lation in the walls and/or roof of a building can be estimated by the following formula:

$$F_c = \frac{(U - U_i) \times N \times (t - t_a) \times A}{C_c \times E_c \times 2{,}000} \qquad (12)$$

where

F_c = saving in fuel in tons of coal per heating season.
U = coefficient of heat transfer of construction without insulation.
U_i = coefficient of heat transfer of construction with insulation.
N = number of hours during heating season.
t = inside temperature at proper level for wall or roof.
t_a = average outside temperature during heating season N.
A = net wall or roof area.
C_c = calorific value of coal.
E_c = overall efficiency of heating system.

To illustrate the use of this formula, suppose that the coefficient U of a certain factory roof without insulation is 0.25 and that the coefficient U_i of this roof with a given thickness of a certain type of insulation is 0.15. Let it also be assumed that the heating season is 210 days or 5,040 hours and that the average outside temperature t_a during this heating season is 35 deg. fahr. The roof area A is 10,000 sq. ft., the calorific value of the coal is 12,000 B.t.u. per pound, and the overall efficiency of the heating system is assumed to be 50 per cent. If the inside air temperature t is 75 deg. fahr. (at the roof in this case) and is maintained constantly during the heating season, the saving in fuel will be:

$$F_c = \frac{(0.25 - 0.15) \times 5{,}040 \times (75 - 35) \times 10{,}000}{12{,}000 \times 0.50 \times 2{,}000}$$

= 16.8 tons of coal per average heating season.

If in the foregoing problem the building is heated intermittently, the fuel consumption and fuel saving will be reduced correspondingly, but not in direct proportion to the number of hours the heating plant is not in operation. Recent tests indicate that a saving in the fuel consumption of from 10 to 20 per cent will result by allowing the heat to be shut off after working hours and only heating the building to the required temperature during the period of occupancy each day. Hence, the fuel saving of 16.8 tons would probably be reduced about 15 per cent by shutting off the heat at night in which case, the net fuel saving would be 14.3 tons of coal per heating season.

If the applied cost of the insulation is 11 cents per square foot for the thickness involved in this case, and the cost of coal including the handling of it, and disposal of ashes is $10.00 per ton, the annual return on the investment will be $100 \times \frac{14.3 \times 10.00}{0.11 \times 10{,}000}$ or 13 per cent, neglecting insurance and depreciation.

Experiments recently conducted at the University of Illinois indicate that ceiling insulation increases the temperature head, thus offsetting the effect of the insulation to a slight degree, and changing the value of t in equation (12).

In the case of flat roofs, the change in temperature head is due solely to the slight increase in temperature of the air underneath the ceiling. In the case of pitched roofs with unheated attics, not only is the temperature underneath the ceiling higher, but the attic temperature is lower after the installation of the insulation, excepting where the attic contains windows, ventilators, etc., in which case the attic temperature will be practically the same in both instances, and will approach or equal the outside temperature. If the attic contains no windows, ventilators or wall surfaces, the attic temperature before and after the insulation is installed may be estimated by equation (10_a), assuming the temperature t under the ceiling to be the same in both cases. By using the combined coefficient of transmission of the roof, attic and top-floor ceiling (Table 35), then the change in temperature of the air in the attic space can be neglected, and only the increase in temperature under the ceiling need be taken into consideration.

To be strictly correct, this change in temperature head should be considered in figuring fuel saving problems, but in most cases this degree of accuracy is not warranted.

In the case of vertical walls, the temperature head will be the same before and after the insulation is installed.

If oil is the fuel burned the annual saving in gallons of oil can be estimated by the following formula:-

$$F_o = \frac{(U - U_i) \times N \times (t - t_a) \times A}{C_o \times E_o \times W} \qquad (13)$$

where

F_o = saving in fuel in gallons of oil per heating season.
C_o = calorific value of oil.
E_o = overall efficiency of the heating system for an oil-fired furnace (usually taken as 60 per cent).
W = weight of oil per gallon, pounds.

The average value of the product of C_o and W is about 141,000 B.t.u. To obtain the fuel saving from formula (13) in terms of barrels of oil, divide the result by 42, the number of gallons of oil in a barrel.

If gas is the fuel burned, the annual saving in cubic feet of gas can be estimated by the following formula:

$$F_g = \frac{(U - U_i) \times N \times (t - t_a) \times A}{C_g \times E_g} \qquad (14)$$

where

F_g = annual fuel saving in cubic feet of gas.
C_g = calorific value of gas in B.t.u. per cubic foot (usually taken as 535 for manufactured gas and 1,000 for natural gas).
E_g = overall efficiency of the heating system for a gas-fired furnace (usually taken as 75 per cent).

It should be understood that the heating efficiencies of 50, 60 and 75 per cent, which are frequently used for estimating fuel savings with coal, oil and gas are approximate values and apply more specifically where the heating plant is not located in the building heated, and consequently, where there is no regain of the sensible heat of the flue gases, and where