Strategic Facility Guidelines for Improved Energy Efficiency In New Buildings

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ABSTRACT

The intent of this article is to offer a convenient list of strategic guidelines to help steer new building designs toward energy efficiency. It is hoped that the project owner, interested in achieving greater than average savings, will provide this list to the design team as part of their project intent instructions. To encourage its use and acceptance, emphasis is placed on keeping the list at a manageable size, with only proven solutions.

Through a top-down approach, using this document as a convenient tool, building owners can set the expectations of energy frugality, create positive changes in building practices, and reward themselves with operational savings.

INTRODUCTION

The old saying "an ounce of prevention is worth a pound of cure" is very applicable to creating energy efficient buildings. The economic realities of retrofitting existing buildings usually result in only the worst ones getting attention, with the average ones left to their life cycle. By contrast, evaluating improvements to designs that exist only on paper has a much smaller economic barrier to change, that being the differential cost from the standard designs. This simple fact makes it easier to create a new efficient building than forcing an older one to be more efficient.

A one-size-fits-all approach is not expected to work for every area of the country, nor for every business segment. Design practices, standard of care, and things that make practical sense will vary by region along with the climate differences and the business it serves. The content of this document was originally prepared for building owners in the Colorado Springs area, and will need local amending for use in other areas like Miami, Florida (all cooling, no heating), and Alaska (all heating, no cooling), and especially in areas with persistent high humidity. Still, many of the concepts presented will be applicable to many areas. One referenced text [1] provides recommendations by climate zone, acknowledging the regional differences. Local adjustments aligned with the eight climate zones are suggested, but beyond the scope of this text. As a starting point, basic allowances have been made to adapt climate-dependent criteria to other areas as follows:

- For most humidity-dependent HVAC operations, a distinction is made for climates that are either below 65 degF or above 75 degF wet bulb temperatures. Interpolation and judgment for points in between is required.
- Evaporative cooling constraints are unique and presented very conservatively, erring on the side of occupant comfort. The climate distinction presented is outdoor air consistently below 52 wet bulb and below 42 dew point. (1)
- Glazing U-value limits are relaxed in areas where HVAC heating is not used. Note that this suggests double pane windows anywhere HVAC heating is used.
- Glazing shading coefficients are relaxed in areas where HVAC cooling is not used, but are otherwise strict. Solar loads drive peak electrical demands if nothing else.

These climate-dependent items will no doubt be a work in progress, and so they are marked with an asterisk (*) with suggested criteria in *italics* for convenience in editing. I did my best!

<u>To the owner who may use this</u>: Not all of the suggestions will apply to all buildings, but many of them will. Don't worry that a number of these won't make sense in your particular building—but do ask the design team to explain which measures do not apply, and why. Doing so will reinforce your intentions to achieve operational savings by smart design decisions up front, and motivate the design team to make a good effort to accommodate.

THE FACILITY GUIDE SPECIFICATION AND THE TOP-DOWN APPROACH.

The approach used for this article is to tabulate a list of suggested "Dos and Don'ts," suitable for use in a facility **guide specification**. A guide specification is a hand-out document given to a design team at the beginning of a project to provide general instructions and owner preferences. The owner handing out the guidelines has more of an effect on the end result than the same suggestions made from a lone team member, hence the term **top-down**. These instructions are then integrated into the other governing documents and codes that eventually form the design. Traditional guide specifications, used by national accounts, campuses, and large facilities, spell out preferred manufacturers, acceptable types of piping, valves, light fixtures, pavement, etc. The concept of energy efficient guidelines in the owner's guide specification is a natural and overdue extension of an existing document. Even if the owner does not have a guide specification to add this to, the listed items in this document can be used in stand-alone fashion to serve the same purpose and provide the same benefit to the owner.

More Top-down Features

Beginning at the point of use is a common theme for all energy engineers. In the case of the office building, stipulating temperature values can have a pronounced effect on energy use. The indoor temperatures become design parameters that calculations and equipment sizing hinge upon. A design that requires 72 degF summer indoor conditions will be larger and use more energy than one designed for 76 degF, and yet with proper attire and humidity control, 76 degF is a very reasonable temperature. A 72 degF design can save energy by turning up the thermostat, but a 76 degF design will additionally conserve first-cost dollars. Many designers are reluctant to push the comfort envelope for fear of reprisal against them, and that is where the top-down support concept comes in. With management support, and some education and encouragement, paradigms can slowly change.

Integrated Design

With more creative design solutions such as **integrated design**, more options are apparent to design teams now than in the past. This concept acknowledges cases where decisions in one trade (e.g. electrical or architectural) benefit another trade (e.g. mechanical). It may seem odd, but traditional design practices are compartmentalized by trade, and haven't always allowed the big-picture benefits to find their way to the owner. This is partly due to traditional fee structures where design fees are influenced by the cost of construction; the resistance to downsizing anything becomes obvious in this light. The integrated design process allows an extra expense in one trade to be considered if it produces a corresponding savings in another trade. To avoid re-design costs, this is best implemented with emphasis on group schematic designs (to air out the ideas early), as well as requiring good cost-estimating skills on the design team. A good architect is needed who can be receptive to new ideas, flexible, encourage the integration process, and also know enough to call a halt to the options at some point to maintain a reasonable schedule and finish the job without escalating design fees. By carefully selecting the design team members, constructive opportunities will come from this process which are usually well worth the effort. Examples of integrated design concepts follow, many of them revenue-neutral with sustained energy benefits for "free."

- The added cost of high performance suspended film windows can be offset in some climates by the elimination of perimeter fin-tube heating.
- Downsizing cooling systems in conjunction with reduced lighting power design.
- Downsizing cooling systems in conjunction with improved window shading coefficients, films, or exterior shading systems.
- Downsizing heating and cooling systems by using 1 percent or 2 percent ASHRAE design outdoor weather conditions [2] instead of 0.4 percent, allowing the temperature to drift up a few degrees a few hours of the year.
- Downsizing a boiler or hot water unit by virtue of selecting higher efficiency equipment. Since output is the design driver, it is often possible to utilize the next smaller size unit, but at higher efficiency, to achieve the same result.
- Downsizing primary heating and cooling equipment in conjunction with upgrades in envelope elements like insulation or, especially, window shading.
- Downsizing primary heating and cooling equipment in conjunction with heat recovery systems.

- Downsizing fan and pump motors, and primary cooling equipment, by increasing duct and pipe sizes, filter areas, coil areas, etc., as the trade-off for using less transport energy. Note that the extra heat of transport energy elements, especially fans, often drives the equipment size up a notch.
- Downsizing overhead lighting and HVAC cooling via an owner commitment to a greater use of task lighting.

In addition to downsizing, integrated design can be used as an investment tool, with utility use reduction as the return. If sufficient funding exists, the owner can allow upgrades with identifiable costs and annual savings to be proposed, with a stipulated payback period such as 2-5 years, to capture the fruit that is just above the proverbial low-hanging level. For example, an upgrade with a 10-year life and a 4-year simple payback is an equivalent internal rate of return (IRR) of 21 percent, which is an attractive return for investment dollars.

<u>To the energy engineer</u>: be SURE of your calculations, and even de-rate them, before leading your owner out with borrowed money.

Sustainability

The guideline includes instructions to the owner's staff as well as designers and contractors. This is because the construction of a well-performing building is not the end of the story. The energy and water use of the building will also depend upon user habits at the points of

Table 1.
Equivalent Rate of Return Values for Various Simple Payments

		ECM PROJECT LIFE			
		5YEAR	10 YEAR	15 YEAR	20 YEAR
	SIMPLE PAYBACK	IRR	IRR	IRR	IRR
	2	40.0%	49.0%	50.0%	50.0%
	3	**20.0%**	31.0%	33.0%	33.0%
	4	8.0%	**21.0%**	23.5%	24.6%
	5	X	15.0%	**18.0%**	19.4%
	6	X	10.6%	14.5%	**15.8%**
	7	X	7.0%	11.5%	13.0%
	8	X	4.3%	9.0%	11.0%
SPB typ	9	X	1.8%	7.1%	9.2%
10-yr max	10	X	X	5.5%	7.7%

Simple Payback vs. Internal Rate of Return
payback periods noted for various project lifespans that achieve greater than 15% rate of return

Derivation: Internal Rate of Return (IRR) is that interest rate where the present worth of the savings is equal to the initial investment.

$$P = A * (P/A, i, n)$$

$$P = A * \frac{(1+i)^n - 1}{i\,(1+i)^n}$$

so, for some value of i,

$$P/A \text{ (simple payback)} = \frac{(1+i)^n - 1}{i\,(1+i)^n}$$

use, and interaction with the building occupants is a vital component for program success. While many endeavors begin a long slide in performance after inception, it is a further intent of this document to encourage **sustainability** of operations. To this end, the suggestions for thorough documentation, commissioning, maintenance, and occupant education are included, and require an ongoing commitment by the owner.

STRATEGIC FACILITY GUIDELINES FOR IMPROVED ENERGY EFFICIENCY IN NEW BUILDINGS

Purpose:

- Implementation of the contents of this guideline will reduce facility energy use by 30-50 percent compared to ASHRAE 90.1 Base Building and Minimum Local Energy Codes.
- Suggested use of this document is for the project owner interested in achieving the stated savings to provide to the design team as part of their project intent guidance.

General:

- Design document submittals must include detailed narrative descriptions of system functionality, features, limitations, design assumptions, and parameters, for use by the owner. The narratives will be detailed enough to provide benefit to subsequent design teams, and will be written to be informative and useful to building operations personnel. The narrative will be provided as a deliverable with the schematic design, and will be updated with each subsequent design delivery including DD and CD phases. In its final form, this document shall be placed on the first sheet of the drawing set behind the title page, so that the information is retrievable years later when all that is available to facility operations are the drawings. Design assumptions include number of people, indoor and outdoor HVAC design conditions, foot-candles of illumination, hours of operation, provisions for future expansion (if any), roof snow load, rainfall rates, etc. that all define the capabilities of the building.
- All equipment schedules, including HVAC, plumbing, lighting, glazing, and insulation shall be put onto the drawings and shall not reside in the specification books, so that the information is

retrievable years later when all that is available to facility operations are the drawings.

- Design thermal insulation values and glazing properties that affect energy use (U-value, shading coefficient, etc.) shall be clearly noted on the drawings.
- Project commissioning that includes identifying measurable energy savings goals and monitoring the design and construction activities with these as project intent items, with early detection and notification of any project changes that impact energy use or demand.
- Project final payment contingent upon:
  - — Receipt of accepted accurate as-built drawings, with accuracy verified by owner and signed by the contractor.
  - — Receipt of accurate and complete O/M manuals, with certified factory performance data, repair parts data, and vendor contact information for all energy consuming equipment, including all HVAC and lighting equipment and controls.
  - — Receipt of test and balance report that demonstrates design intent is met for air, water, and ventilation quantities, showing design quantities, final adjusted quantities, and percent variance. This would include all VAV box minimum settings shown, including both heating and cooling balanced air quantities. This would also include any equipment performance testing that was specified for the project.
  - — Verification by the owner that the test and balance settings include permanent markings so these settings can be preserved over time.
  - — Receipt of on-site factory-authorized start-up testing for primary HVAC equipment including chillers and boilers, with efficiency and heat/cool performance figures and heat exchanger approach temperatures to serve as baseline. The submitted reports would include as a minimum heating/cooling output, gas/electric energy input, heat exchanger approach temperatures, water and air flows.
  - — Receipt of control shop drawings with detailed descriptions of operation.
  - — Acceptance testing of the automatic control system using the approved sequence of operation, and verification that the sequences are fully descriptive and accurate. Acceptance testing

also includes review of the control system man-machine interface provisions to become familiar with each adjustable point in the system. Acceptance is by the owner, who will witness each sequence as part of the turnover training requirements.

- Building design must prevent negative pressure condition, unless safety considerations require it.
- Electric resistance space heating, air heating, and water heating not allowed, unless there is no means to get natural gas to the site.
- Portable space heaters not allowed, unless required for an approved emergency measure.

Energy Use, Overall Performance:

- Using ASHRAE 90.1 or local energy code as a baseline, demonstrate through computer modeling that the building energy use will be at least 30 percent less than this value.

Irrigation Water Use, Overall Performance:

- Using standard Kentucky Bluegrass sod and average regional rainfall rates as a baseline, demonstrate that irrigation use for the property will be 50 percent or less of this value.

Test and Balance:

- Balance using "proportional balancing," a technique that strives to reduce throttling losses, which permanently energy transport penalties (pump and fan power).
- Any motor over 5 hp found to be throttled with a resistance element (valve or damper) more than 25 percent must be altered by sheave change or impeller trim to eliminate lifelong energy waste from excessive throttling losses.
- All 3-phase motor loads, including HVAC equipment, must include voltage balance verification as part of the TAB work. Voltage imbalance of more than (1) percent indicates unbalanced electrical service in the building and unacceptable efficiency losses.
- Vertical return air shafts serving multiple floors require a balancing damper at each branch outlet to proportion the return air by floor.
- Air flow performance testing for all ARI certified HVAC factory packaged unitary equipment greater than 5-tons capacity. Heating and cooling performance and efficiency verification is assumed via the ARI certification process.

- Heating efficiency, cooling efficiency, and air flow performance testing for all HVAC split system equipment greater than 5-tons capacity or 200,000 Btuh input heating capacity.
- Water flow performance testing for all ARI certified factory packaged water chillers. Cooling performance and efficiency verification is assumed via the ARI certification process.
- Water flow and combustion efficiency testing for all boiler equipment.
- Combustion efficiency testing for all boiler equipment unless factory startup is provided on site.
- Cooling tower thermal performance verification is assumed via the CTI certification process.

Electrical Service:

- Provide separate utility metering for electric, gas, and water for the building, separate from other buildings.
- Electrical transformer conversion efficiency not less than 95 percent efficient at all loads from 25 percent to 100 percent capacity. Dry-type transformers NEMA TP-1 compliant.
- Locate transformers in perimeter areas that do not require air conditioning for cooling.
- Power factor correction on large motor loads, for overall building PF of 90 percent or better. Large mechanical equipment can be provided with the correction equipment. If motor loads are segregated, this can be done at the switchgear.
- Arrange switchgear and distribution to allow metering of the following electrical loads (requires segregating loads):
    - Lighting
    - Motors and Mechanical
    - Plug Loads and Other

Envelope:

- Orient buildings long dimensions E-W where possible to reduce E-W exposure and associated solar load.
- Provide building entrance vestibule large enough to close one door before the next one opens (air lock).
- Where thermal breaks are used, the thermal break material must have thermal conductivity properties of the higher conductivity material it touches, and must be at least 1/2 inch thick.

- *Minimum wall insulation *25 percent beyond ASHRAE 90.1 values, but not less than R-19.* Insulation is generally not expensive during new construction. Incorporate exterior insulation system (outboard of the studs) for at least one half of the total R-value, to avoid thermal short circuits of standard metal stud walls, which de-rate simple batt insulation system by approximately 50 percent, e.g. a standard stud wall with R-19 batts between the studs yields an overall R-9.5.
- *Minimum Roof insulation R-value *25 percent beyond ASHRAE 90.1 values, but not less than R-30.* Insulation is generally not expensive during new construction. Select insulation that will retain its thermal properties if wet, e.g. closed cell material.
- Glazing meeting the following requirements:
  - — Thermal breaks required.
  - — *U-factor of 0.35 or less *where HVAC heating is provided.*
  - — *Low-E coatings on east- and west-facing glass *where HVAC cooling is provided.*
  - — *Max shading coefficient of 0.2 *where HVAC cooling is provided.* Note: any combination of tinting, coating, awnings, or other exterior shading can be used to achieve this. This is to say that no more than 20 percent of the heat energy from the sunlit glazing is to get into the building.
  - — Glazing not more than 25 percent of gross wall area.
- Skylight/Clerestory elements must meet the following requirements:
  - — Thermal breaks required.
  - — Triple pane (layer) construction with sealed air space(s).
  - — Overall U-value of 0.25 or less.
  - — *Skylight shading coefficient must be 0.2 or less *where HVAC cooling is provided.*
  - — *Low-E coating *where HVAC cooling is provided.*
- Skylight/Clerestory area not to exceed 5 percent of roof area.
- Return plenums and shafts designed with an air barrier for leakage not exceeding 0.25 cfm/square foot of building envelope surface area @ 50 Pa (EBBA Criteria). Shaft construction requires field testing and verification.
- Building envelope devoid of thermal short circuits. Provide thermal break at all structural members between outside and inside surfaces.
- Building leakage testing required (new buildings), with no more

than 0.25 cfm/square foot of building envelope surface area @ 50 Pa (EBBA Criteria).

- Utilize lower ceilings to reduce necessary light input power for equivalent light levels at the work surface.
- Utilize reflective (light) color interior colors for ceilings, walls, furniture, and floors, to allow reduced lighting power for comparable illumination. It can take up to 40 percent more light to illuminate a dark room than a light room with a direct lighting system.
- Good reflectance parameters to use when picking interior surfaces and colors follow. If these values are used and the lighting designer is informed of it, the integrated design process will allow reduced lighting power to achieve the desired light levels.
  - Min 80 percent reflective ceiling
  - Min 50 percent reflective walls
  - Min 25 percent reflective floor and furniture
- Provide operable blinds for vision glass.

Lighting:

- Follow ASHRAE 90.1 or local energy code requirements for lighting power budget guidelines, and verify that designs are lower than these limits while meeting current applicable IES lighting illumination requirements.
- Utilize task lighting and less on overhead lighting for desk work.
- Provide separate circuits for perimeter lights within 10 feet of the wall, to allow manual or automatic light harvesting.
- Use 1-2-3 switching for large open interior area spaces.
- Use ballast that will tolerate removing at least one bulb with no detriment.
- Where occupancy sensors are used, provide “switching ballast” that will tolerate large numbers of on-off cycles without bulb or ballast life span detriment.
- Use electronic ballast instead of magnetic ballast.
- Use ballast factor in the lighting design to improve lighting system efficiency. Because the ballast mostly determines how many watts are used, ballast choice is critical to achieving best energy efficiency.
- Coordinating light output with “ballast factor” is an excellent tool for providing optimum light levels and energy use.
- Use high power factor ballast, with minimum PF of 95 percent at all loads.

- Occupancy sensors in conference rooms, warehouses, and multi-function rooms. Also in locker rooms and restrooms, but with some continuous manual switched lighting in these areas.
- Photo-cell controlled lights in the vicinity of skylights.
- Do not use U-tube fluorescent lights, due to high replacement bulb costs.
- Do not use incandescent lights.
- Outdoor lighting on photocell or time switch.

Motors and Drives:
- All motors meet or exceed EPACT-1992 efficiency standards.
- VFD on all HVAC motors larger than 10 hp that have variable load.
- Motor nameplate HP not more than 20 percent higher than actual brake horsepower served (i.e. do not grossly oversize motors).

HVAC:
- Provide HVAC calculations and demonstrate equipment is not oversized. Equipment selection should not be more than 10 percent greater capacity than calculated values indicate.
- HVAC calculations will include both maximum and minimum heat/cool loads and equipment shall be designed to accommodate these load swings, maintaining heat/cool efficiency equal to or better than full load efficiency at reduced loads down to 25 percent of maximum load, e.g. equipment capacity will track load swings and energy efficiency will be maintained at all loads.
- Provide necessary outside air, but no more than this. Excess ventilation represents a large and controllable energy use. Reduce exhaust to minimum levels and utilize variable exhaust when possible instead of continuous exhaust. Reduce 'pressurization' air commensurate with building leakage characteristics. If the building is tested to low leakage as indicated herein, there should be little need for this extra air, or the heat/cool energy it requires. Design controls to dynamically vary outside air with occupancy.
- VAV box primary heating CFM shall be not higher than the cooling minimum CFM. This is to say the VAV box primary damper will NOT open up during heating mode.
- Zoning:
  — Design HVAC zoning to require heating OR cooling, not both. This will improve comfort and also reduce the inherent need for

simultaneous heating and cooling.
- — Do not zone any interior areas together with any exterior areas.
- — Do not zone more than three private offices together.
- — Do not zone more than one exposure (N, S, E, and W) together.

- Design and control settings for ASHRAE Standard 55 comfort envelope, which indicates 90 percent comfort in our climate at the following space temperatures:
  - — 71 degF heating
  - — 76 degF cooling
  - — Facilities may institute a range 68-72F heating and 74-78F cooling, provided a 5 degree dead band is kept between the heating and cooling settings.
- Do not heat warehouses above 60 degF.
- Do not cool data centers below 72 degF.
- Do not use electric resistance heat.
- Do not use perimeter fin-tube hydronic heating.
- *_In cooler climates_ where HVAC economizers are used, designs should normally favor air-economizers over water-economizers since the efficiency kW/ton is better for the air system. The water economizer "free cooling" includes the pumping and cooling tower fan horsepower, as well as the air handler fan. If the air handler fan power is considered required regardless of cooling source, the air-side economizer is truly "free" cooling.
- *_In very dry climates, with outdoor air wet bulb temperatures consistently less than 52 degrees and dew point consistently less than 42 degrees_, evaporative cooling (direct, indirect, or direct-indirect) should be used in lieu of mechanical refrigeration cooling, as long as indoor humidity of 40 percent rH or less can be maintained. To the water consumption issue, it is this author's opinion that water is a renewable resource and does not disappear from the planet like fossil fuels do, and so this technology should be used without environmental resources concern.
- Packaged HVAC cooling equipment not less than SEER-13 or EER-12, as applicable.
- *Air-side economizers for all rooftop equipment, regardless of size, _for climates with design wet bulb temperatures below 65 degF._
- Avoid duct liner and fiber-board ducts due to higher air friction and energy transport penalties.
- Insulate all outdoor ductwork to R-15 minimum.

- Use angled filters in lieu of flat filters, to reduce air friction loss.
- Reduce coil and filter velocities to a maximum of 400 fpm to lower permanent air system losses and fan power.
- Avoid series-fan-powered VAV boxes.
- For fan-powered VAV boxes, use ECM motors to achieve minimum 80 percent efficiency. Although the motors are not large, when there are many of them this efficiency benefit is significant.
- Heat recovery for any 100 percent outside air intake point that is greater than 5000 cfm when the air is heated or cooled.
- Air filter requirements:
  - — Terminal units (fan coils, fan powered boxes, unit vents): 20 percent (1-inch pleated) Note: this may require an oversize fan on small terminal equipment, and not all manufacturers can accommodate.
  - — Air handlers with 25 percent or less OA: 30 percent—MERV-7
  - — Air handlers with 25-50 percent OA: 45 percent—MERV-9
  - — Air handlers with more than 50 percent OA: 85 percent—MERV-13
  - — Provide manometers across filter banks for all air handlers over 20 tons capacity. Equip manometers with means to mark the "new-clean" filter condition, and change-out points.
- *Air cooled condensing units over 25 tons, provide evaporative pre-cooling, *for climates with design wet bulb temperatures below 65 degF.*
- Make-up meter for all hydronic systems to log system leaks and maintain glycol mix.
- Separate systems for 24-7 loads to prevent running the whole building to serve a small load.
- *Direct evaporative post cooling for all chilled water systems, *for climates with design wet bulb temperatures below 65 degF.*
- Require duct leakage testing for all ducts 2 in. w.c. design pressure class or greater.
- For process exhaust and fume hoods, design for variable exhaust and make-up.
- Utilize general exhaust air as make-up for toilet exhaust and other exhaust where possible.
- Dedicated outside air system (DOAS) for large office facilities (over 50,000 SF) with VAV systems, allowing ZERO minimum settings for all VAV boxes. This will eliminate the VAV reheat penalty, and eliminate the internal zone over-cooling effect from VAV minimums

which often requires running the boilers throughout the year for comfort control.

- Separate interior and exterior VAV zoning for open-plan rooms to utilize zero-minimums in the interior spaces.
- Do not use grooved pipe fittings in hydronic heating or cooling piping systems to prevent operating central heating and cooling equipment year-round on account of these fittings.
- Verify that all manufacturer's recommended clearances are observed for air cooled equipment.
- Humidification:
  — Do not humidify any general occupancy buildings such as offices, warehouses, or service centers.
  — In data centers ONLY, humidification should not exceed 30-35 percent rH.
  — Where humidification is used, humidifiers should be ultrasonic, mister, or pad type, and should not be electric resistance or infrared type.
  — Do not locate humidifiers upstream of cooling coils, to avoid simultaneous humidification—dehumidification.
  — Where humidification is used, provide for elevated apparatus dew point of cooling coils or other means to prevent simultaneous humidification—dehumidification.
- Dehumidification:
  — Do not dehumidify below 45 percent rH.
- Provide performance and efficiency testing of package heating and cooling equipment over 7000 CFM or 20 tons or 500,000 Btu input heating units with factory authorized equipment representatives. Test figures to include on-site gross heat/cool output, fuel and electrical input, and efficiency, compared to advertised values.

Energy Transport Systems—Energy Budget:

- For HVAC air systems, the maximum energy transport budget will be:
  — No less than 10 Btu cooling and heating delivered to the space per Btu of fan energy spent at design conditions.

    This will generally steer the design toward generous sizing of sheet metal ducts, air handler cabinetry, coils and filters, higher efficiency fans (0.7 or better), and higher system differential temperatures to reduce air flow rates, but will result in greatly reduced lifetime energy use since it lowers the bar of system pressure.

— Fan hp limitation from:
Cooling fan hp max input = Cooling Btu gross output/(10 * 3413 * motor-eff).

— Air hp limitation from:
Cooling fan hp max budget * fan-eff.

— TSP limitation from:
TSP = (air-HP * fan-eff * 6360)/CFM.

For example, a 100-ton HVAC air system using 80 percent e motor, 70 percent e fan, and 350 cfm per ton would be limited to 44 hp motor load and 3.9 inches w.c. total static pressure.

NOTE: for systems with both supply and return fans, the transport energy considers both combined as the "fan."

- For HVAC water systems, the maximum energy transport budget will be:
  - — No less than 50 Btu cooling and heating delivered to the space per Btu of pump energy spent, at design conditions.

    This will generally steer the design toward generous sizing of piping, strainers, coils, and heat exchangers, higher efficiency pumps (0.75 or better) and higher system differential temperatures to reduce water flow rates, but will result in reduced lifetime energy use since it lowers the bar of system pressure.

    - — <u>Pump hp limitation from</u>:
      Cooling pump hp max input = Cooling Btu gross output/(40 * 3413 * motor-eff).
    - — <u>Water hp budget from</u>:
      Pump max hp * pump-eff.
    - — <u>HEAD limitation from</u>:
      HEAD = (water-HP * pump-eff * 3960)/GPM.

Hydronic Circulating Systems:

- Heating: minimum 40 degree dT design, to reduce circulating flow rates and pump HP.
- Cooling: minimum 16 degree dT design, to reduce circulating flow rates and pump HP.

Boilers and Furnaces:

- No atmospheric burners.
- No standing pilots.
- Design hydronic system coils to return water to the boiler at or below 140 degree water with a minimum of 40 deg temperature drop. This will reduce circulating pump energy and improve boiler efficiencies.
- Minimum efficiency of 85 percent at all loads down to 25 percent load.
- For heating load turn-down greater than 4:1, provide modular boilers or a jockey boiler.
- For multiple boilers sharing multiple pumps, provide motorized valves to cause water flow to occur ONLY through the operating boiler.
- Provide stack dampers interlocked to burner fuel valve operation.

Chillers:

- *Water-cooled centrifugal efficiency 0.5 kW/ton or less with 70 degF condenser water and 45 degF chilled water *for climates with design wet bulb 65 degF and lower. 0.58kW/ton or less with 85 degF condenser water and 45 degF chilled water in climates where design wet bulb temperatures are above 75 degF.*
- *Water-cooled centrifugal units able to accept 55 degree condenser water at 3 gpm per ton, all loads. *Beneficial in dry climates with design wet bulb temperatures less than 65 degF and typical wet bulb temperatures less than 50 degF.*
- *Water-cooled positive displacement units 0.7 kW/ton or less with 70 degF entering condenser and 45 degF chilled water *for climates with design wet bulb 65 degF and lower. 0.81kW/ton or less with 85 degF condenser water and 45 degF chilled water in climates where design wet bulb temperatures are above 75 degF.*
- Do not provide chilled water temperatures less than 45 degF. Select cooling coils to provide necessary cooling with 45 degF chilled water or higher.
- Air-cooled chiller efficiency 1.0 kW/ton or less with 95 degF entering air.
- *Air-cooled chillers over 25 tons, provide evaporative pre-cooling *where design wet bulb temperatures are less than 65 degF.*

Cooling Towers:

- Selected for 7 degree approach at design wet bulb and 0.05kW/ton or less fan input power. This will steer the design toward a larger free-breathing cooling tower box with a small fan, minimizing parasitic losses from the cooling tower fan. Cooling tower fan kW/ton should not be more than 1/10th of the chiller it serves.
- *Set condenser water temperature set point to no higher than 70 degF *for climates with design wet bulb 65 degF and lower. For climates with higher wet bulb temperatures, design to 7 degrees above design wet bulb with reset controls to lower the setting whenever conditions permit.*
- Water treatment control for minimum 7 cycles of concentration to conserve water.
- Specify cooling tower thermal performance to be certified in accordance with CTI (Cooling Tower Institute) STD-201.

Air-Cooled Equipment and Cooling Towers in Enclosures:

- Locate to prevent air short-circuiting and associated loss of thermal performance. Rule of thumb is the height of the vertical finned surface projected horizontally. The fan discharge must be at or above the top of the enclosure, the distance to the enclosure walls should be as indicated above, and there should be amply sized inlet air openings in the enclosure walls as low as possible.

Ground Source Heat Pumps:

- COP 4.0 or higher at 40 degF entering water.
- EER 17 or higher at 80 degF entering water.
- No electric resistance heating.

Controls:

- Design OUT all simultaneous heating and cooling through the use of proper zoning, interlocks, and dead bands. This includes all constant volume systems and terminal unit systems. VAV systems inherently have an overlap which should be minimized by water and air reset in heating season, prudent use of minimum VAV box settings, and consideration of systems that separate the outside air from the supply air.
- Programmed start-stop for lighting and HVAC systems, with option for temporary user overrides. Use these controls to prevent

unnecessary operating hours.

- Lock out air flows for conference rooms and intermittent occupancy rooms by interlocking VAV box to close with occupancy sensors.
- Lock out chiller operation below 50 degrees, except for data centers or humidity-sensitive areas that cannot use outside air for cooling.
- Lock out boiler operation above 60 degrees, unless space temperatures cannot be maintained within the specified ranges any other way.
- *All cooling by air economizer below 55 degrees *for climates with design wet bulb 75 degF and lower.*
- Night setback for heating. Suggested temperature for unoccupied time is 60 degF.
- No night set-up for cooling—no cooling operation in unoccupied times for general occupancy buildings. If building temperature rise during unoccupied times can cause detriment, then limit off-hours cooling operation to 85 degrees indoor temperature.
- Reset boiler hot water temperature settings in mild weather.
- *Reset chilled water temperature settings in mild weather, *provided outdoor air dew point is below indoor dew point levels.* Refrigeration savings generally exceeds increases in pump power.
- Provide appropriate interlock for all exhaust fans to prevent infiltration of outside air from uncontrolled exhaust fans that operate in unoccupied times.
- All analog instruments—temperature, pressure, etc. other than on-off devices—must be calibrated initially (or verified for non-adjustable devices). Merely accepting out-of-the-box performance without verification is not acceptable.
- 2-year guarantee on calibration, with 18-month re-calibration of all analog inputs.
- Air handler control valves with a residual positive seating mechanism for positive closure. Use of travel stops alone for this is not acceptable.
- For terminal units and heating/cooling hydronic water flow rates less than 10 gpm, use characterized ball valves for control valves instead of globe valves or flapper valves, for their inherent improved long-term close-off performance. This will reduce energy use from simultaneous heating and cooling.
- Valve and damper actuator close-off rating at least 150 percent of max system pressure at that point, but not less than 50 psid (water)

and 4 inches w.c. (air).

- Dampers at system air intake and exhaust with leakage rating not more than 10 CFM per square foot at 4" water column gage when tested in accordance with AMCA Standard 300.
- Water coil control valve wide open pressure drop sizing not to exceed the full flow coil water-side pressure drop.
- Provide main electrical energy and demand metering, and main gas metering. Establish baseline and then trend and log "kBtu/SF," "kW/SF-yr," and "kW demand" perpetually and generate alarm if energy use exceeds baseline.
- Implement demand-limiting or load leveling strategies to improve load factor and reduce demand charges. Stagger-start any large loads, e.g. morning warm-up or cool-down events. Use VFDs to limit fan, pump, chiller loads to 90 percent during peak hours, etc.
- Independent heating and cooling set points for space control.
- Space temperature user adjustment locked out or, if provided, limited to +/- 2 degrees.
- 5 degree dead band between space heating and cooling set points to prevent inadvertent overlap at zone heat/cool equipment, and from adjacent zones.
- 5 degree dead band between air handler heating and cooling (or economizer) set points, e.g. preheat coil cannot share a single, sequenced, set point with the economizer or cooling control.
- Provide separate lighting and HVAC time schedules.
- For chillers (condenser) and hot water boilers, use temperature sensors to log heat exchanger approach values, to prompt predictive maintenance for cleaning fouled heat exchange surfaces. New-equipment approach will be the baseline value, and approach temperature increases of 50 percent will prompt servicing.
- Interlock heating and cooling equipment in warehouses serving doorway areas to shut off when roll-up doors are open to reduce waste.
- Optimization routines:
  — Automatically adjust ventilation rates for actual people count.
  — Optimal start to delay equipment operation as long as possible.
  — Demand limiting control point that will limit all VFD-driven air handler fans components to a maximum of 90 percent max output in summer. This will cause system temperatures to drift up slightly during extreme weather, but will reduce electrical

demand for this equipment (and the cooling equipment it serves) compared to full output operation, during times when utility demand is highest. Do not oversize equipment capacity to compensate for this requirement.

— Optimal static pressure setting based on VAV box demand, not a fixed set point. This is a polling routine.
— **For areas with design wet bulb temperatures below 65 degF only,* optimal supply air reset that will reset the supply air temperature set point upward from 55 to 62 for VAV systems during heating season, to reduce reheat energy. This can either be from two methods.
  * Method 1. Basic Optimization. When the main air handler fan is below 40 percent of capacity and OA temperature is below 40 degrees.
  * Method 2. Fully Optimized. Polling VAV boxes (at least 80 percent of the boxes served are at minimum air flows).
— Do not reset SA temperature from return air. Do not reset SA temperature during cooling season.
— Reset condenser water temperature downward when outdoor conditions permit, using the lowest allowable condenser water the chiller can accept.

Plumbing:

- Max shower flow 1.5 gpm.
- Max bathtub volume 35 gallons.
- Max urinal water flow 0.5 gpf, or waterless.
- Max lavatory water flow 0.5 gpf.
- Metering (self closing) or infrared lavatory faucets.
- Avoid single lever faucets since these encourage complacency for the use of hot water.
- All domestic hot water piping insulated.
- Heat trap in domestic hot water main outlet piping.
- If a circulating system is used, provide aquastat or timer to prevent continuous operation.
- Max domestic hot water temp for hand washing 125 degrees.
- Gas water heaters in lieu of electric where natural gas is available.
- Domestic water heater equipment separate from the building boiler and heating system, to prevent year-round operation of central heating equipment.

- Water fountains instead of chilled water coolers.
- Operate the building at reduced pressure (such as 50 psig) instead of 70 psig, to reduce overall usage. Verify that design maintains at least 10 psig over the required minimum pressure at all flush valves.

Management and Maintenance Activities to Sustain Efficiency:

- Management Support
  - Create buy-in from the building occupants. Distribute information to building occupants to raise awareness of energy consumption, especially communicating that the user's habits are an essential ingredient to overall success, and are useful and appreciated. This would be in the form of occasional friendly and encouraging reminders of how user participation is helping, fun facts, etc., along with estimated benefits from behavior changes. Provide measured results whenever available.
  - Enforce temperature setting limitations, including the explanation of why this is helpful and also why it is reasonable. Encourage seasonal dress habits to promote comfort and conservation together.
  - Prohibit space heaters.
  - For offices, utilize LCD monitors and the software-driven "monitor power-off" feature, since the monitor represents 2/3 of the whole PC station energy use.
  - Track monthly energy and water use and maintain annual graphing lines, comparing current and prior years. Establish new benchmark curves after major renovations, alterations, or energy conservation projects. Compare annual use to benchmark and verify building energy and water usage per SF is not increasing. Report results to the building occupants as an annual energy use report for their feedback.
  - Escrow (save) approximately 5 percent of the replacement cost per year for the energy consuming equipment in the facility that has a normal life cycle, such as HVAC systems, lighting systems, control systems. This will allow 20-year replacement work without 'surprises' to sustain efficient building operations.
  - For leased office space, show the tenants their utility costs to increase awareness and encourage conservation by the users. The typical industry arrangement is to build in utilities into the lease

price, so the tenants do not see a separate utility bill. Although the customers are paying for the utilities, having those costs clearly shown will reduce the complacency in utility use.

- Chillers:
  - — Owner provides annual equipment "tune up," including cooling efficiency testing and heat exchanger approach measurements.
  - — Owner adjusts temperature settings or cleans heat exchangers, or adjusts water flows whenever cooling efficiency tests are less than 90 percent of new-equipment values. For example, if the new equipment benchmark is 0.5 kW/ton, then a measurement of 0.5/0.905=0.55 kW/ton would trigger corrective action.

- Boilers:
  - — Owner provides annual equipment "tune up," including combustion efficiency testing and heat exchanger approach measurements.
  - — Owner adjusts temperature settings, cleans heat exchangers, or adjusts air-fuel mixture whenever combustion efficiency tests are less than 95 percent of new-equipment values. For example, if new equipment benchmark is 80 percent, then a measurement of 0.8*0.95=0.76 would trigger corrective action.

- HVAC air coils:
  - — Owner changes filters at least quarterly, and verifies there are no air path short circuits allowing air to bypass the filters.
  - — Owner cleans HVAC coils whenever there is any sign of visible accumulation or if air pressure drop is found to be excessive.

- HVAC air-cooled condensers:
  - — Owner provides location free from debris, leaves, grass, etc. and adequate spacing for free 'breathing' and no re-circulation.
  - — Owner cleans heat exchange surfaces annually.

- Controls
  - — Owner re-evaluates system occupancy several times each year,

to reduce unnecessary HVAC and lighting operating hours.

— Owner re-evaluates control set points each year including space temperature settings, duct pressure settings, supply air temperature settings, reset schedules, heating and cooling equipment lock-out points.
— Owner re-calibrates control instruments each two years other than on-off devices.
— Owner cycles all motorized valves and dampers from open to closed annually, and verifies tight closure.
— Owner cycles all VAV box dampers from open to closed annually and verifies the control system is responsive, since these often have a short life and can fail without the user knowing it.

CONCLUSIONS

The listed items in this document are intended to supplement traditional facility guide specifications, as a tool to help steer new building designs toward sustained low energy use.

It is easier to design efficiency into a new building than to retrofit an existing one, for practical and monetary reasons. While we continue to search for ways to upgrade existing buildings, we should influence the new buildings as much as possible for the long term benefits. Engineers and architects alone may understand the benefits and opportunities available, but may not be effective at altering the default course of events for new building designs. The most effective way to assure energy savings as a built-in feature is through a top-down approach where owner support conveys efficiency as a design team priority. The energy-efficient design commitment is made more effective through the use of integrated design, and commissioning can be an effective tool to be certain the design intentions are realized through construction. The sustained energy efficiency goal requires an ongoing commitment from the owner, maintenance staff, and building occupants, and includes training, appreciation, and feedback.

Footnotes

1. This will no doubt be debated by some designers in semi-arid climates. However, experience has shown that at moisture levels much above these values it becomes increasingly hard to *guarantee* comfort all the time. Since the choice to use evaporative

cooling is a large fork in the road for the customer, presenting conservative parameters is deliberate and are sure to work. If evaporative cooling is chosen in "fringe" climates, a supplemental conventional cooling system integrated into the first stage of evaporative cooling is suggested.

References

1. Advanced Energy Design Guide for Small Office Buildings, ASHRAE, 2000.
2. ASHRAE Fundamentals Handbook, 2001.

ABOUT THE AUTHOR

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