



Developing a Design Review Tool for Use in the Commissioning Process

Kenneth L. Gillespie, Jr.
Pacific Gas and Electric Company

Karl Stum, P.E.
Summit Building Engineering

Kristin Heinemeier, Ph.D., P.E.
Portland Energy Conservation, Inc.

Gail Stranske, P.E.
CTG Energetics



*Pacific Gas and
Electric Company™*

Overview



- Energy Design Resources and Cx Assistant
-Ken Gillespie
- The Design Review Tool
-Kristin Heinemeier
- Items to Check in a Design Review
-Karl Stum

www.energydesignresources.com

energydesignresources

YOUR GUIDE TO ENERGY EFFICIENT DESIGN PRACTICES

By Topic

DESIGN PRACTICES

[Integrated Energy Design](#)[Building Commissioning](#)[Energy Detailing](#)[Financial Analysis & Benefits](#)

ENERGY EFFICIENT TECHNOLOGIES

[Lighting Design](#)[Daylighting Design](#)[Building Envelope Design](#)[HVAC Design](#)

By Building Type

[Schools](#)[Offices](#)[Retail Stores](#)[Manufacturing & Distribution Facilities](#)[Hospital & Labs](#)[Libraries & Assembly Buildings](#)

By Resource

PUBLICATIONS

[Design Guidelines](#)[Design Briefs](#)[Case Studies](#)[Newsletters](#)

SOFTWARE

[eQUEST](#)[eVALUator](#)[SkyCalc](#)[EDR Charette](#)[Commissioning Assistant](#)

TRAINING

[Virtual Workshops](#)[On-Site Seminars](#)[Energy Centers](#)

RESOURCES

[Organizations](#)[Codes & Standards](#)[End Use Technologies](#)[General Resources](#)[Latest Efficient Design News](#)

CLICK HERE

Welcome

Energy Design Resources is a resource center for information on energy efficiency design practices. [More on EDR...](#)

Designing in CALIFORNIA?

www.savingsbydesign.com

Order CD-Rom

These tools and resources are also available on a CD-ROM. [Order now...](#)

DESIGNERS Sign-up for e-News

Cx Assistant Modules: Output Based on Project Specifics



- Probable Cx cost
- Appropriate Cx scope (& draft scope)
- Customized draft design intent
- Customized draft basis of design
- Sample Cx Specifications
- Sample Sequence of Operations (reflects T24)
- Customized draft Cx Plan
- Customized draft Cx training plan
- Customized draft systems manual

Levels of Cx in the Cx Assistant



Cx Path			Commissioning Process Element
Abbreviated	Standard	Comprehensive	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Design Intent Document
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Commissioning Plan
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Design Development Design Review
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Construction Documents Design Review
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Commissioning Specification Development
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Submittal Review

Objectives of Tool



- Flexible checklist that can be used directly or adapted
- Used by experienced CxP, designer, or owner to organize and track a design review:
 - including enough information to “remind” them of the issues that need to be checked, ensuring review is complete and methodical.
- Also used by a less experienced CxP, designer, or owner to provide additional information and resources
- Useable for a range of design review applications
 - (sampling, thorough peer review, or quality control)
- Integrated with the existing Cx Assistant tool
- Allows additional checks to be added in the future

Design Review “Checks”



- Nearly 800 checks that designers or commissioning providers can use in reviewing a design

The mixed air low limit control is clearly specified and is not higher than it needs to be, recognizing that in cold climates, with high minimum outdoor air fractions (and preheat coils) a mixed air low limit may not be appropriate. Higher mixed air low limit values reduce economizer hours.

- Selected based on the experience of the tool developers and peer reviewers

Organization



- “Design Review Areas”
 - “Issues”
 - “Checks”

Design Review Area 14: Outdoor Air Control Issues

Issue 14.4: Economizer sequence of operation is clear and adequately describes proper operation

Check 14.4-B: The mixed air low limit control is clearly specified and is not higher than it needs to be, recognizing that in cold climates, with high minimum outdoor air fractions (and preheat coils) a mixed air low limit may not be appropriate. Higher mixed air low limit values reduce economizer hours.

Selection of Scope



- Include all checks
- Automatically filter the checks according to:
 - System
 - Phase (Design Documents, Construction Documents, or Submittals (or all phases))
 - Direct Impact on Energy
- Manually eliminate checks



Design Review Filter - Cx Assistant Design Review Module

[Cx Assistant](#)

[Home](#)

[Other Cx Modules](#)

-REQUIRED DATA

[General Info](#)

[AHUs](#)

[Plant](#)

[DHW](#)

[Lighting](#)

[Cx Process](#)

[Commissioned Systems](#)

[Design Review Topics](#)

-COMPLETED DATA

[General Info](#)

[AHUs](#)

[Plant](#)

[DHW](#)

[Lighting](#)

[Cx Process](#)

[Commissioned Systems](#)

Which design review areas would you like to include?

- Only the items relevant the Equipment specified for this project
- All items

Would you like to include the design review elements that should be reviewed in all phases of the design/construction process, or limit the items to a specific phase of design/construction?

- Display for all phases of design/construction
- Display only items that should be checked in the design documents review
- Display only items that should be checked in the construction documents review
- Display only items that should be checked in the design or construction documents reviews
- Display only items that should be checked in the contractor submittals

Would you like to limit the Design Review Topics displayed to those having direct energy implications

- No
- Yes

Automatically Filtering

Select Elements of Commissioning Process - Cx Assistant Design Review Module

- [Cx Assistant Home](#)
- [Other Cx Modules](#)
- REQUIRED DATA**
 - [Design Review Topics](#)
- COMPLETED DATA**
 - [General Info](#)
 - [AHUs](#)
 - [Plant](#)
 - [DHW](#)
 - [Lighting](#)
 - [Cx Process](#)
 - [Commissioned Systems](#)

Please select the Design Review areas you would like to include for the project. To select subtopics, click on the "+" link, and select the subtopics you would like to include. To view the details of what will appear on the Checklist, or Reference Guide for any topic, click on the link for the relevant topic.

Once you have selected all the topics you would like to include for the project, click on the appropriate button to generate a project specific **Checklist** or a **Reference Guide** for the Design Review.

Expand	Review Area	Include?
+	Sequence of Operation and Control Drawing Issues	<input checked="" type="checkbox"/>
+	Sensor Issues	<input checked="" type="checkbox"/>
+	Maintainability Issues	<input checked="" type="checkbox"/>
+	Constructability Issues	<input checked="" type="checkbox"/>
+	Design Clarity	<input checked="" type="checkbox"/>
+	Specification of Requirements, Roles and Responsibilities Issues	<input checked="" type="checkbox"/>
+	Energy Efficiency Issues	<input checked="" type="checkbox"/>
+	Air and Water Balancing Issues	<input checked="" type="checkbox"/>
+	Outdoor Air Control Issues	<input checked="" type="checkbox"/>
+	Duct Design Issues	<input checked="" type="checkbox"/>
+	Building and Space Pressurization Issues	<input checked="" type="checkbox"/>

Deselecting Items

Outputs



- Checklist
 - Open or Save a Word document with a Checklist Table, to be used in design review

Phase (Doc ID; Date):

DD: 100% DD, 6/7/07

CD: 90% CD, 10/23/07

Sub: 06/15/08

ID	Check	Phase to Ck	Review in Phase? (Note 1)	Ck'd: Plans, Specs, Cut-sheets, Shop Drawings	Method: Sampled (%), Revu'd All	Chk in Next Submission?	Results: OK or Comments Added to Report
AIR AND WATER BALANCING ISSUES							
	Drawings and specifications are coordinated and contain sufficient technical data.						
1	Specific requirements that appear in the Owner's Project Requirements and Basis of Design are clearly stated. For example: <ul style="list-style-type: none"> Construction-quality leakage (leakage from everything but the actual raised floor plate) is less than 8% of total design flow at 0.05 in. WC pressure. Floor plate leakage (with diffusers sealed) is less than 17% of design flow at 0.05 in. WC pressure. 	DD	○	S	A	N	A
		CD	●				
		Sub	N/A				
2	The diversity factor for air and hydronic flows is determined from review of the equipment schedules (see next check) and matches the design intent obtained from the designer.	DD	○	P; S	S	Y	IN
		CD	●	P; S	S	--	OK
		Sub	●				
3	The sequences of operation will work with the piping and valve layout (e.g., bypass leg in primary / secondary systems, proper isolation in common header systems and overflow of primary chiller loops). This can be verified from review of the flow schematic and flow rates.	DD	○	P; S	A	Y	IN
		CD	●	P; S	A	--	A
		Sub	N/A				

Check items in Phase to Ck column during Design Development (DD), Construction Documents (CD) or contractor Submittals of cut sheets and shop drawings (Sub).

○: An open circle indicates that a preliminary review may be conducted if there is sufficient detail, otherwise it may be deferred till a later phase.

●: A filled circle indicates that a complete review should be completed during this phase.

N/A: N/A indicates that the review is not relevant for that phase. IN = Insufficient progress in this design submission to make a substantive review of this Check.

Outputs



- Checklist
 - Open or Save a Word document with a Checklist Table, to be used in design review
- Reference Guide
 - Open or Save a Word document with more description of checks, to be used as a reference

Reference Guide

Air and Water Balancing Issues

Proper air and water balancing are essential for proper functioning of HVAC systems, ensuring that they maintain comfort and air quality in the most energy efficient manner possible. Technically sound and transparent design, combined with clear instructions to the air balancing contractor are needed, but they are not always found in design documents. Too often the contractor, because of insufficient information, makes improper decisions in the field or unneeded requests for information, and change orders are needed to properly balance the system.

Below are four categories of balancing issues, each with a number of checks.

1. Drawings and specifications are coordinated and contain sufficient technical data
2. Flow and riser diagrams for major systems (chilled water, heating water, and air) are included
3. Sufficient and appropriate balancing dampers or valves are shown in drawings and in the specifications
4. Balancing requirements are complete and clear

1. Drawings and specifications are coordinated and contain sufficient technical data

Checks:

		DD	CD	S
A.	<i>Specific minimum outside air quantities and set up parameters are shown on drawings (e.g., set air quantity with 75% of air terminal boxes in heating). See Design Area 14 Outdoor Air Issues.</i>	X	XX	
B.	<i>The diversity factor for air and hydronic flows is determined from review of the equipment schedules and matches the design intent obtained from the designer.</i>	XX	XX	
C.	<i>Air flow quantities on the mechanical floor plans correlate with the totals in the equipment schedules. For example, if the floor diffusers totaled 30,000 cfm and assuming 5% duct leakage, 5% reasonable safety factor, and 85% as a reasonable diversity factor, then the equipment schedule should show the fan to be 28,100 cfm (30,000 x 1.05 x 1.05 x 0.85).</i>	X	XX	
D.	<i>The sequences of operation will work with the piping and valve layout (e.g., bypass leg in primary / secondary systems, proper isolation in common header systems and overflow of primary chiller loops). This can be verified from review of the flow schematic and flow rates.</i>	X	XX	

Outputs



- Checklist
 - Open or Save a Word document with a Checklist Table, to be used in design review
- Reference Guide
 - Open or Save a Word document with more description of checks, to be used as a reference
- Either will include all the Design Review Areas, Issues, and Checks that were determined with the filters and selections

Breadth of Issues & Checks



- Design concepts
 - e.g., hydronic piping of chiller plant
- Equipment specific issues
 - e.g., VFD bypass functions & sequences of operation
- Clarity of roles and responsibilities
 - e.g. who writes Cx test procedures / scripts
- Construction processes
 - e.g., air sealing in UFAD
- Design guide or design review guide?

Examples of Design Review Areas, Issues, and Checks



Design Review Areas:

- 1 Sequence of Operation and Control Drawing Issues
- 2 Sensor Issues
- 3 Control Software and Hardware Issues
- 4 Maintainability Issues
- 5 Constructability Issues
- 6 Clarity and Detail of Contract Documents
- 7 Specification of Requirements, Roles and Responsibilities Issues
- 8 Test Port and Gauge Issues
- 9 Energy Efficiency Issues
- 10 Air and Water Balancing Issues
- 11 Underfloor Air Distribution Issues
- 12 Moisture Issues – Envelope and HVAC Related
- 13 Staging and Low-Flow Operation Issues
- 14 Outdoor Air Control Issues
- 15 Duct Design Issues
- 16 Pump, Piping and Plant Design Issues
- 17 Building and Space Pressurization Issues
- 18 Daylight Dimming Issues

Example Design Review Issues



7. Specification of Requirements, Roles and Responsibilities Issues

7-1: Contractor and supplier commissioning requirements included in the specifications are complete, clear and consistent.

7-2: Training requirements are clear and complete.

7-3: Contractor controls submittal requirements are clear and complete.

7-4: Equipment feature and installation requirements are clear.

Example Design Review Checks



7-1: Contractor and supplier commissioning requirements included in the specifications are complete, clear and consistent.

7-1A: Specification clearly states the commissioning requirements and responsibilities are consistent with the owner's project requirements. The specification is organized such that the roles and responsibilities of various supplier and subcontractors are reasonably apparent during bidding.

7-1B: Contractor commissioning responsibilities are referenced in Division 1 and in the general section of each division with commissioning responsibilities, preferably also in the technical equipment specification, particularly when the equipment supplier has commissioning responsibilities. The fact that commissioning is required is clearly stated, and reference is made to the main commissioning sections.

7-1C: Specification clearly states the commissioning and testing responsibilities of the contractors and commissioning provider for each equipment discipline (electrical, fire life safety, security, etc. vs. conventional HVAC). A check and testing responsibility matrix by equipment has been included.

7-1D: Specification clearly states who creates construction checklist and functional and performance test forms, who reviews and approves them, who fills them in during execution and who reviews and approves them when complete. A check and testing responsibility matrix by equipment has been included.

... (11 checks total)

A Closer Look



7-1D: Specification clearly states who creates construction checklist and functional and performance test forms, who reviews and approves them, who fills them in during execution and who reviews and approves them when complete. A check and testing responsibility matrix by equipment has been included.



7: Specification of Requirements, Roles and Responsibilities Issues



7-1: Contractor and supplier commissioning requirements included in the specifications are complete, clear and consistent.

7-1I: Specification clearly states performance acceptance criteria. Examples include: space conditions (dry bulb, RH), equipment efficiency (chillers and boilers), control loop performance (e.g., control air handler discharge air temperature to +/- 1.0F without hunting), control system network speed (workstation refresh rate), and other project requirements.

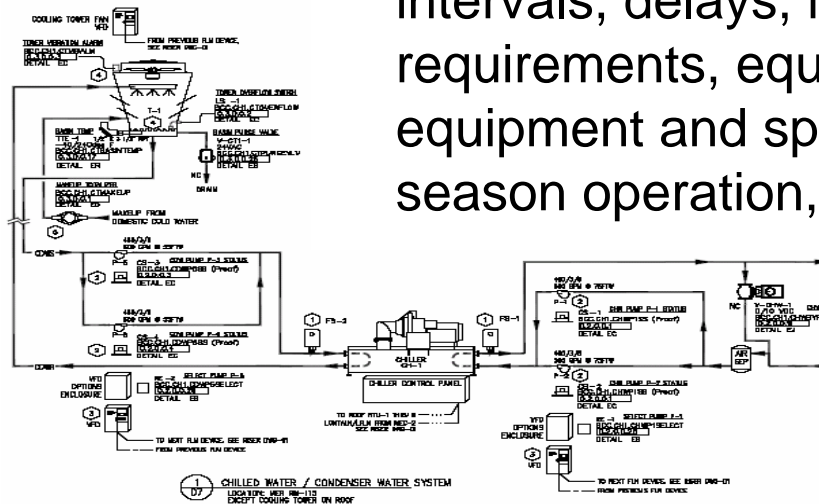


7: Specification of Requirements, Roles and Responsibilities Issues



7-3: Contractor controls submittal requirements are clear and complete.

7-3D: Control sequences of operation submittal requirements include: enhancing the designer's sequences to include all of the following detail that is missing, incomplete or inaccurate: Equipment starting and stopping, staging up and down, capacity control, resets, lockouts, deadband intervals, delays, interlocks, loss of power results, power reset requirements, equipment failure and standby response, all equipment and specified control features, low load and off season operation, delineation of control and monitoring for interfaces with packaged equipment.



13: Staging and Low-Flow Operation Issues



13-1: Chiller, boiler or DX staging plan is clear and will work as intended

13-1C: Conditions for staging up and down, deadband settings and/or delays are clearly specified and provided at each stage of primary plant equipment to prevent pre-mature staging and short cycling. A method is explicitly given for managing the transient spiking up and down of flows and resultant changes in chilled water supply temperature during chiller staging to prevent short cycling.



13: Staging and Low-Flow Operation Issues



13-2: Chillers and boilers cannot operate at low enough loads without short cycling.

13-2B: The designer has considered installing a small local chiller to handle very low load requirements, rather than hot gas bypass on the main chiller (trading off the higher first costs against long-term energy savings).

13-2C: Sequences clearly describe how short cycling will be avoided at low loads. Minimum flow rates are clearly described in the sequences. Installation of equipment and piping are consistent with the sequence.



11. Underfloor Air Distribution Issues



11-1: Air sealing details are effective and clear.

11-1A: All details (arch., struc. and mech.) relating to areas of pressurization actually show the sealing method required for the specific instance.



11. Underfloor Air Distribution Issues



11-1: Air sealing details are effective and clear.

- 11-1B: All space **temperature sensors in walls** are sealed from any communication with wall cavity air (even when walls are sealed at their perimeter). This requires the J-box to be sealed on its outside or inside and the box edge to be sealed to the sheet rock. This includes sealing the wiring to the inside of control conduits (where wire enters or exits the conduit) that come up from pressurized underfloor areas.
- 11-1C: Each **opening between the underfloor space and a wall or floor cavity** or to other spaces or zones is necessary and all openings that should not be communicating to the underfloor space are sealed.
- 11-1D: Requirements are included for the underfloor perimeter along **exterior walls and above unconditioned spaces** to be sealed absolutely airtight (drywall or sheet metal to concrete deck, vertical and horizontal drywall joints, other penetrations). Requirements are included for caulking of any overlapping or butting building elements used as a seals.
- 11-1E: Requirements are included for any penetrations from **underfloor space into interior walls** to be sealed reasonably airtight, as well as caulked (drywall to concrete deck, vertical and horizontal drywall joints, around duct, pipe, conduit, and cabling penetrations). Requirements are included for all framed walls extending below the raised floor to be sheet rocked and sealed.
- 11-1F: Requirements are included for **open ends of conduits** in underfloor space to be sealed with caulk.
- 11-1G: Requirements are included for **penetrations of ducts and piping** and other assemblies through the concrete subfloor or through the raised floor to be sealed.
- 11-1H: Requirements are included for **raised floor panels butting finished walls** to be gasketed and sealed reasonably tight.
- 11-1I: Requirements are included for **mock-up and pressure/leak testing** prior to all floors being installed, for any complex or not well understood cases.

11. Underfloor Air Distribution Issues



11-5: Balancing requirements are complete.

11-5C: Requirements are included for the balancer to determine the lowest under floor static pressure that can maintain design cfm at the furthest diffusers and set the setpoint at that value (unless reset). Diversity assumptions are included in the requirement, as appropriate.



11. Underfloor Air Distribution Issues



11-6: Performance and performance testing requirements are adequate.

11-6A: Specific requirements that appear in the Owner's Project Requirements and Basis of Design are clearly stated in the project specifications. For example:

- Construction-quality leakage (leakage from everything but the actual raised floor plate) is less than 8% of total design flow at 0.05 in. WC pressure.
- Floor plate leakage alone with carpet installed and diffusers and data / electrical boxes sealed (with diffusers sealed) is equal to or less than the floor panel manufacturer's certified leakage rate. If no certified leakage rate exists, the leakage is less than 15% of design flow at 0.05 in. WC pressure. Note, that some manufacturer's floor plate leakage rates are is near zero. The floor plate leakage is determined by subtracting the construction-quality leakage from the total system leakage.
- The above two criteria result in a total system leakage, which shall be tested after carpet is laid with diffusers sealed and shall be less than the sum of the construction leakage and floor plate leakage criteria. This total system criteria is only valid in conjunction with a passing construction-quality leakage test.

9. Energy Efficiency Issues



9-5: Air handler moderate cost or more involved system energy efficiency features are utilized.

9-5O: For DX air handlers with water-cooled condensers, the entering condenser water temperature is reset based on outdoor wet bulb or surrogate conditions. See cooling tower control under Low-Cost Chilled Water ideas.



9. Energy Efficiency Issues



9-8: No-cost/low-cost chilled water energy efficiency measures are utilized.

9-8F: Cooling tower capacity is optimized by using the following stages: 1) running condenser water over all towers with fans off, 2) starting all fans on low speed, and 3) ramping all fans up together. (Multiple fans running on low speed use less energy than a single fan at high speed, due to the cube law of power to flow). The condenser water flowrate for any tower should never go below one-half of its design flowrate without checking with manufacturer first, and it should generally never go below two-thirds of its design flowrate unless hot deck (top) weir dams and special nozzles are specified. The tower fans should never operate at full speed without at least 50% of design water flow.

9. Energy Efficiency Issues



9-10: Hydronic piping and pumping system utilizes energy saving concepts (chilled, condenser and heating water).

9-10E: Pumps are not oversized. The capacity of each pump does not exceed the sum of the coil capacities served.
(No additional safety factor is needed, since the normal coil load diversity provides the pump safety factor).



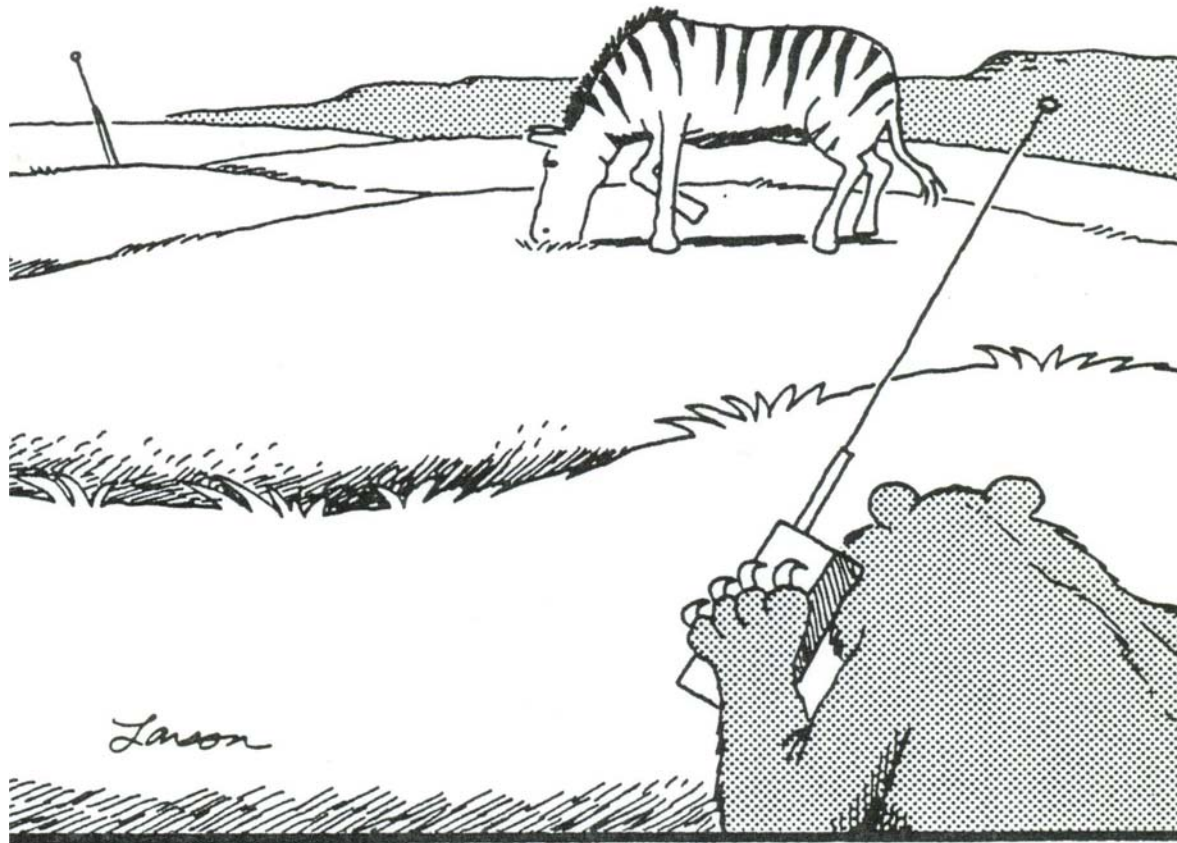
9. Energy Efficiency Issues



9-1: The issues of equipment sizing, training and control capabilities are properly addressed

9-1A: For moderately sized and larger buildings, a simulation tool is being used to understand the part-load performance and operating costs of system alternatives.

Applying New Tools



The modern lion

Application Experience



- Checks were excellent **reminders**
- **Thoroughness** was significantly **increased**, for the same time spent
- Review **took longer**, overall, because there were so many more issues to look at in the documents
- Checks provided **comment language**
- Found checks to be almost **too much data**—too many checks to ‘check’
- Will work for comprehensive **peer review** as well as **sampling review** approaches

Application Process



1. Filter in Cx Assistant by system type
2. Filter in Cx Assistant by Issue and Check type
3. Delete those that:
 - Don't apply
 - Aren't that important
 - You don't have time or scope to deal with
4. Save and print project-specific word checklist

Application Process



5. Use hard copy of checklist to track checks through the various document reviews

6. Cut and paste wording from elec copy of checklist into your review form/report
 - Change language into deficiency language

	Phase to Ck	Review in Phase? (Note 1)	Ck'd: <u>P</u> lans, <u>S</u> pecs, <u>C</u> ut-sheets, <u>S</u> hop Drawings	Method: <u>S</u> ampled (%), <u>R</u> evu'd <u>A</u> ll	Chk in Next Submission?	Results: <u>OK</u> or Comments <u>A</u> dded to Report
ISSUES						
ated and contain sufficient						
s Project Requirements and Basis of everything but the actual raised floor at 0.05 in. WC pressure. s less than 17% of design flow at 0.05	DD	○	S	A	N	A
	CD	●				
	Sub	N/A				
etermined from review of the ches the design intent obtained from	DD	○	P; S	S	Y	IN
	CD	●	P; S	S	--	OK
	Sub	●				
iping and valve layout (e.g., bypass tion in common header systems and	DD	○	P; S	A	Y	IN
	CD	●	P; S	A		A

Application Process



- Ultimate application goal
 - Carefully filter the checks for relevance and importance and provide those checklists to A/E BEFORE the design submission is CREATED

Summary



- Commissioning Assistant will soon have a Design Review Tool Module:
www.energydesignresources.com
- The Design Review Master Reference Document is available from the CCC Library
www.cacx.org
- Your comments and suggestions will help to enhance and expand the tool in the future.

Contacts



- Ken Gillespie, PG&E
klg2@pge.com
- Kristin Heinemeier, PE/CI
kheinemeier@peci.org
- Karl Stum, Summit Building Engineering
kstum@stummitbe.com

www.energydesignresources.com

www.cacx.org