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A Mathematical Evaluation of HVAC Energy Recovery

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ABSTRACT:- The energy saving and recovery of building HVAC system are so important that it is major guidelines of the American Society of Heating, Refrigerating and Air-Conditioning Engineers and others. Here we will mathematically compute and discuss, among others, about the nature of HVAC energy recovery, fuel consumption and capital investment of the system.

I. INTRODUCTION

We must first consider the Psychrometric Chart of Figure 1. It will explain everything we want to talk about the energy, temperature, latent or sensible. Here we must also remember the majority of the buildings now in use were designed and constructed when most forms of energy were readily available and inexpensive. However, the structures, the electrical and mechanical systems were designed to minimize initial costs and to fit into the contemporary architectural mode. As a result, the majority of these buildings are now become energy inefficient, while nearby office buildings and warehouses of the same plant location utilize other fuels as energy for the building environmental systems.

However, before energy recovery is attempted, all efforts should be concentrated on conservation of energy by using good maintenance procedures on the environmental systems. and realistic use of the building systems. The remaining energy that is being discarded throughout the year can then be analyzed against the cost of the installation and operation of recovery systems.

In existing buildings, the proposed use of an energy recovery system would depend on many factors: The physical space requirements and the distances between airstreams, the temperature and latent heat differences between the airstreams, the mass flow rates of the airstreams. the efficiency of the recovery devices. The additional energy required to operate the recovery system, etc.

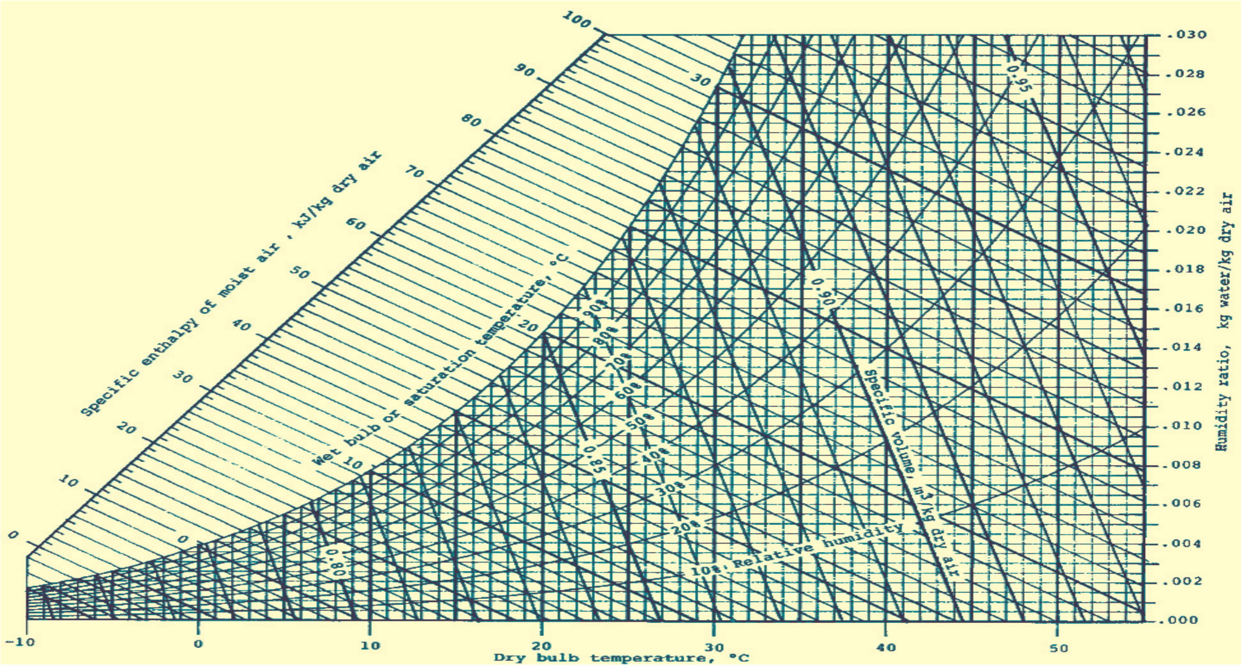

Figure 1 – A General Psychrometric Chart

When all of the above data is used in a building energy analysis and there is a yearly net savings in energy consumption, it would seem that an energy recovery system would be feasible if the economic analysis was reasonable or additional energy was unattainable.

a. Building exhaust systems when one or more of the following occur:
1. The flow rate is over 1000 CFM.
2. Heating degree days are over 3500.
3. There are 8000 cooling degree hours above78°F.
4. There are 12,000 wet bulb degree hours above 66°F wet bulb temperature.

b. Incinerators consuming 1000 pounds of solid waste per day or greater.

2. NEW Buildings

ASHRAE Standard 90-75; Energy Conservation in New Building Design contains the following recommendation for use of energy recovery systems:

It is recommended that consideration be given to the use of recovery systems which will conserve energy (provided the amount expended is less than the amount recovered)when the energy transfer potential and the operating hours are considered.

II. BENEFITS OF ENERGY RECOVERY

In general, the motivation for building owners to invest in energy recovery is that they expect the resulting benefits to exceed investment costs. Factors that have recently made such investments attractive are rising fuel costs and curtailment of regular fuel sources which threaten production cutbacks and changeover to other energy sources. In addition, mandatory pollution controls and rising labor costs cut into profits and cause firms to look more closely for ways to control costs. The kinds of potential benefits which may result from energy recovery are:

1. Fuel savings
2. Reduced size, hence lower capital cost, of heating/cooling equipment
3. Reduced maintenance costs for existing equipment
4. Reduced costs of production labor
5. Pollution abatement
6. Improved product
7. Revenue from sales of recovered heat or energy

These benefits were suggested by a preliminary look at existing applications. However, only fuel savings was found in every case examined. The other benefits; savings in capital and maintenance costs on existing equipment, pollution abatement, labor savings, product improvement, and revenue from sales of recovered appear limited to certain applications.

1. Fuel Savings

Fuel savings result when waste heat is recovered and used in substitution for newly generated heat or energy. For example, heat from stack flue gas maybe recovered by an energy recovery device and used to preheat the input water, thereby reducing the amount of fuel needed for steam generation.

2. Lower Capital Costs

Savings in capital costs for certain items of existing equipment (i.e., regular equipment apart from that required for waste heat recovery) may be possible if recovered heat reduces the required capacity of the heating and/or cooling equipment. For example, installation of rooftop energy recovery equipment on buildings with high ventilation requirements can enable significant reductions in the size and cost of the building heating and cooling system. This potential for savings is not limited to new construction when existing equipment needs to be replaced.

III. REDUCED MAINTENANCE

Reduced maintenance and repair on certain items of existing equipment may, in some instances, be a further benefit of investment in energy recovery. principal impact on the maintenance of existing equipment is likely to result from the planning, engineering, and installation phases of investment. in energy recovery, when the existing equipment and plant processes are often scrutinized. Existing faults may be identified and corrected; and improved maintenance practices may be extended to existing equipment.

IV. LOWER LABOR COSTS

Another kind of benefit which may result from investment in energy recovery systems, is savings in labor costs. Labor savings can result, for example, from a lowering of industrial furnace change overtime (i.e. ,the time needed to alter furnace temperatures required for a change in production use) by preheating combustion air with waste heat. Savings may also result from faster furnace start-ups, accomplished by similar means. By reducing the amount of labor; down time unit labor costs are reduced. (A tradeoff may exist between idling the furnace at higher; down time during furnace start-ups. If the existing practice is to idle the furnace at high temperatures in order to avoid. The savings from using waste heat recovery to preheat air would be in terms of fuel reductions rather than lower labor costs.

V. POLLUTION ABATEMENT

Pollution abatement is a beneficial side effect which may result from recovery of waste heat. For example, the pollution abatement process in textile plants will often be facilitated by waste heat recovery. Pollutants (plasticizers) are usually collected by circulating air from the ovens (where fabrics are coated or backed with other materials) through electrostatic precipitators. The air must, however, be cooled to accomplish collection of pollutants. If it were not for heat recovery, it would be necessary to cool the air by other means, which would generally entail additional fuel consumption. Thus, there is a twofold impact on fuel use from this application of heat recovery. Another instance of pollution abatement, as a side effect of waste heat recovery, occurs if pollutants are reduced by the higher furnace temperatures resulting from preheating combustion air with waste heat. The pollution abatement side effects represented by the two preceding examples are distinguishable from the use of systems tore cover heat from a pollution abatement process, where recovery of heat does not in itself contribute to pollution abatement. For example, the recovery of waste heat from the incineration of polluting fumes is a method of reducing the cost of pollution abatement by producing useful by-product from the abatement process. However, the waste heat recovery does not itself contribute to the pollution abatement process and therefore does not yield multiple benefits; the only benefit is the value of the fuel savings from using the recovered heat in other processes.

VI. PRODUCT IMPROVEMENT

Product improvement is a further potential side effect of energy recovery. For example, by achieving a more stable furnace temperature and a reduction in furnace aeration, use of a recuperated to preheat combustion air may reduce the undesirable scaling of metal products. In absence of preheating combustion air, it would be necessary to invest in improvements to furnace controls or in some other means of preventing scaling; to secure the same product quality.

VII. RECOVERY GENERATING

A final potential benefit from energy recovery, a suggested by existing applications, is the generation of revenue from sales of recovered waste heat or energy. In some cases, the recoverable waste heat cannot all be used by the plant itself. Recovery may still be advantageous if there are adjoining plants which are willing to purchase the recovered heat. In this case, the potential benefits are revenue-generating, rather than cost-reducing, and would be measurable in terms of dollars of revenue received.

8. Existing Performance Records

With information such as records of past operating levels and expenses, the efficiency of the proposed energy recovery equipment, the level of expected furnace operation, the demand for recycled heat, and the expected price of fuels, it should be possible to make a close estimate of the savings in fuel costs that would result from substituting waste heat for newly-generated heat or energy. Certain of other potential benefits, such as labor cost savings and product improvement, might be more difficult to estimate. However do not use past performance data for a building furnished by others without verification, particularly when firm price contracts are involved.

$\Sigma H \ x\Delta_1$ $\qquad\qquad$ $\Sigma H \quad \Delta_1$

H = Heat recovered — Btu/hr at design conditions. operates in the time period used in the analysis (e.g. for an Oct. 1 to May 1 heating season— 212 days x 24 hrs/day = 5,088 hours)

E = Efficiency of fuel using device or system over the time period (express as a decimal)

Δ_1 = Entering temperature difference between average ambient for the specified time period and the hot inlet temperature in °F

Δ= Entering temperature difference at design conditions ($Ti - ti$) in °F

Ti = Temperature of the hot gas or air entering the heat recovery unit at design conditions in °F

ti = Temperature of the cold fluid (air to liquid) entering the heat recovery unit at design conditions in °F

$ti\ a$ = Average ambient temperature for time period (N) — °F

For a one-year period, tia is calculated as follows:

The degree-day values for major cities throughout the United States, Canada, and Republic of Korea, select the appropriate

COMPUTINGFUEL SAVINGS

Before any economic analysis can be made on a heat recovery system, four basic steps must be completed:

1. Determine design and operating conditions for flows, temperatures, allowable pressure drops, hours of operation including different seasons, type and cost of fuels used, and efficiency of fuel- using equipment.
2. Using design conditions, size and the energy recovery system, and determine the amount of recovered energy.
3. Calculate fuel saved for a given time period, usually one year.
4. Determine installed cost of system. Energy recovery equipment usually accounts for a small portion of the total installation cost. The customer will eventually need accurate cost estimates which usually must be obtained from an installing contractor. Only after the equipment energy consumption rates, the installed cost of the recovery system, and the hours of operation are known, can the economics of the installation be determined.

Some energy recovery systems operate in dependent of ambient conditions. But often it is required that make-up air be returned to a plant or process. When this is the case, the heat recovered should be calculated using the degree-day method, which takes into account daily variations in the ambient temperature. The economic analysis in this section will be developed around the following two methods:

1. Heat recovery — independent of ambient temperature
2. Heat recovery — dependent on ambient temperature

The basic calculation in any economic analysis of an energy recovery system is the determination of fuel saved for a given time period. The equation for determining this value is:

Equation 13-1

Q x N x (ETD) a
E x C x (ETD)
F = Units of fuel saved during time period.
C = Heat value of unit of fuel.
Q = Heat recovered — Btu/hr at design conditions.

N = Number of hours heat recovery system operates in the time period used in the analysis (e.g. for an Oct. 1 to May 1 heating season— 212 days x 24 hrs/day = 5,088 hours)
E = Efficiency of fuel using device or system over the time period (express as a decimal)
(ETD) a = Entering temperature difference between average ambient (tia) for the specified time period and the hot inlet temperature (Ti - ti a) in °F
(ETD) = Entering temperature difference at design conditions (Ti - ti) in °F
Ti = Temperature of the hot gas or air entering the heat recovery unit at design conditions in °F
ti = Temperature of the cold fluid (air to liquid)entering the heat recovery unit at design conditions in °F
ti a = Average ambient temperature for time period (N) in °F
For a one year period, tia is calculated as follows:
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