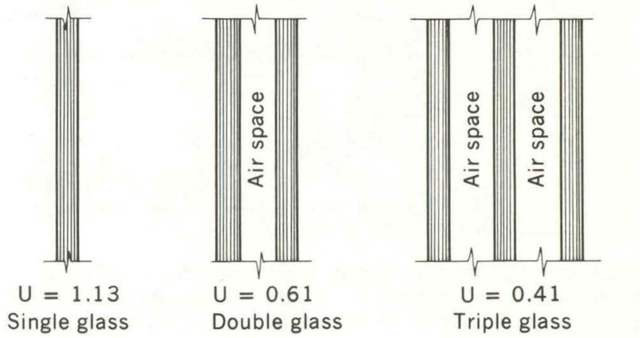
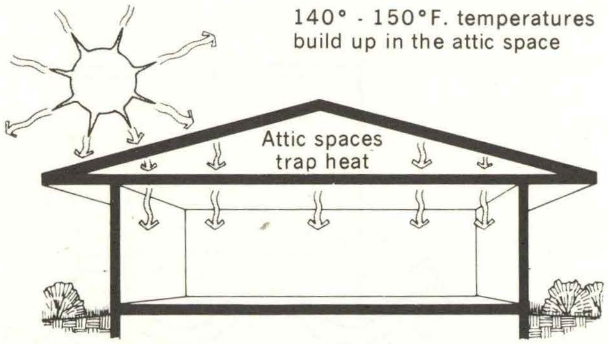
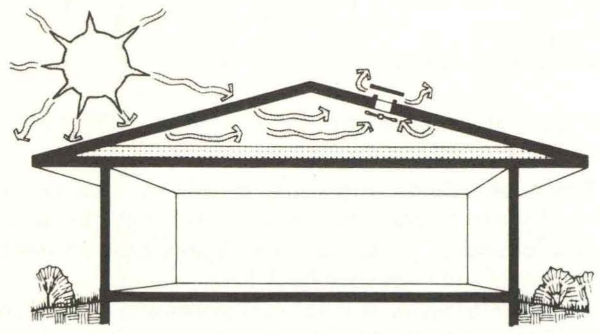


Fig. 12. Relative heat losses through insulated and non-insulated glass.



Without insulation, ceiling is warmed by attic heat until it is a hot plate giving off much radiant heat

Fig. 13. Effects of solar transmission with inadequate attic insulation and ventilation.

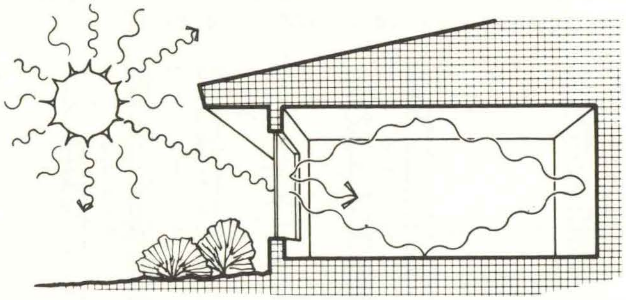


Well-insulated ceiling and a fan to drive off hot attic air can save up to 25% on air conditioning requirements

Fig. 14. Effective controls for solar transmission.

Figure 14 illustrates how a well-insulated ceiling, plus the use of an exhaust fan, can keep the attic space from attaining a high temperature. This in turn prevents the ceiling from becoming too warm. Consequently, the air conditioning load of the rooms below the attic is reduced up to 25 percent of an uninsulated and stagnant attic.

In an industrial plant where there might not be an attic space, it is extremely important that considerable insulation be used on the ceiling area. Then it will not become a hot plate providing radiant heat. Insulation is very much worth its cost in most cases.



Solar infrared rays go through glass on short waves. Rays are reradiated on longer wave length not passing out through glass. Use of double thickness glass is recommended in situations like this.

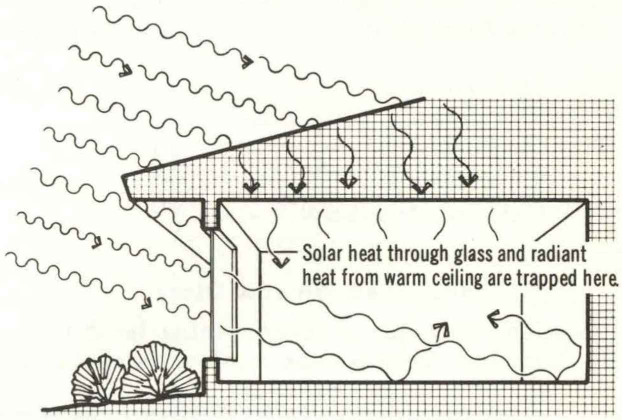
Fig. 15. Solar transmission through glass.

Buildings Are Heat Traps

Any building is a heat trap as illustrated in figures 15 and 16. It operates like an automobile in a parking lot with its windows closed on a hot summer day. Solar infrared rays are short waves until they hit the glass. Then they turn into longer waves and reflect off the various surfaces of the rooms inside. In effect, they are trapped and tend to build up the heat level within the building as more and more solar rays penetrate.

To design against these solar rays, it is necessary to understand a few basic facts relative to the sun's movement. Here in Iowa, we are just north of 40 degrees north latitude, with the 42nd parallel passing through Ames.

Figure 17 shows the position of the sun at noon on December 21. Note that the angle it makes with the earth is quite low, 26½ degrees. Note also Figure 18, which shows the position of the sun at



A building is literally a "heat trap." Heat builds up through roofing, doors, walls, windows, ceiling, lights, and appliances. Keeping heat out of a building is the most important step for conserving energy in summertime. Keeping it in during winter is equally important. Insulation does both of these jobs.

Fig. 16. Trapping solar heat in buildings.

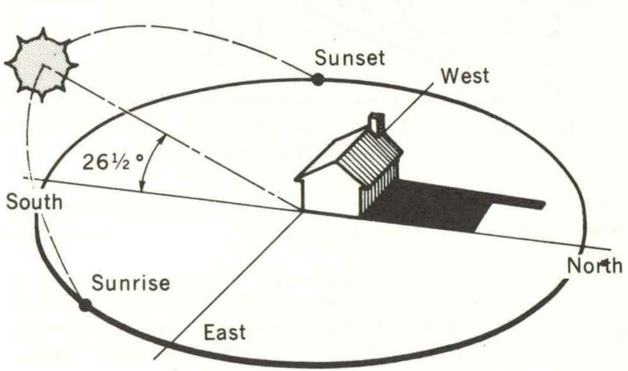


Fig 17. Position of the sun at noon on December 21 at 40 degrees latitude.

noontime on June 21. The angle of the sun in summer is approximately 73½ degrees with horizontal. Quite simply, overhangs keep out the unwanted solar rays in the summer and allow them to enter in the winter when needed.

Also important is the angle of sun's rays during early morning and late afternoon. Figure 18 also shows that the sun rises in the northeast in the summer. The sun is at a low angle to the earth at sunrise and sunset. Further, the sun also sets late in the evening during summer hours. Consequently windows on the east and west sides of a building are subject to these low-angle rays of the sun. However, overhangs cannot adequately intercept the low rays. One must use trees, fences, or awnings to intercept these rays.

It has been found that on June 21 at 40 degrees north latitude, on an easterly exposed wall at 7 a.m., approximately 215 BTUH of heat can be gained through one square foot of glass unprotected from the solar rays. The same is true for one square foot of glass on a westerly exposure.

Intercepting Solar Rays

Devices for intercepting solar rays that are placed outside the window, such as awnings, baffles, high fences, trees, etc., will be approximately 80 percent effective in reducing the solar heat buildup through the window. However, if interceptors such as curtains or blinds are placed inside the building, they are only 55 percent effective, even if they are light colored. If the shades or blinds inside the glass are dark in color, they may be only 20 percent effective.

Roof overhangs or intercepting louvers are generally more effective on the south side of a building. Table 2 provides the factors for calculating the proper size of an overhang so it will be effective in covering a window with a given amount of shade.

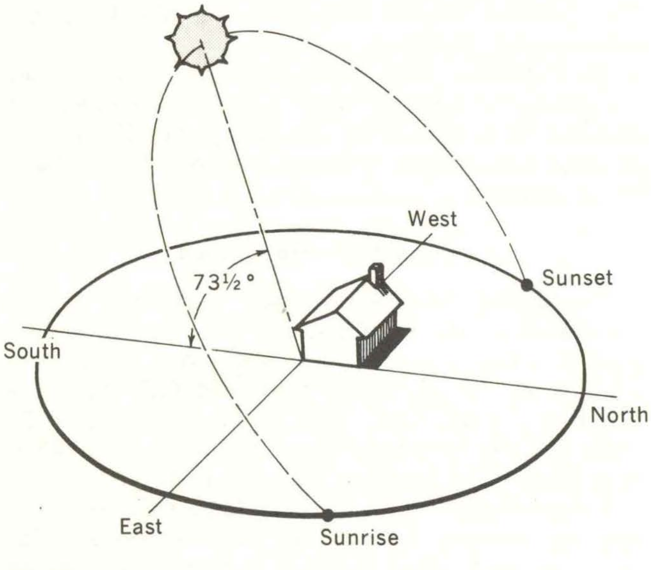


Fig. 18. Position of the sun at noon on June 21 at 40 degrees latitude.

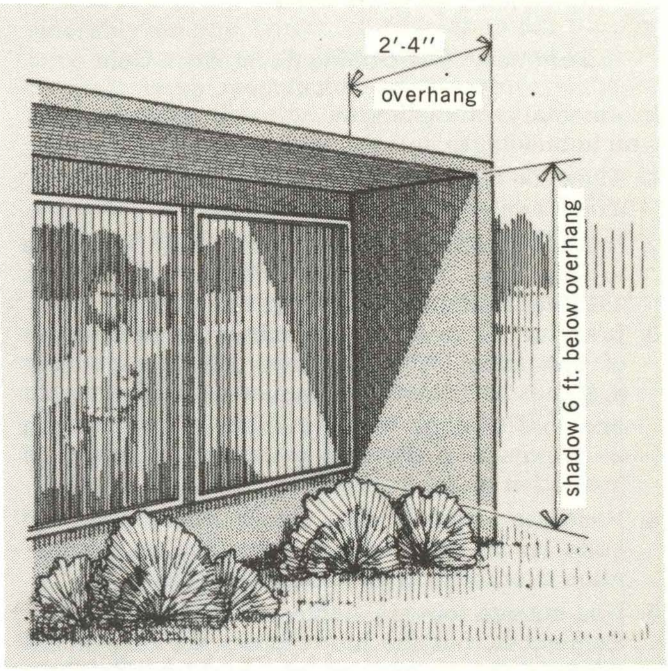
It is reprinted by permission of the National Warm Air Heating and Air Conditioning Association from Load Calculation for Residential Winter and Summer Air Conditioning, Manual J.

In using table 2, simply find the distance that you prefer the shadow line to fall below the edge of the overhang. The following example will demonstrate how it is computed: the window is on the south side of a building. The shadow should extend to the bottom of the sill, which is 6 feet below the overhang. The shade line factor for 40 degrees latitude on the south side of the building is 2.6. By dividing 6 feet by 2.6, the answer of 2.3 feet is the proper length of the overhang. Thus 2 feet, 4 inches will produce a shadow that will be approximately 6 feet below the overhang. See Figure 19.

Notice the shade line factors on the east and west sides of buildings are 0.8. These factors are quite small, and would have to be multiplied by large numbers to give 6-foot shadows as figured in the previous example. Consequently, it is not expedient to intercept solar rays on east and west exposures by overhangs.

Table 2. Shade Line Factors.

Direction window faces	Latitude in degrees 25	30	34	40	45	50	55
East	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Southeast	1.9	1.6	1.4	1.3	1.1	1.0	0.9
South	10.1	5.4	3.6	2.6	2.0	1.7	1.4
Southwest	1.9	1.6	1.4	1.3	1.1	1.0	0.8
West	0.8	0.8	0.8	0.8	0.8	0.8	0.8



In Iowa near 40° north latitude, with south window exposure; shade line factor from table 2 shows 2.6 as proper factor under these conditions. 2.6 x ? = 6-foot shadow cast by overhang. Answer is 2.3-foot overhang = 6 feet.

Fig. 19. Calculating adequate shade lines.

Shade Trees Protect Against Heat Gain

Among the most effective protectors against direct solar rays and heat gain buildup in a building are shade trees. They are especially helpful for shading walls facing to the east or west.

Most important, one should use decidous trees. This type of tree loses its leaves by the winter months. This allows solar rays to warm the portions of the building they shield in the summer months. The location, height and size of the trees are important if the shaded pattern is to cover the correct areas of the walls and roof. The sun is higher in the sky during the summer and will consequently cast shorter shadows than in winter, when it is at a lower angle in the sky. Following is a list of some suitable trees and their approximate heights:

Type of tree	Shape	Height	Growth
Red Oak	Broad	60-75	Fast
White Oak	Broad	60-75	Fast
Sugar Maple	Broad	50-70	Fast
Red Maple	Broad	50-60	Fast
Crabs	Dense	10-35	Slow
Hawthorn	Spread	15-35	Slow
Flowering Cherries	Various	5-45	Fast
Apple, Pear, Plum	Various	20-35	Fast

Free-standing vertical sunshades such as fences provide fine shade against low sun angles on east and west walls. If they have open louvers, they will allow breezes to pass through and keep the walls cooler in summer. Sunshades also work well in combination with taller trees.

Summary: Controlling Solar Heat Gain

In summary, the following acts will minimize heat gain in buildings.

1. Allow no sun to strike glass during summer months on any wall of the building.
2. Install double or triple glass where exposure to solar rays is inevitable. You may also wish to use heat-absorbing or gray glass.
3. Insulate all roofs with a minimum of 6 inches of insulation. With our Iowa climate, at least 8 inches is preferred because of the heat gain and loss at that level. Insulate all walls with a minimum of 3½ and preferably 6 inches of insulation where possible.
4. Ventilate attics or any places where heat can build up to high temperatures and cause radiation over large areas of inside surfaces.
5. Use outside louvers, baffles, awnings, or shades. Remember, outside interceptors are 80 percent effective against solar waves, where interior blinds of a light color are about 55 percent effective. Also, dark colored interior shades or blinds are only about 20 percent effective.
6. Shade every possible surface that could contribute to heat gain. Do this with trees, shrubs, and rather high fences, or combinations of these things.
7. Orient buildings on the site to take advantage of the sun's path of travel, existing trees, topographical features that could help shield the building, or seasonal breezes.
8. Install light-colored roofs.

Controlling the Introduction of Outdoor Air

Outdoor air is generally introduced into the heating system of a building at the rate of 20 to 25 percent of the air volume used for heating during each cycle. This air plus the air that infiltrates into a building can use tremendous amounts of energy.

During the cooling operation in the summertime, air is exhausted from a building at 75 degrees, and the same volume of air is introduced, often at 95 degrees. A tremendous amount of energy is consumed to cool and dehumidify the outdoor air to 75 degrees and 40 percent relative humidity. Similarly in the winter, the air leaving the building is 70 degrees, and air to replace it is introduced at perhaps 20 degrees below zero.

In addition, buildings that house industrial processes often exhaust large quantities of air. The resulting negative pressures cause higher infiltration and ventilation rates, thereby demanding more energy use to keep the building at a desirable temperature for working conditions.

To reduce heat loss or gain during periods of cold or hot outside temperatures, the following should help: caulking windows, weatherstripping doors, and installing revolving doors and automatic door closers.

However, whenever outside conditions are favorable, use cool outside air in place of powered cooling systems. Many cooling systems continue to operate when comfortable outdoor conditions exist. The systems usually can make use of outdoor air if they are so modified.

In buildings that have separate heating and cooling systems, install interlock controls to eliminate simultaneous operation. In many buildings, the heating and cooling systems may overlap without being detected.

Air for Odor Reduction

Ventilation rates are usually regulated by the occupancy of the building. For example, a factory worker doing moderately heavy work could give off 375 BTUH of (pure) heat and 625 BTUH of moisture (latent heat). This could require about 25 cubic feet per minute of odor-free air supply needed to prevent odors building up in the factory.

Unnecessary ventilation should be reduced by installing suitable interior air filtering devices for odor and particulate removal to lower the need for outside air. Variable-volume air conditioning and variable-pumping systems can also assist in conserving energy. Consult a mechanical engineer on these items.

Heat Loss From Chimneys

Other means where energy is lost in buildings are through direct draft flow through chimneys, laboratory hoods, and other exhaust hoods that expel furnace heat and gases. If great amounts of energy are expelled, this should be collected and recycled to such uses as heating water and preheating incoming air. Such heat could even be used to melt snow on walkways and driveways in winter.

Individual-Clustered Building Arrangements

If an industrial complex is made up of many individual buildings, they collectively expose more square feet of wall surface to the outside air. Consequently more heat is lost through the wall surfaces in winter, and more heat is gained during the warmer seasons.

If feasible, these individual buildings should be combined so that fewer square feet of exterior wall is the final result.

Another cause of lost energy occurs when a single-purpose building houses a function requiring short occupancy. This means that the building is wasting energy if the interior is heated while not in use. Even if the heat is shut off while not in use, the building must be heated from a cold state or cooled from a warm state to begin manufacturing operations.

Selection of Electric Lamps

A sizable amount of energy can be conserved by analyzing the illumination of areas. Lighting not only uses energy, but in some commercial buildings it represents about half the load on the air conditioning system.

First here are definitions of a few terms important to a basic understanding of illumination. One candlepower (cd) is the equivalent of a lighted wax candle as the source in the center of a hollow sphere of one foot radius. The luminous intensity at any point on the inner surface of the sphere will be one candlepower. The *lumen* is the unit measurement of quantity of light. The *footcandle* is equal to the number of lumens per square foot. One lumen falling on an area of 1 square foot produces an illumination of one footcandle.

Some tasks may require up to 200 footcandles of illumination, but hallways, lobbies, and passageways may only require 20 to 30 footcandles. Light-colored finishes on walls, floors, and ceilings will increase the efficiency of illumination, resulting in more light with less power.

Relatively high footcandle requirements may be needed in large rooms for extra-fine machining work, inspection work, and fine assembly. However, other tasks in the same room may require considerably lower levels of illumination. Consider each different function. Install additional switches so that unneeded lights can be turned off when work operations change.

Footcandle tables are available from lamp manufacturers recommending the number of footcandles for different types of tasks and functions. Install the most efficient light fixture to meet the work area needs.

A 100-watt incandescent light bulb operating at 120 volts will produce an average of 1,750 lumens. A 200-watt bulb at 120 volts will produce about 4,000 lumens. Watts tell only the amount of power necessary to make the bulb work.

Larger wattage bulbs are usually more efficient, producing more lumens per watt than the smaller bulbs. This means more light produced with less energy used. The incandescent bulb is very inefficient in that about 95 percent of its energy goes to heat, leaving about 5 percent for light.

The fluorescent lamp offers more light for less energy than the incandescent lamp. For example, a 40-watt fluorescent lamp produces more light than a 100-watt incandescent lamp. It does so while using about one-half the energy. The number of lumens produced from a 40-watt fluorescent lamp, T-12, 48-inch-long lamp will be about 3,250 lumens. This means that such a lamp produces about twice as many lumens as does a 100-watt incandescent bulb.

Fluorescent Lamp Life Compared

The life of a fluorescent lamp will depend considerably on the length of time it is left burning once it is switched on. The average lamp life given in most lamp manufacturers' literature is based on a burning time of 3 hours per start. The term *average life* means that one half of the lamps used are burned out and the other half remain in operation at the end of a certain period of time. Figure 20 shows the surviving percentages of lamps subject to varying burning times per start.

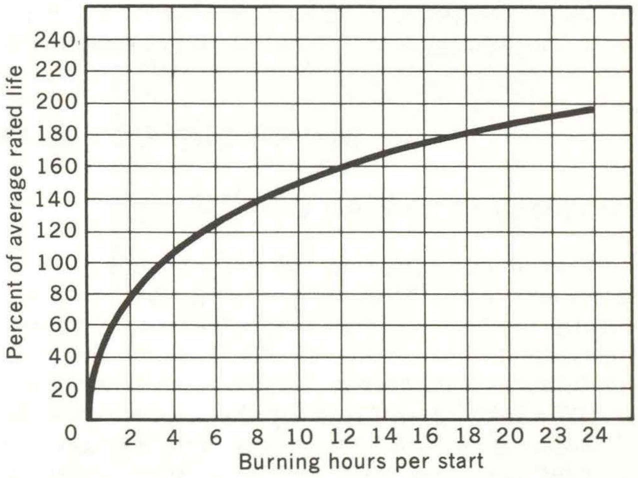


Fig. 20. Surviving percentages of fluorescent lamps by burning hours per start.

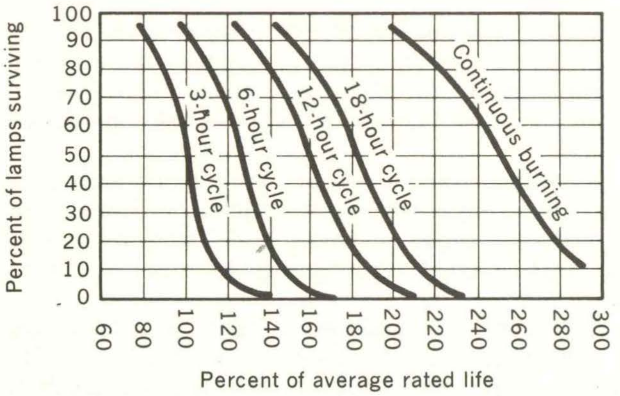


Fig. 21. Comparison of burning cycles of fluorescent lamps.

When planning the installation of fluorescent fixtures, a decision must be made how often they will be switched on and off in any given 24 hours. Thus it is important to calculate the optimum conservation of energy without shortening the life expectancy of the fluorescent lamps.

Our example is an industrial building where lights are switched on at 6 a.m. and turned off at 6 p.m., a 12-hour burning cycle. This building is lighted by 300 fluorescent fixtures that each contain two 40-watt lamps, 48 inches long.

Checking Figure 20, we find a 12-hour burning cycle would allow the lamps to burn at 160 percent of their rated life. This means about 50 percent of those lamps would still be in operation after that length of time.

The average rated life of these fluorescent lamps is about 12,000 hours. Thus we could expect at least 50 percent of the lamps to still be burning after 19,200 hours. Looking to Figure 21, we see that on a 12-hour burning cycle, all lamps would have to be replaced at about 210 percent of their rated life.

Similarly, we can note in Figure 21 that continuous burning will tend to double the average rated life of fluorescent lamps. Thus an average life with continuous burning conditions would be 12,000 x 2 = 24,000 hours. This is equivalent to 5½ years before total replacement would be necessary. To determine if it would be more economical to burn the lamps continuously or shorten the lamp life by using the 12-hour cycle, proceed as follows:

12 burning hours per day during working hours
12 extra burning hours per day for continuous operation. 12 x 365 days = 4,380 extra hours burning per year.
300 fluorescent lamps each with 2 lamps = 600 lamps
600 x 4,380 hours = 2,628,000 lamp hours
2,628,000 x 40 watts = 105,120,000 watts

This is 105,120 kilowatt hours of energy used per year. At 2 cents per kilowatt hour, the cost of extra energy is 105,120 x 2 cents = $2,102.

The cost of extra replacement of lamps due to a shortened life caused by the 12-hour burning cycle in lieu of continuous burning is as follows:

12-hour burning cycle = 160 percent of average life
Average life = 12,000; thus 12,000 x 160 percent = 19,200 hours life

This means total replacement every 4.4 years in contrast to 5½-year replacement on a continuous burning basis. If changed every 4.4 years, the new replacement lamps would burn 1.1 years before reaching 5.5 years age.

Approximate cost and labor for replacing 600 lamps at $1.98 per lamp = $1,188; 1.1 years is 25 percent of their life span under 12-hour burning conditions. Thus, 25 percent x $1,188 = $297 as the extra cost of replacement lamps on a 12-hour burning cycle.

If we compare the additional cost of continuous operation, which was $2,102, with the extra cost of a shorter lamp life of $297, we find it is not only $1,805 less costly to use the 12-hour burning cycle but that it saves about 90,257 kilowatt hours of electricity.

This method can be used to approach a similar problem in your industrial plant. Shortening the burning hours will not always provide a savings, but it could easily save you money and energy with just a little preliminary thought.

The most efficient lamp source available today is the high-pressure sodium-vapor lamp. It converts approximately one-fourth of the input energy into visible light for an efficiency of 25 percent. Most fluorescent lamps cannot match this efficiency.

MORE ENERGY CONSERVATION METHODS

Efficiency of Unit Air Conditioners

When considering the purchase of unit air conditioners, a bit of simple arithmetic may save several dollars as well as considerable energy consumption. An index of efficiency for such air conditioners can readily be found by dividing the BTUH rating of the unit by the number of watts at which it is rated to operate. The wattage can in most instances be found on a metal plate attached to the unit. Another way to figure the wattage rating is to multiply the voltage recommended for the unit's operation by the rated amperes of the unit. This gives watts.

In a recent study by the City of New York's Interdepartmental Committee of Public Utilities, they found the efficiency ratings of 13 readily available brands of unit air conditioners to range from a low of 5.1 to a high of 12.

Of course, the higher the efficiency number, the more efficient the unit is in terms of the number of BTU's obtained for each watt of electrical energy.

This information comes from an article by Dr. Charles W. Lawrence entitled "New York Grapples with the Energy Crisis" in a periodical entitled *Building Systems Design.*

Costs Comparing Three Different Units

Let us take three different unit air conditioners having an original cost as follows:

Unit X—Purchase price of $292.
Unit Y—Purchase price of $256.
Unit Z—Purchase price of $271.

For our example, each air conditioner will run an average of 1,500 hours each year for a lifetime of 7 years. The cost of electrical energy is set at 2 cents per kilowatt hour.

Unit X is rated at 16,100 BTUH and 1,840 watts
Unit Y is rated at 15,200 BTUH and 2,850 watts
Unit Z is rated at 15,500 BTUH and 3,000 watts

Comparative results of the three units are based on original cost and electrical energy cost for a 7-year lifetime. See figures 22, 23 and 24 for cost comparisons.

On the basis of the preceding figures, we find the unit costing least at the start was second lowest in cost over the 7-year period. However, the unit that cost the most initially had the lowest total cost. The unit costing second in initial purchase price was by far the most expensive to operate. It used considerably more electrical energy, which was chiefly responsible for its over-all cost.

These comparisons are only intended to give you an approach for your particular problem when buying or making a decision to buy unit air conditioning for an area of your plant.

Zoning and Weekend Operations

On weekends when equipment is idle, consider shutting down heat treating or cooling equipment totally or else reducing it to holding temperatures. Timing devices can provide the means to bring the equipment to processing temperature before the first shift arrives.

Reduce the use of cooling and heating systems by turning them off in unoccupied areas such as halls and storerooms and during times of non-occupancy. Off-hours work might be concentrated in small areas of the plant so that heating and cooling system in the remaining areas can be reduced or turned off. Actual cooling and heating equipment can be turned off or down shortly before the close of the work day.

Regular Maintenance of Equipment

Regular checkups should be maintained on valves, fittings, steam lines, filters and fuel lines. Heat transfer interfaces must be kept clean to prevent barriers to heat transfer.

Check furnace linings as well as furnace shells for deterioration. Good maintenance will eliminate excessive heat losses and give you more return for your fuel dollar as well as less fuel consumption.

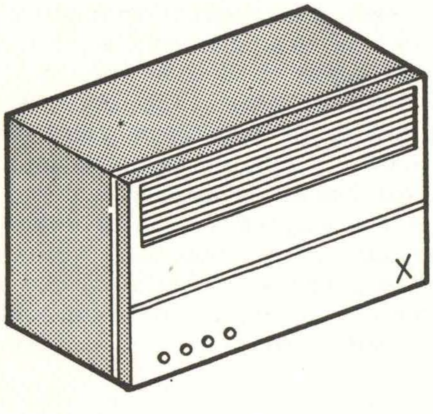


Fig. 22. Unit X:
Retail cost = $292
Energy cost for 7 years = $386
Total cost = $678

Efficiency rating: $\frac{16{,}100 \text{ BTUH}}{1{,}840 \text{ watts}} = 8.7$

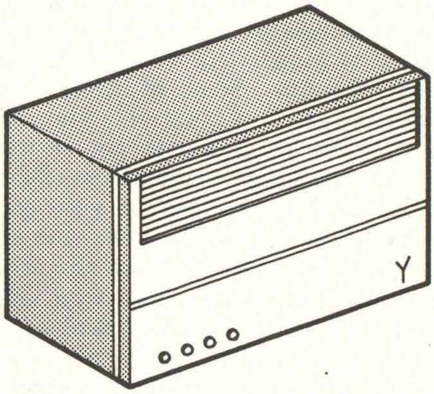


Fig. 23. Unit Y:
Retail cost = $256
Energy cost for 7 years = $598
Total cost = $854

Efficiency rating: $\frac{15{,}200 \text{ BTUH}}{2{,}850 \text{ watts}} = 5.3$

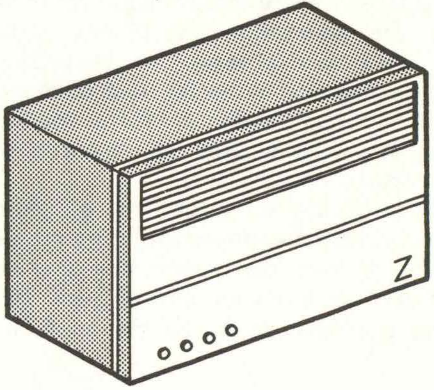


Fig. 24. Unit Z:
Retail cost = $271
Energy cost for 7 years = $630
Total cost = $901

Efficiency rating: $\frac{15{,}500 \text{ BTUH}}{3{,}000 \text{ watts}} = 5.1$

Fuel Burner Care

Check burners for optimum combustion and heat transfer efficiency. Keep all flames within the heating areas. All burners should be checked so that proper air and gas ratios are used. Contact your utility company about persons who are qualified to properly clean gas burners. Consider the installation of control devices that insure proper air to gas ratios at all times.

It is often stated that burners using gas or oil are 70 to 80 percent efficient in burning their fuel. This may be true while these burners are on the testing rack in the plant. Usually the efficiency depends on how often the burners are checked. Often the efficiency is somewhere in the 50 percent range; however, 30 percent efficiency has been found in some instances.

Therefore, make certain that burners are kept clean. Trained personnel should be used who can properly clean the carbon that collects around the jet holes in the burner. If this carbon is allowed to fall into the jets, nothing has been accomplished.

Proper operation of burner controls is also important in getting top efficiency from your fuel. The burner controls generally regulate the amount of air flow through the combustion chamber up through the flue. Some of these controls get out of adjustment in a relatively short time. The result is that the burners may not be getting sufficient combustion air to get maximum efficiency from the fuel. Or, the burners may be getting too much air, thereby allowing a greater amount of the heat energy to go up the flue and into the atmosphere.

Large atmospheric combustion systems are not as efficient as power burners. Seal in as many burners as possible in lieu of open chamber furnace firing. Insulate pipes and conduits carrying steam or hot liquids through the plant or outside.

Reorganize and Improve Processes

Consider revisions in plant layout such as organizing heat treatment processes adjacent to each other to allow the interconnection of one furnace with another. This can provide for recycling of heat used in one process to be fed into another furnace or interconnecting element. Here materials can be preheated before they are treated with high degrees of heat.

Furnaces giving off quantities of radiant heat from their exterior surfaces might be placed strategically throughout the processing portion of the plant to give an even amount of heat. Removable insulation perhaps could be replaced in warmer weather to provide less load on the cooling system.

Consider the use of shaft-type melting furnaces that will preheat incoming materials. High bay spaces could be heated with radiant heaters.

Use direct firing in lieu of indirect firing wherever possible. This suggests a use of direct flame impingement.

If conveyors carry long lines of materials and objects that are very warm, consider using continuous equipment that is housed within heated chambers or tunnels. Then the heat might be conserved and reused in another process.

Consolidate Auto Trips

Attempt to get the most transportation for your vehicle fuel dollar. Filling the gas tank of our high-horsepower cars requires the input of a 42-gallon barrel of oil at the refinery. From oil in the ground to the car on the road, the auto is only 5 percent efficient. This means the full energy value of only one gallon in 20 is used in the modern car.

Consider developing a plan to consolidate auto trips and make use of mass transit if possible. Encourage employees to form car pools, by providing a matching service for those interested and special reserved lots or reduced parking fees for car pool autos.

Modifying Existing Buildings

The information in this publication may seem more adaptable for designing a new plant. However, existing plants can be revised to a considerable extent.

You can, for example, construct overhangs over windows on existing buildings that will intercept the solar rays and thus cut down on heat gain. You can place dampers in existing stacks which now exhaust considerable heat from the plant into the atmosphere. Heat energy can be recycled from its primary use and channeled to a second or third use within an existing plant.

If you have oversized or undersized air conditioning or heating equipment in an existing plant, obtain the proper sized unit when it is time to change a worn-out system. Lighting levels can always be altered in an existing plant. Insulation can be added, ventilation volumes altered, and improved exhaust hoods installed.

Using these suggestions can be a vital step to reducing your energy costs and needs and aid in improving your profits. The combined efforts of many firms are needed to insure that our energy supply does not run dry.