# COMSTOCK'S TECHNICAL SERIES. LIGHT, HEAT AND POWER IN BUILDINGS

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Comstock's Technical Series. Light, Heat and Power in Buildings by  Alton D. Adams



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## PREFACE.

In this volume the object is to present in compact form the main facts on which selection of the sources for light, heat and power in buildings should be based. The problem for which a solution is sought is to determine the kind of equipment that will yield the service required in any case at the least total cost. Such a purpose leaves little room for discussions of theory relating to any particular class of apparatus, which has already been done in separate and larger volumes. It follows that the only novelty to be expected here is that of arrangement, by which the costs of service from widely different sources are set down side by side.

Should this arrangement prove convenient for those charged with the selection of apparatus for light, heat and power, the labor spent on the following pages will have accomplished its purpose.

ALTON D. ADAMS.

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# Light, Heat and Power in Buildings.

## CHAPTER I.

### COSTS OF HEAT, LIGHT AND POWER FROM PUBLIC GAS AND ELECTRICAL SUPPLY AND FROM COAL.

An open gas flame of sixteen candle power consumes five cubic feet of average gas per hour. At one dollar per 1,000 cubic feet, the cost of this gas flame is 100 × .005 = 0.5 cent hourly. Ten cents per kilowatt-hour is a moderate rate for electrical energy. Fifty-six watts is a fair rate of energy consumption for an incandescent lamp of sixteen candle power. Such a lamp requires an hourly expense of 10 × .056 = 0.56 cent at the rate for energy just named. Simple, non-condensing engines, with good boilers, will readily yield each horse-power hour of work with a consumption of four pounds of fairly good coal. If this coal costs three dollars per ton of 2,000 pounds, the expense for fuel per horse-power hour amounts to 300 × 0.002 = 0.6 cent. This brake horse-power, when delivered on the shaft of a dynamo which has an efficiency of 90 per cent., produces an output of 746 × .90 = 671.4 watts. At 56 watts each, the number of sixteen candle power lamps that may be supplied from this output is 671.4 ÷ 56 = 12. As the fuel cost of the horse-power hour is 0.6 cent, the charge against each sixteen candle power lamp is 0.6 ÷ 12 = 0.05 cent hourly.

Gas from public supplies usually contains 20 to 40 per cent. of the heating power of coal, from which it is derived, according to its variety. It seems at once evident from this fact that gas is ill-suited for general warming in buildings, and when the cost of heat derived from gas at current public rates is considered, its common use to heat buildings is seen to be entirely impracticable. As an illustration, take average city gas, yielding 650 heat units per cubic foot and selling for one dollar per 1,000 cubic feet. This gas yields, therefore, $650 \times 1{,}000 = 650{,}000$ heat units for one dollar on perfect combustion. Good anthracite coal has a heating power of 13,000 units per pound, or $13{,}000 \times 2{,}000 = 26{,}000{,}000$ heat units per ton. The amount of gas to supply heat equivalent to that from one ton of coal is therefore $26{,}000{,}000 \div 650 = 40{,}000$ cubic feet, costing forty dollars at the rate named. Considered as a general heating agent, electric energy is in a much worse position as to the portion of the energy of coal that it can deliver, and as to its cost at usual rates, than is gas. Ten cents per kilowatt-hour is a low average rate for electric energy, and as the kilowatt-hour is the equivalent of 3,412 heat units, this rate gives 34,120 units of heat for one dollar. To equal in heating power one ton of coal, the kilowatt-hours necessary are $26{,}000{,}000 \div 3{,}412 = 7{,}620$, costing $7{,}620 \times .10 = 760.00$ dollars at the rate named. In practice, the actual cost of electrical energy at ten cents per kilowatt-hour, when used for general warming, is less than the cost of coal at 760 dollars per ton, because nearly all of the electrical energy is available as heat in the apartments warmed, while more than 75 per cent. of the total energy of coal is seldom so available.

Mechanical power may be produced in buildings by means of either steam, gas or electrical energy. Power from steam implies both a boiler and engine. Gas develops power by means of an engine only, and electrical energy is transformed into mechanical work by a motor.

For apparatus of equal quality, to develop a given power, the steam boiler and engine will usually cost most, the gas engine a somewhat less amount, and the electric motor least. The cost of either of these equipments for power production is very small compared with the fuel or energy it consumes during its useful life, so that a moderate advantage in efficiency, or in the cost of power development, may more than offset a considerable excess in the first cost of the plant.

It has been previously shown that a good steam plant should deliver a horse-power hour at a fuel cost of 0.6 cent, when using fair coal at a price of three dollars per ton. Gas engines of small and moderate capacity, such as are commonly used in city buildings, may be fairly expected to consume twenty cubic feet of gas per delivered horse-power hour. The gas implied in this rating is of the quality generally distributed for illuminating purposes in towns and cities, having a heating power of not less than 650 units per cubic foot, on perfect combustion. If a gas of lower heating power is used, as one of the so-called fuel or producer gases, which may develop as little as 150 heat units per cubic foot, the consumption per unit of work will increase in inverse ratio to the energy of combustion. The lowest rate common for illuminating gas in the United States is one dollar per 1,000 cubic feet, and, while this rate is in force for but few cities, the cost of power may be stated for it as a convenient basis from which to compute the cost at other rates. At one dollar per 1,000 cubic feet, twenty feet of gas, to develop one brake horse-power hour, cost $100 \times 0.20 = 2$ cents. As coal to produce this same unit of work was found to cost 0.6 cent, the fuel outlay for power from gas at one dollar per 1,000 cubic feet is more than three times as great as that for coal at three dollars per ton. Electrical energy for power production in motors can usually be had at materially lower rates than those charged when it is devoted to lighting purposes. A frequent rate for energy supplied to electric motors is 3.33 cents per electrical horse-power hour, corresponding to a charge of 100 dollars for a horse-power year of 3,000 working hours. Electric motors do not, of course, deliver as mechanical work the equivalent of all of the electrical energy that they absorb, and the average efficiency of small and medium sizes may be taken at 80 per cent., under the conditions of use. The exact figure for motor efficiencies increases slowly with the capacity of the motor. The average loss of 20 per cent. in motors raises the cost of their delivered work to $3.33 \div .80 = 4.16$ cents per horse-power hour. It thus appears that for the rates named the primary development of power in buildings with electric motors costs more than twice as much as that from gas and nearly seven times as much as that from coal, so far as the outlay for fuel and energy is concerned. In this comparison it should be noted that the steam is developed on the premises, while the gas and electrical energy are procured from the public supply. Fuel or energy is obviously only one of the items that go to make up the cost of power in buildings, and whether it is the most important should be decided on the circumstances of each case. Notwithstanding the low cost of fuel for the production of steam power, such power would be the most expensive possible where its total was small, no heating was required and it was necessary to employ an engineer for the care of the engine and boiler. For the case just named, where the power is quite small, and especially if it is fluctuating in amount and intermittent in point of time, electrical energy from