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# Space Heating and Energy Conservation

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*D.G. Stephenson*

## Please note

The energy equivalent of 60 million tons of coal is used each year in Canada to heat and cool residential and commercial buildings, and to provide the power for lighting, heating hot water, cooking, and operating appliances and equipment in these buildings. It is forecast that the rate of energy consumption for such purposes will more than double in the next 30 years. To put this in perspective, energy consumption for residential and commercial purposes is approximately one third of the total national consumption; industrial uses and transportation account for the remainder.

There are three compelling reasons for being frugal in the use of fuel:

1. in general, lower consumption means lower costs for fuel;
2. pollution is a side effect of the use of fuel; hence, one way to curb pollution is to burn less fuel;
3. fossil fuels are irreplaceable and should be used in such a way that they will yield the maximum possible benefit both now and in the future.

This Digest points out some ways by which building designers and utility planners can help to conserve fuel.

### Building Heat Losses

A building loses heat in two ways: by heat conduction through the walls, windows and roof; and by leakage or expulsion by fan of warm inside air that is replaced by fresh air at the outside air temperature. Both these components of heat loss are functions of the difference between the air temperatures inside and outside the building. The total heat loss can be reduced, therefore, by reducing the temperature inside a building when the space is not being used. But the reduction that can be obtained by setting the thermostat at a lower temperature during unoccupied periods is quite modest: for a typical location in the southern part of Canada there is about a 1 per cent reduction in annual fuel consumption for every 3 degrees of thermostat setback, assuming that the setback is used for 8 hours every night during the entire heating season. The savings are greater, naturally, for buildings such as schools and offices that are unoccupied for a greater percentage of the total heating season.

There is much more scope for conserving heat by increasing the resistance to heat flow through the walls and roof. A typical wall with 2½ inches of glass fibre insulation has a resistance of about 11 units; an extra inch of insulation would increase the total wall resistance to about 14 units and hence reduce the conduction heat loss by 21 per cent. Extra thermal resistance in walls and roof helps to reduce heat gain in summer as well as heat loss in winter.

The economic aspect of using more insulation is difficult to establish precisely because the financial saving associated with reduced heat losses depends on the cost of heating for the lifetime of the building. This will certainly depend on the kind of fuel that will be used, although it seems reasonable to anticipate that the cost of all fuels will continue to increase. The only way in which an increase in the cost of energy for heating might be avoided would be by the development of district heating systems that utilize "cheap heat" from thermal power stations and refuse incinerators. Although district heating will probably be developed in some parts of Canada(1), it would be unwise for building designers to cut down on the amount of insulation in buildings in anticipation that heat will become cheaper. It is much more likely that district heating will only help to hold down the rate of increase in the cost of heat. In spite of the uncertainty about the future cost of heat, there is little doubt that it is in the national interest to use more insulation than is commonly used at present. For example. it is advisable to use enough insulation to fill the spaces between studs in a conventional frame wall completely rather than partially. Similarly, it is advisable to use up to 6 inches of insulation in the spaces between ceiling joints.

Windows have much lower resistance to heat transfer than do equal areas of insulated wall. A single pane of glass has a resistance of only about 1 unit compared to more than 10 units for insulated walls. Ordinary double-glazed windows have resistances of about 2 units, and some heat reflecting double glazing units(2) have over 3 units of resistance. Thermal resistance is not the only factor to consider: windows also transmit solar radiation, an energy gain that helps to offset higher heat losses. In fact, an ordinary double-glazed window in the south wall of a building in the southern part of Canada has about the same net heat loss over a full heating season as an equal area of insulated wall. This is due to the relatively large amounts of solar energy that enter through south windows in winter. Windows facing directions other than south receive less solar irradiation and, consequently, have higher net heat losses. It can be concluded, therefore, that it is advisable to use double-glazing and to keep the size of windows as small as will be consistent with their function of admitting daylight and permitting a view of the outdoors.

For many buildings, the heat loss associated with air infiltration and ventilation is of about the same magnitude as the heat loss by conduction. This component can be reduced by using weatherstripping on open able windows and doors and by sealing any openings through which air can leak into or out of a building. It is possible, however, to overdo this and have too little fresh air. A fresh air supply equivalent to one air change every 2 hours is needed to control odours and prevent stuffiness. Larger amounts of fresh air are required for spaces where there is heavy smoking or other sources of pollution. If the natural air leakage of a room or building is not sufficient to provide adequate ventilation, some other means has to be provided. The amount of fresh air needed to maintain acceptable air quality can be minimized, however, if the exhaust air is withdrawn from rooms where odours originate rather than simply let air leak out round windows and doors. Thus, it is desirable to make the unintentional air leakage as small as possible and to provide exhaust fans and fresh air inlets in the most advantageous locations. This will result not only in reduced heat losses but also will give better air quality in the building.

The heat loss associated with the discharge of warm air from a building can be reduced by more than 50 per cent by using a heat exchanger to transfer heat from the warm air to the cool fresh air that is entering the building. These heat exchangers are particularly valuable in buildings such as hospitals that require very large amounts of fresh air.

## Fuel-Fired vs Electric Heating

Fuel can be conserved in ways other than by reducing heat losses from buildings. Any measure that increases the efficiency of the utilization of energy in fuel will cause a proportionate decrease in fuel consumption. Fuel-fired heating systems typically have efficiencies between about 65 and 80 per cent, i.e. between 65 and 80 per cent of the energy in the fuel is available as useful heat output from the furnace or boiler; the remainder is unavailable because of incomplete combustion or because heat is lost with the hot gases that go up the chimney. A furnace that receives regular maintenance will operate at a higher efficiency than one that is neglected, so that regular cleaning and checking of combustion efficiency can result in some reduction in fuel consumption.

The proponents of electric heating often claim that electric heating systems have 100 per cent efficiency. This is true in the sense that every kilowatt-hour of electric power used produces 3412 Btu of usable heat. A more appropriate way to look at it, however, is to consider how much fuel is actually used to produce this 3412 Btu of usable heat. Modern thermal generating stations achieve an efficiency of between 35 and 40 per cent, i.e. only 35 to 40 per cent of the energy content of the fuel used leaves the generating plant in the form of electricity, and there are further losses in the transmission system before the energy finally reaches the consumer. Thus, the real efficiency of electric heating is of the order of 35 per cent when it is related to the energy content of the fuel burned at a power station.

Much of the electricity now used is generated at hydroelectric plants and consequently involves no consumption of fuel. But the demand for electricity is increasing steadily and thermal plants are being used to a greater and greater extent to supplement hydroelectric plants. It is appropriate, therefore, to consider that electric heating entails a consumption of fuel; if power were not being used for heating, it could be used for other purposes and thereby reduce the demand for power from the supplementary thermal generating plants. From the point of view of fuel conservation, therefore, electric heating is much more wasteful than systems that produce heat directly by burning fuel in a furnace or boiler.

## Heat-Pump Heating and Cooling Systems

A heat-pump is a refrigerating machine that takes heat at one location at a low temperature and delivers it to another location at a higher temperature. Power is needed to drive the heat-pump and the heat that is delivered is the sum of the heat removed from the heat source and the heat equivalent of the power used to drive the machine. The relation between the amount of heat pumped and the power consumed depends on the difference between the temperature of the heat source and the temperature at which the heat is delivered. Heat-pumps used for heating and cooling buildings typically produce about 2 kw of cooling and 3 kw of heating for 1 kw of power consumed. Thus, if electricity is used to drive a heat-pump rather than for direct conversion to heat, the effective efficiency is increased by a factor of about 3, i.e. instead of 35 per cent it becomes 105 per cent, which is markedly better than the efficiencies of direct fuel-burning heating systems.

A heat-pump must have a source of heat and it cools the heat source while providing heat to some other location. A heat-pump is doubly attractive, therefore, if both the cooling effect and the heating effect can be utilized. This is possible in most large modern buildings. The core of a large building requires cooling to remove heat from lights, equipment and people while the perimeter regions require heat to make up for heat lost by conduction through the walls and windows. A heat-pump is a very economical way of satisfying both requirements simultaneously. In warm weather, when there is no need for heating, the heat-pump can still provide cooling. In this case, the heat output is discharged to the atmosphere through a cooling tower and it functions as an ordinary air-conditioning cooler.

## Utilization of Waste Heat

As noted earlier, an increasing proportion of electricity production in Canada during the next 20 years will be generated at thermal plants. At present over half of the energy content of the fuel burned at these plants is ultimately discharged as waste heat. It is normally at a temperature of less than 100°F and is of no value for space heating. It is possible, however, to reject heat from a thermal power station at a sufficiently high temperature for it to be usable for space heating; although a higher temperature for the rejected heat causes a reduction in the amount of electricity produced. When heat is discharged at 250°F, the electrical output is only about 23 per cent of the energy in the fuel and 60 per cent of the energy in the fuel is rejected as heat. The cost of obtaining this heat at a usable temperature is just the value of the electricity output that is lost. A recent analysis (1) has shown that heat produced at a combined heat/power plant has a cost of about $0.45 per million Btu, whereas heat produced at a large central heating plant costs more than $1 per million Btu; and heat produced in a furnace or boiler for a single building costs $1.50 or more, depending on the size of the building. One million Btu of heat produced by direct conversion of electricity to heat would cost $2.93 if power cost 1¢ per kilowatt-hour. Thus, it would be economically feasible to utilize heat from a combined heat/power station provided the cost of distribution did not exceed about $1 per million Btu.

Heat produced at a combined heat/power station is cheap, primarily because of the utilization of the by-product heat from the electricity generating process. Another important aspect of the utilization of the heat that would otherwise be wasted is that there is about a 30 per cent reduction in fuel consumption compared with that needed to produce the same amount of heat and power at separate plants. There is, therefore, a significant benefit in the conservation of fuel resources and a significant reduction in the total amount of combustion products that are discharged into the atmosphere.

District heating systems utilizing by-product heat from power stations are very common in Russia. It is quite probable that similar systems will be built in Canada as more and more thermal power plants are needed. Building designers should keep this possibility in mind and plan heating systems that can be changed over to district heating supply when it becomes available.

## Conclusion

As with any type of conservation, the conservation of fuel for space heating is primarily a matter of minimizing losses. It includes minimizing the amount of energy that leaves a building by conduction through the building envelope, air leakage or exhaust from the building, and the discharge of heat by the cooling system. It goes even further, and involves reducing wastage of heat from power stations by having the heat rejected at a sufficiently high temperature to enable it to be utilized for heating buildings. The implementation of all these concepts can result in very significant savings in the amount of fuel used for space heating in Canada.

## References

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