

4

Evaluation functions

An evaluation function, as used in the engineering design process, can be defined as a relationship of one characteristic of a system to another that can be utilized in some way to evaluate the design, performance, or other similar merit of the system. Whether or not one has ever consciously considered it, an evaluation function is one of the most powerful tools in achieving successful engineering designs with a minimum of error. Unfortunately, some engineering practitioners become so convinced of the overwhelming value of evaluation functions that they tend to totally replace the normal process of engineering analysis with the evaluation function, basing a design on the function alone. Misused in this way, the evaluation function becomes what is commonly called a rule of thumb.

Properly used, on the other hand, an evaluation function can be employed in the early stages of the design process to set budgets or goals—in this way, it is used as a self-imposed design parameter—and in the intermediate and final stages to “check” both manual and computerized calculations. And finally, it can be used to determine many aspects of the success of the design.

Consider some examples of evaluation functions, categorized by general areas of relevance, with some commentary as to where in the design process they are employed.

Design capacity and loads

The function of space heating or cooling load per unit area of building can and should be employed as a design target or budget when the designs of the building envelope and interior energy dissipation systems are being developed. The commonly used units are power per unit area for heating (Btuh per sq ft) and area per unit power for cooling (sq ft per

ton). The “reference” values will vary depending on primary building use and location, but typical values used in the Midwest at about 40 deg north latitude are 30 Btuh per sq ft for heating and 400 sq ft per ton for cooling. Once the building envelope and internal energy systems (such as lighting) are established and the space loads carefully and accurately calculated, the specific load should be calculated to determine how closely the actual design compares with the “target” or the value considered the norm. At this point, not only is the success of the designs of the building envelope and internal energy systems evaluated by the function, but errors in calculation will also be flagged if a value varies significantly from the reference value. This is the “checking” use of the evaluation function.

Other capacity-related functions are air flow rate per unit area (cfm per sq ft) air flow rate per unit cooling capacity (cfm per ton), design water circulation rate in a chilled water system per unit installed capacity (gpm per ton), and specific water flow rate for a water heating system (gpm per MBtuh). A brief look at two of these reveals some common misuse of evaluation functions.

Air flow rate per unit area is quantitatively related to a more fundamental design parameter, air changes. In years past when the air was being “changed” in a space for some purpose other than maintaining comfort conditions with mechanical cooling and heating, air change rates were used as an absolute design tool. More recently, minimum air circulation rates were found to be necessary to achieve adequate ambient velocity for convective and evaporative cooling comfort. Subsequent study of air distribution devices, however, has revealed that previously established minimum air circulation rates are not absolute

values but rather are related to the location, shape, and design of the supply air device. Yet there are building codes in some areas that actually require minimum air change rates or minimum cfm per sq ft values.

Another example of a common misuse relates to the water flow rate per unit installed capacity for a chilled water system. The gpm per ton is a useful evaluation function properly applied. It should not be used, however, as a design value in designing the system. The proper approach should be to design each load device (coil) so as to achieve the most beneficial resolution of air temperatures, flow rates, and pressure drops; water temperatures, flow rates, and pressure drops; and cost burdens of the coil and air handling unit. It is then that the system flow rate is calculated, and the gpm per ton function reveals the success of the work by comparing it to a norm. If a norm value of 2 gpm per ton is used and the answer comes out to 1.2 gpm per ton, this would indicate an extremely successful design from the standpoints of pumping energy and piping system costs. If the answer comes out to 3 gpm per ton, a reconsideration of the design should be undertaken.

Power and energy consumption

A brief summary of some of the more common functions relating to power and energy are annual thermal energy per unit area of building (Btu per sq ft per yr), annual electric energy per unit area (kW-hr per sq ft per yr); electric power requirements of cooling system auxiliaries per unit installed capacity (kW per ton), annual electric energy requirements of cooling system auxiliaries per unit of refrigeration produced (kW-hr per ton-hr), electric power requirements of refrigeration machine drive (compressor) per unit capacity (kW per ton), and annual electric energy requirements of refrigeration machine drive per unit of refrigeration produced (kW-hr per ton-hr).

These functions have become commonly used in energy management efforts and are being extended into the design development process.

Economic evaluation functions

The commonest economic evaluation functions, familiar to all designers, are system cost per unit area of building (\$ per sq ft) and system cost per unit system capacity (such as \$ per ton).

There are other functions that are actually building block components of these two, such as \$ per cfm for air distribution systems and air handling units. In addition to their use in evaluating the economic success of a design, these functions are commonly used in the development of preliminary cost estimates. Another interesting function that can be used in the development of preliminary estimates is the weight of sheet metal in the distribution duct system per unit volume of air delivered (lb per cfm).

In building management, the function of energy cost per square foot has been used historically. Recent studies have revealed a close interrelationship between energy consumption and maintenance service costs. It has been found that the sum of these two (energy plus M/S) in the numerator often provides a more meaningful function. In revenue-generating building projects, the dimensionless function of the energy plus M/S costs divided by the gross revenue has proven quite useful.

Other evaluation functions

Another type of evaluation function not addressed above (except the last one) includes dimensionless ratios, which have the same uses as the dimensional functions discussed. Dimensionless functions have additionally been found to be valuable tools in mathematical formulations of physical phenomena. Examples of these are expressions of efficiency, coefficients of performance, and the dimensionless numbers such as Reynolds, Prandtl, etc.

There are many other evaluation functions, including those that are commonly used and those that individual designers have formulated and developed over the years for their

own use. The vast majority of those in the latter category have never been printed or even written down; they are simply the mental tools that have enabled their users to develop successful designs. A major component of the "experience" that enables designers to improve with time is the continual development of a growing reservoir of evaluation functions that are employed consciously or subconsciously.