Use the File Menu from your browser to Save, Print or E-Mail this document

---

8/29/03
Discussion 8-03
Design Parameters

It was stated in last month's discussion that when designing by the "laws of physics" concept, assuming a thorough understanding of the fundamental principles, the success of the design is generally a function of how well the design parameters have been established.

At the outset of the design, in addition to a building "program" a series of design parameters should be established and agreed upon between the owner and the design team. Following is a generic list of the parameters that should be established for any building. The parameters are not in prioritized order as all are of equal importance.

- **Performance**
- **Safety**
- **Simplicity**
- **Power and Energy Requirements**
- **Construction Cost**
- **Owning and Operating Cost**
- **Reliability**
- **Durability, Maintainability and Serviceability**
- **Operational Considerations**
- **Flexibility**

There are, of course, interrelationships among all of the parameters. Properly executed, they tend to be intersupportive and "trade-offs" should not be required. For example, a simple system is usually a less expensive system; a less expensive system, well engineered, usually requires less power and energy, etc. The following discussion will expand this list of 10 generic parameters into more specific definition.

PERFORMANCE

All systems should be designed to provide indoor environmental conditions necessary for human comfort and health at all times of occupancy and maintain the space under control at pre-established conditions during non-occupancy hours. These conditions should

include control of:

- **Temperature**
- **Humidity**
- **Air motion**
- **Mean radiant temperature**
- **Air quality (purity)**
- **Ventilation rates**
- **Thermal consistency**
- **Lighting levels and types**
- **Ambient sound and room acoustics.**

Precise environmental conditions shall be in accordance with appropriate ASHRAE and IES standards or as agreed to between the designer and the building Owner.

The quantitative and qualitative characteristics should be specifically established and agreed to prior to initiating the design.

SAFETY

Safety, as a design parameter has been, in recent years at least, taken for granted. It wouldn't occur to anyone not to build a "safe" building; or, stated the other way - it wouldn't occur to anyone to build an unsafe building. Most of the safety issues have been mandated over the years by inclusion into the building codes, various national standards, the fire codes, the national electrical code and the national plumbing code in the United States.

The expectations of the people who occupy buildings has been changing. A statistic published by the National Research Council in 1981 stated that the average person in the United States spends 90% of his/her time indoors. As a result, people have become much more demanding of the quality and safety of that environment.

The life safety aspects of the HVAC systems, for example, in many health care facilities mandate control of the migration and containment of microbes. In laboratories, protection of workers from chemical irritants and odors is mandatory under both ordinary and extraordinary circumstances (such as chemical "spills", etc.). The concern for chemical or biological contamination and containment has become a concern, particularly in high risk buildings.

Although the cost of adding these protections generally far outweighs the need in the majority of buildings it is a topic that should be discussed and agreed upon when establishing design parameters.

SIMPLICITY

Albert Einstein once said "everything should be made as simple as possible but not simpler". Recognizing that the successful accomplishment of the design objectives for a contemporary building requires a certain level of technical complexity should not prevent the designer from striving for the goal "as simple as possible". Simplicity will enable the contractor and his tradesmen to more clearly understand and to more accurately and successfully carry out the objective of the designer. Simplicity will enable the commissioning agent to more successfully achieve performance as intended and the building operations staff to more successfully operate the system in accordance with the concepts envisioned by the engineer. And simplicity will, through numerous channels of maintenance, service, and operational success, promote the longevity of the system and prevent premature obsolescence.

In incorporating simplicity into the designs the following guidelines should be followed and could be used as a basis of design:

1. **All energy distribution and conveying systems including air ducts, steam and water piping, drain piping, electric power conduits, control cables, and fire protection and sprinkler piping should be geometrically analyzed to provide the shortest lengths possible between the sources and each terminal device or connection, while maintaining symmetrical distribution and 90 degree or parallel geometry except for under-slab or in-slab conduits.**
2. **Efforts should be made to avoid confusion in the purpose of various subsystems that relate to one another. As an example, ventilation air (which is that outdoor air which is introduced into and removed from the building to provide a safe environment free of harmful gases and odors) should preferably not be confused with outdoor air being introduced for thermal purposes (economizer cycle). Another example would be that energy conservation efforts such as varying the speed of a fan or pump should not be confused with on-line control devices such as control valves and dampers that are inherent components of variable flow control systems.**
3. **Temperature control systems should be kept as simple as possible. If a given control function can be accomplished with proportional control, the design should not require the use of proportional-integral-derivative technology. Another example would be that if a deep dehumidifying coil is used for dewpoint control a simple dry bulb temperature sensor would be far superior to sensing both dry bulb and humidity and performing a software calculation to control the dewpoint. *With control systems, we tend to do too many things only because we can, not because they're needed. This simple act adds untold complexity to most systems.***
4. **Temperature control systems and fluid systems should be designed in modular concept with interlocked communication with the system as a whole; thus, each module should be limited to a readily understandable and definable unit. As an example, a given air handling system should have a control "system" totally capable of providing all control functions related to that specific unit. It should then be connected to a building wide system capable of monitoring each such subsystem, providing operational mode signals, reset functions, performance monitoring, etc. Another example would be extensive hydronic fluid systems in which the use of decoupled secondary pumping circuits would provide modular subsystems, the hydraulics of which could be readily understood, diagnosed and controlled.**

All schematic design and construction documents should include simplified (ladder diagram type) flow diagrams of all fluid systems with flow quantities and flow control devices. It is through the use of ladder type flow diagrams that simplicity in fluid systems is maintained.

POWER AND ENERGY

A significant design parameter is the power and energy that will be required to operate the building. These parameters are, of course, related to the operating cost, since if they are smaller they will cost less (and visa versa). However, the reason for considering power and energy as parameters independently of costs is two-fold.

1. **If power and energy decisions are made on the basis of economic analyses based solely on the concept of initial investment costs being funded from lower operating costs the analyses are seldom valid. The reason, simply, is that no one knows what the future energy costs are going to be.**
2. **In reality, most really meaningful reductions in power and energy have a lower investment cost and a lower operating cost.**

Power as it is incorporated into building designs relates to the size of the machine or apparatus required to accomplish a task. Some power terms relating to HVAC systems are kilowatts, horsepower, tons of cooling load or equipment, BTU/Hour heating load or equipment, etc. These terms all describe size or capacity. Since cost in turn is directly proportional to size, if the power can be held to a minimum the cost will be held to a minimum. Below are a series of limitations on power that designers can strive for unless more stringent restrictions are desired or required. If, due to unique performance requirements, or the need to satisfy other parameters, power levels in excess of those stated are required, the designer should consider changes in the systems concepts until the targets are met.

Just as an engineer must work to a cost budget, self-imposed power budgets can be similarly helpful in achieving an energy-efficient design. Examples of some budgets that designers have set for themselves for offices buildings in a typical midwestern or northeastern temperature climate are:

Installed lighting overall	1.3 W/ft^2
Space sensible cooling	20 Btu/h·ft^2
Space heating load	15 Btu/h·ft^2
Fan system pressure	4 in. of water
Air circulation rates	1 cfm/ft^2
Electric power (overall)	4.5 W/ft^2

Thermal power (overall)	30 Btu/h·ft^2
Hydronic system head	70 ft. of water
Water chiller (water cooled)	0.6 kW/ton
Chilled water system auxiliaries	0.15 kW/ton
Unitary air-conditioning systems	1.0 kW/ton
Annual electric energy	15 kWh/ft^2·yr
Annual thermal energy	10 Btu/ft^2·yr·°F day

Then, as the building and its systems are designed, all decisions become interactive as the result of each subsystem s power or energy performance being continually compared to the budget.

Energy use can be further minimized by the sequential application of the following techniques:

1. **Design to hold all power requirements at their lowest possible value.**
2. **Provide a controlled unoccupied cycle for all HVAC systems to hold the unoccupied space at a predetermined setback temperature in the winter, hold the indoor dewpoint at a predetermined setpoint in the summer, reduce or eliminate ventilation air, and reduce air circulation rates to the lowest possible level to maintain the conditions, while consuming a minimal amount of primary and auxiliary system energy.**
3. **Reduce the flow rates with reduction in load for all air systems (VAV) to the extent possible while maintaining adequate space air circulation. Configure system design to approach the cubic reduction in power with flow reduction to the extent feasible.**
4. **Reduce water system flow rates with reduction in load (variable flow systems). Configure system design to approximate the cubic relation in turndown with flow reduction to the extent feasible.**
5. **Provide systems for thermal interchange between exhaust air and make-up air, limiting the cost of such systems to no more than six times the anticipated annual energy cost avoidance.**
6. **In addition, all building materials, systems, and equipment should comply with the latest publication of the applicable standard in the ASHRAE Standard 90 Series.**
7. **Domestic hot water systems should be distributed type, utilizing minimum piping and arranged for "off cycling" during non-occupied hours.**
8. **All three-phase electric motors should be energy efficient motors.**

CONSTRUCTION COST

Each Building or project should have a unique budget which should represent the size of the building, the current construction

market condition, construction cost indices, and type of facility. Regardless of the specific budget, however, designers of all major components of the building such as mechanical, electrical, plumbing and safety systems should exercise certain controls beginning with the conceptual designs to maintain the construction costs at the lowest level consistent with the other design parameters. The following steps of cost control through design are suggested:

1. **The engineer for each component of the work (i.e. HVAC, plumbing, electrical, etc.) should participate in the establishment of the budget for that component and should confirm that in his/her professional opinion, the scope of work can be accomplished within that budgetary amount before proceeding with the design.**
2. **Designs should not employ "hidden" safety factors. However, safety factors considered by the design engineer to be necessary and to be within the limits of accepted practice or standard of care should be employed, but should be clearly identified during design reviews.**
3. **Lengths of all piping, power, communication and all distribution systems should be held to a minimum through the use of multiple source systems (such as fan systems) and geometric analyses of configurations and network options.**
4. **Where square or rectangular ducts are used, aspect ratios should be held as close as practical to unity. All fittings should be designed to minimize flow separation and to have the lowest practical Co value.**
5. **Air systems should be low pressure construction (i.e., 3 inch water column maximum by SMACNA construction standards).**
6. **Air flow quantities should be held to the minimum quantities required to serve the loads or satisfy relevant standards or building codes.**
7. **Materials employed should represent the best available technology and should be suitable for the purposes intended, but should not employ material weights, thickness, or surface conditions in excess of the lowest value necessary for performance and safety, and consistent with accepted industry practice.**
8. **Unless there are extenuating circumstances, a minimum of three alternative products should be specified for all items of equipment.**

RELIABILITY

In the design of all systems and machinery, consideration should be given to total systems reliability commensurate with the requirements of the respective building or space. Use of redundant or "stand-by" machinery is discouraged unless for special requirements because of its impact upon first cost and ownership burden. Adequate reliability in most situations is inherent in equipment and machinery that satisfies the other design parameters and should be inherent in the design philosophy employed. Examples of design techniques to enhance reliability are:

1. **When designing pumping systems, multiple pumps in parallel are recommended such that if an "on" pump fails or is otherwise out of service, the remaining pump or pumps can provide continued service at a modest reduction in capacity, until the failed unit is restored to service.**
2. **When designing an electronic variable speed motor drive (VSD) into a circuit, a bypass magnetic starter should be provided to**

assure service when the VSD is unavailable.

3. **All temperature control systems and devices should be designed to fail in a pre-determined "fail-safe" mode, which mode shall specifically be described in the sequence of operation.**
4. **Electric or electronic safety and signal systems should be provided with a self-monitoring feature to signal when a circuit or component is not functional or otherwise is out of service. If this is not practical, a simple, integral test cycle should be employed.**
5. **Load shed plans should be an integral consideration of the design. Upon the failure of any individual machine or component, a plan should be implemented to reduce the load to the extent necessary to continue near normal operation of the building.**

DURABILITY, MAINTAINABILITY, SERVICEABILITY

The durability (anticipated longevity) of the machinery and components employed in any system must be tailored to the perceived needs of the owner. As an example, in an administrative office building on a University Campus the owner usually has a long range ownership prospective and does not want to face the problem of replacing the machinery in, say, ten years. However, in a commercial office building, the owner (developer) may have his/her needs better met with less durable machinery of lower cost since his/her objective may be to lease the building, generate maximum revenue and sell the building in a few years.

The durability is intrinsically linked to the investment cost. However, the maintainability and serviceability must be considered at all times when selecting, placing, and installing system components. Some aspects that should be considered in all systems designs include:

- **Building service transformers and primary switching should be installed outdoors on-grade when possible. If this is deemed impractical, they should be installed indoors above-grade level (preferably) or in a below-grade equipment room or vault. No below-grade equipment rooms (electrical and/or mechanical) should be allowed if they are below the level that would allow gravity drainage through the sanitary or combination sewer system. In addition, such below-grade equipment rooms should be provided with no smaller than 6" floor drains appropriately spaced, one of which should be located in a sump sized for the emergency installation of an emergency high capacity sump pump. All drain lines from below-grade equipment rooms should be provided with a backflow (check) valve. No water or steam pipes should be installed in rooms housing main electrical switchgear.**
- **Accessibility for service should be provided to all moving or wearing parts and components that require inspection, cleaning, adjusting, connection or replacing.**
- **Construction contracts should require complete Maintenance and Service manuals for all mechanical, electrical, and electronic equipment, and the engineer for the respective system should take reasonable steps to assure that no requirements for such maintenance have been overlooked.**
- **Equipment should be designed for no less than the service life required by the owner, free of rattles, vibration, corrosion, erosion, wear, or other failure of non-maintainable or not readily replaceable components. If, in special cases, it is deemed**

necessary to install equipment of less anticipated service life, such cases should be limited to unitary type equipment which can be replaced in whole as a shorter term maintenance requirement.

- **If possible, equipment should be employed which does not require special technical skills for operation, maintenance or service, and which utilizes readily available components.**
- **If special skills are required for service or maintenance they must be readily available from local service agencies. Components should be available from local stock or obtainable by overnight delivery.**
- **The design of all machinery and apparatus must be arranged for easy inspection, maintenance, service and removal. Major components such as coils and tubes must be readily cleanable and removable without removing any building element.**
- **All electrical equipment should be designed to NEMA standards where applicable.**

OPERATIONAL CONSIDERATIONS

Systems and equipment selection should consider understandability and ease of operation in all regards. The systems should be designed such that failure of control system power will move the controls to a predetermined fail-safe operating mode. Unless there are more overwhelming reasons that dictate, heating/cooling systems should fail- safe in the "heating" mode in climates where temperatures below freezing can be experienced.

All systems and devices should be capable of remote setpoint adjustments, operating mode selections, and performance monitoring by a local and/or remote energy management system.

FLEXIBILITY

Most buildings, whether they be permanent institutional building, commercial office buildings or housing are often in a state of change and modification. Thus, all systems should be designed such that they can be readily adaptable to modifications in terminal configuration, expansion, capacity changes, and system supplements. Adequate spaces should be allowed in all buildings to reasonably accommodate future needs for conduits, pipes, ductwork and machinery.

Structural, mechanical, and electrical systems should be established during the schematic design phase and the coordination between these designs should be such that serious constraints are not placed upon the flexibility of any of these systems either as the design progresses or as subsequent needs might dictate.

****

Preceding any design effort, agreement between the owner and the design team should be reached on some qualitative or quantitative statement of each of the design parameters. If this is done the systems designer has a focused objective at all times. Then, applying the laws of physics to create an idealized design to meet these parameters should inevitably lead to a successful design effort.