

**Description of cumulative DOE-2.2 version 48z bug fixes (since initial CEC certification of version 44c3) that affect Title 24 analysis:**

1. The calculations for the change in extraction rate with zone temperature omitted the 0.5 factor in the X, Y, Z terms for the PVVT subzone case only. For those subzones this results in small changes in the max/min extraction rates (typically <1%), and small changes in hourly zone temperature (typically < 0.5F). Net effect on annual heat/cool energy is << 0.1% per zone.
2. In Dual Duct system problems with redistribution of HSUPPLY-FLOW were fixed. 1) If all ZONE's had their HASSIGNED-CFM specified the SYSTEM was getting zero OA (but OA is always wrong being low by the amount for ZONES with A-CFM specified.) This can happen if the heating flow CFMAXH had to be made greater than the HASSIGNED-CFM due to the box min flow being larger than the assigned heating flow; this can happen when the MIN-CFM-RATIO time the maximum box flow (minus the CMIN-CFM-RATIO x cooling flow) is greater than the HASSIGNED-FLOW. 2) Also fix a bug related to the redistribution of SUPPLY-CFM out to ZONES not having ASSIGNED-CFM specified; the amount being distributed out was not accounting for the SIZING-RATIO.
3. Fixed a problem with redistribution of SUPPLY-CFM to zones. In case when a ZONE ASSIGNED-CFM was specified the entire redistribution calculation was skipped, thus the summation of that ZONE's OA into the SYSTEM total OA was also skipped. In this case SYSTEM OA total is always wrong being low by the amount for ZONES with ASSIGNED-CFM specified unless MIN-OUTSIDE-AIR was used (SYSTEM level) rather than ZONE keywords.
4. Fixed a problem with air-to-air heat pump formulations. The defrost calculation assumes that the defrost mode happens each hour for its full time as if PLRh was 1.0 each hour the heat pump operates in defrost mode; if HP is operating and OA temp < defrost T, the defrost time is independent of HP run time. We changed this method to estimate the HP heat PLR and then reduce the full defrost time by multiplying by the estimated HP heating mode PLR. **NOTE: In the results summary, certification tests involving heat pumps show the largest change in results.**
5. Fixed a bug in reporting fan power for fan coils in ZONES with a MULTIPLIER or FLOOR-MULTIPLIER not equal to 1.0 In this case the SS-L report value was correct but the value placed on the meter (and thus PS-E/F, ES-x and BEPS) reports was not including the multipliers.
6. A BDL keyword default expression change was implemented. In cooling towers, DESIGN-APPROACH calculation was backwards; as a result the design approach was always 5; never greater. This would cause an over sizing for cooling towers; energy could either go up or down depending on how the tower was controlled.

**Description of cumulative DOE-2.2 version 48z bug fixes (since initial CEC certification of version 44c3) that DO NOT affect Title 24 analysis:**

1. Replace the mod in -044b1 for duct losses to unconditioned zones with a more general solution. Results should be identical. Hourly reports for HENOW, ERMAX, ERMIN, ERMAXM will be different, as these terms now include pipe/duct losses, rather than just representing active heating/cooling extraction.
2. Fixed bug in fan/heat/cool schedules that can have negative values. For example, if optimum start feature is used and the fan schedule has more than 6 -999's in a sequence, the FON on flag gets set to 999 rather than 0, which causes the fan to be on rather than off and FON is used as an on/off multiplier on some flows (especially in dual duct (DDS/MZS/PMZS) systems - this causes the result for that hour to be junk (999 times to high flows that can cause negative electric and gas consumptions).
3. Fixed a bug in crankcase heater energy calculation for the case of MIN-HGB-RATIO = 0.0 (default for PVVT and RESVVT) and also for all PMZS cases. When MIN-HGB-RATIO is zero the compressor runs for the entire hour if PLR > 0, thus crankcase heater does not run at all; code incorrectly had crankcase heater running for (1-PLR) fraction of the hour; for PMZS the crankcase heater ran for (1-plr) fraction of the hour independent of the MIN-HGB-RATIO value.
4. Added numerous Error/Warning messages and new sizing calculation for OA-FROM-SYSTEM referenced SYSTEMs. Previously, if a SYSTEM had an OA-FROM-SYSTEM specified, its MIN-OUTSIDE-AIR was reset to the MIN-OUTSIDE-AIR of the referenced OA-FROM-SYSTEM; this has been removed and replaced with the opposite action; the sum of the OA requirements for all SYSTEMs that reference an OA-FROM-SYSTEM is used to set the OA-FROM-SYSTEM MIN-OUTSIDE-AIR, SUPPLY-FLOW and adjust its ZONEs flows and minimum flows for both heating and cooling. Additionally the OA-FROM-SYSTEM has its calculated/specified cooling (total and sensible), heating, and preheat capacities adjusted if its SUPPLY flow was increased. If the OA-FROM-SYSTEM and its ZONEs have sufficient minimum OA specified (greater than that required by the referencing SYSTEMs) no adjustments are made. If any adjustments are made a warning is issued that informs the user of the adjustments and recommends the project be re-run with the values in the input corrected. Also, errors are issued (and the simulation terminated) if the OA-FROM-SYSTEM is either an incorrect type (a zonal system or a system that cannot have outside air) or the OA-FROM-SYSTEM is not placed into the input file before any referencing SYSTEM.
5. Fixed three inter-related issues relating to primary/secondary CIRCULATION loop interactions. 1) An expression sets the secondary valve type, when to specified by the user, to 0 when no secondary pump is specified; in the hourly calculation this 0 was not handled correctly. The result is that the primary pump "sees" constant flow from the secondary loop, in cases when it was specified to be variable. 2) During the hour a loop starts, the start-up calculations for a secondary loop did not take into account the correct loop thermal loss dT when calculating the required supply temperature. An entering CHW coil temperature could be unrealistically high, and exceed the limits of the coil temperature curve; this could result in the termination of the simulation (crash) with an X\*\*Y where Y is non-integer and X < 0 error message. 3) During a start-up hour, a check was added to determine whether the coil loads are large enough to make the loop temperature float away

from setpoint and make appropriate calculation adjustments as needed. Chiller energy may increase by 1% on an annual basis as a result of these changes in projects that were running into these problems (mostly when the primary loop was incorrectly undersized relative to connected variable flow secondary loops.)

6. Fix inconsistency if metric/english conversion factor for btu/hr-sqft-f ... it was 5.67446 in BDL but other values in LOADS for reporting ... changed to be consistent with ASHRAE 2005 HF p 38.1 to be 5.67826.
7. Fixed bugs in LOADS reports. error in LS-I that caused more than 299 SPACES defined when both LV-C and LS-I requested to cause the report generator to throw an error and terminate while creating the .sim reports after completing the LOADS. Start LV-C reports at 10000 rather than 1000 to prevent overlap with LS-I which starts at 1300. Fix LS-G, LS-H and LS-I incorrect values. The IDENT Time (done in 1999!) changed lines that collected data for these reports incorrectly. The flag value for the daylighting report schedule (=1 when on and 0 when off) was used as the collected quantity rather than the lighting schedule value ... so results were not very predictable and always wrong unless lighting was scheduled 1.0 and the daylight report schedule was not specified. Basically it always thought the lighting schedule was 1 and thus the power reduction it thought was in effect for the reports was reduced by (1-actual lighting schedule value). Energy reporting and hourly reports were not wrong only the daylighting LS- reports.
8. Fix divide-by-0 program crash when dhw loop has recirculation flow, but recirculation pump is on the dw-heater rather than attached to loop.
9. In cooling towers, excessive start-up loads resulting in large condenser loop temperature changes could result in a divide-by-zero in rare circumstances when bumping up against the upper limit of the range curve. No noticeable effect on simulation results.
10. Faulty (out of range) input for loop temperature setpoint could cause the coil temperature performance curve to produce a negative value, causing a program crash. No noticeable effect on simulation results.
11. DHW loop pump runs continuously even when a pump schedule is defined. Pump energy and loop thermal losses are overestimated by the difference in hours the pump should have been off.
12. Waterside economizer would crash due to a negative loop flow when attached to a LAKE/WELL loop. No impact on simulation results.
13. Cooling towers could generate a divide-by-zero if the low-speed-cfm or min-vfd-cfm was the same as the fan-off-cfm. No change in results.
14. When boilers and chillers cycle, a HW/CHW-PUMP attached to the unit also cycles if the loop has its own pump. This change will keep these equipment pumps on so that the units can detect the loop temperature. Depending on how much of the time the units are cycling, keeping the pumps on when the unit is cycled off may increase the energy for this pump by 10%-50%; the increased pump energy may also affect the loop heat/cool load and equipment loads by ~1%.
15. Previously, cycling losses for boilers and chillers are approximated by adding 50% of the START-UP-TIME to the equipment load at PLR=0, and prorating this penalty between  $0 < \text{PLR} < \text{MIN-RATIO}$ . The cycling losses are now separated by the addition of a keyword that explicitly accounts for the operating loss at zero PLR. The losses are prorated as before. The effect is most pronounced when LOOP-OPERATION is STANDBY, so equipment runs (cycles) a large fraction of the hours; energy consumption of the unit

changes by 1%-5% for electric chillers, and 1%-10% for absorption chillers; depending on cycling characteristics. Net effect on building source energy is typically <1%.

16. When PVVT system with staged-volume control was combined with refrigeration casework input (old style) a negative airflow could be calculated when in the deadband floating state; this was fixed.
17. Energy recovery ventilators could attempt to size HX for effectiveness greater than the maximum theoretical; this put the design UA calculations into an infinite loop. No effect on results.
18. Fixed a bug in SYSTEM flow balancing into ZONEs. When the SUPPLY-FLOW or CFM/TON is specified for a SYSTEM such that the flow to the ZONEs needs to be "balanced" to ensure the ZONE flows sum to the SYSTEM specified value, the OA-FLOW/AREA keyword was ignored unless another ZONE level OA keyword was also specified (OA-CHANGES or OA-CFM/PER)
19. Changed model to allow whole house fan kw (NATURAL-VENT-KW) to modulate its power fraction based upon the fractional natural venting in the first zone. This is like an "ideal" control that turns the WHF on/off during the hour to match the venting cooling setpoint.
20. Fixed a problem in setting heating minimum flow when a zone flow is "allocated" from a specified total system flow: the minimum heating flow was defaulting to the minimum cooling flow ratio times the zone cooling flow rather than using the minimum heating flow.
21. An energy recovery ventilator could get trapped in an infinite loop when the ERV is bypassed (shut down) and exhaust condensate was happening (flag was set) in a previous iteration. No impact on results.
22. Fixed a bug that allowed the air heat capacity (the CONS()) variables during a start-up hour to be based on an entering coil temperature = 0, which was the previous hour's zeroed value for TM. Modify to use last start-up hour's value. Also, the heating and cooling coil loads in single and dual duct air handler routines were being calculated based on a density different than used in establishing the CONS() terms; this created an inconsistency in mass flow rates between the zones and the coil. Overall delta on annual energy is <0.5%; delta on peaks can be larger.
23. The default minimum CFM ratio for heating mode was not being adjusted when the SUPPLY-CFM was user-specified and thus zonal CFMs were calculated by reallocating the AHU flow. Negligible impact on heating/cooling energy.
24. The fan reports (SS-L) to allocate operating power to cooling when an evaporative cooler or desiccant system is operating.
25. Fixed a bug in the setting of supply temperature min/max (in DKTEMP) for single duct systems when the maximum heating flow is not equal to the minimum cooling flow and the min cooling flow is <1. In this case the heating coil flow rate was incorrectly getting set to the cooling coil flow rate. This then caused the maximum heating temperature to be incorrect. Usually heating flow was supposed to be lower so the heating temperature is underestimated leading to long fan run times in cycling systems or possible unmet loads in constant operation systems.
26. Fix a bug in the sub-zone (those that are not CONTROL-ZONEs) in PVVT systems relating to VAV heating flow. If the control zone is in the heating mode ensure that all sub-zones are also using their heating mode flow rates. Prior to this fix the sub-zone flow minimum was being set by its temperature relative to its thermostat setpoint, thus if the

control zone was in the heating mode but the sub-zone temperature put it into cooling, it would use its cooling minimum flow rather than heating minimum flow - in the case that the cooling minimum flow is above the heating minimum flow, the zone temperature would be further forced up and the fan flow would be too high. This was causing an over-estimate of heating energy and heating mode fan energy; the over-estimate could be a significant fractions of the correct amount.

27. Increased BDL memory for the maximum problem size from 80 to 100 megabytes.
28. Renamed report LS-SH to LS-P.
29. Fix LS-G, LS-H and LS-I incorrect values. The IDENT Time (done in 1999!) changed lines that collected data for these reports incorrectly. The flag value for the daylighting report schedule (=1 when on and 0 when off) was used as the collected quantity rather than the lighting schedule value ... so results were not very predictable and always wrong unless lighting was scheduled 1.0 and the daylight report schedule was not specified. Basically it always thought the lighting schedule was 1 and thus the power reduction it thought was in effect for the reports was reduced by (1-actual lighting schedule value). Energy reporting and hourly reports were not wrong only the daylighting LS- reports.
30. Fix warning message that prints "\*\*\*\*" for time zone and says it does not agree with weather file value when T-Z was not specified. No effect on results.
31. Fix div-by-0 error that occurred when a dhw loop has a recirculation flow, but the recirculation pump is on placed onto the dw-heater rather than attached to loop.
32. Fix two staged-volume PVVT system issues: 1) Limit the staged-volume outlet temperature to maximum control value allowed. Has a very small effect on results since the zone thermostat will limit supply temperature to that needed. 2) Do not let staged-volume calculate negative airflow when floating. This problem is very rare and has only been observed only with concurrent use of the obsolete simplified refrigeration equipment models.
33. Message enhancements: 1) enhance the ZONE and SYSTEM "insufficient heating capability" messages and change ERROR condition to a warning. No effect on results; 2) fix debug output of SPACE/ZONE name matching since LOADS does not pass full SPACE name, only first 16 character can be printed (rather than the 32 being output previously with the last 16 being junk.
34. The PTAC routine was incorrectly passing the values of the LOW-SPEED-RATIOS keyword into the air-to-air heat pump routine. This caused energy to be substantially over-estimated for a 2-speed heat pump during low-speed heating; possibly doubling the annual heating energy. Documentation was changed to indicate that TWO-SPEED compressors should not be used with PTAC.
35. Fixed a bug that caused the simulation to terminate due to a fan coil with intermittent fan and loop losses causing a negative CFM to be calculated due to parasitic round-off errors in TEMDEV. Very rare case and no effect on results as simulation was terminated by error.
36. Improve default expressions for PSZ/PVAVS/PVVT/RESYS2 for keywords that apply differently for water cooled vs. air cooled condensers: 1) Turn off defaults (make unused) crankcase heating keyword (but put them in for PMZS systems - they were missing); 2) Change PVVT zone thermostat to be proportional rather than reverse action when the min-flow-ratio is less than 1.0 3) Lower the MIN-UNLOAD-RATIO to 0.1 4) Set MIN-HP-T to MIN-ALARM-T for water cooled HP's. Also change default for MIN-UNLOAD-RATIO to 0.15 (from 0.25) for non-WLHP systems and set MIN-HGB-RATIO to 0.0 for

- PSZ when indoor fan is not intermittent (used to equal M-U-L) and also make M-H-R equal to M-U-R for PVVT when intermittent indoor fan (used to be zero.)
37. Fix default expressions for ZONE HEATING-CAPACITY and COOLING-CAPACITY for IU SYSTEM. These were defaulting to any value specified at the SYSTEM level - that is incorrect - they now default to auto-sizing based on specified design conditions and peak loads.
  38. Changed a BDL error to be a warning for the case of incorrectly positioned window on wall that was issued when the wall has a polygon shape.
  39. Fixed an error in LS-I in models with more than 299 SPACES defined and both LV-C and LS-I were requested to cause the non-hourly report generator to issue an error and terminate while creating the .sim file reports after completing the LOADS portion of the simulation. Changed code to start LV-C reports at at report number 10000 rather than 1000 to prevent overlap with LS-I which starts at 1300.
  40. Fix LS-G, LS-H and LS-I incorrect values. The IDENT Time (done in 1999!) changed lines that collected data for these reports incorrectly. The flag value for the daylighting report schedule (=1 when on and 0 when off) was used as the collected quantity rather than the lighting schedule value ... so results were not very predictable and always wrong unless lighting was scheduled 1.0 and the daylight report schedule was not specified. Basically it always thought the lighting schedule was 1 and thus the power reduction it thought was in effect for the reports was reduced by (1-actual lighting schedule value). Energy reporting and hourly reports were not wrong only the daylighting LS- reports.
  41. Fixed warning message that prints "\*\*\*\*" for time zone and says it does not agree with weather file value when T-Z keyword was not actually specified.
  42. LS-SH report header was broken when renamed and modified to be LS-P.
  43. Fixed a divide-by-0 error that happened when dhw loop has recirculation flow, but recirculation pump is on dw-heater rather than attached to loop.
  44. Fixed loop pumping algorithm so that if a secondary loop does not have pump, it can still be off independent of primary loop operation if it is scheduled off or snapped off (to simulate an isolation valve.)
  45. Staged volume fixes. Limit staged-volume outlet temperature to the maximum allowed. Very small effect on results, as zone thermostat will limit supply temperature to that needed. Do not let staged-volume calculate negative airflow when floating - very rare, observed only with concurrent refrigeration equipment.
  46. Enhanced the ZONE and SYSTEM insufficient heating capability messages and change ERROR condition to a warning.
  47. The PTAC routine was incorrectly passing LOOW-SPEED-RATIO's (LSR(3)) into the air-to-air heat pump routine. This caused energy to be substantially overestimated for a 2-speed heat pump during low-speed heating; possibly doubling the annual heating energy.
  48. IwinReturn (internal simulation termination request flag) could sometimes be set to 1 (by user pressing the abort button) before any days simulated, resulting in a report divide by zero.
  49. Fixed problem for a fan coil with intermittent fan and loop losses that could produce a negative CFM due to parasitic round-off errors in TEMDEV when cycle time was very short.
  50. A bug fix in version 044c3a pertaining to PVVT subzone airflows introduced a bug where a VAV box with heating HMIN-FLOW-RATIO larger than cooling MIN-FLOW-RATIO

would use the IZMODE (heat/cool/float mode flag) set by the previous zone when the current zone was in the deadband. This could cause the deadband airflow to be the heating minimum rather than the cooling minimum.

51. MIN-UNLOAD-RATIO could be less than MIN-HGB-RATIO, in which case the PLR curve would be used down to the min-unload-ratio, while cycling losses and PCTON are calculated at a higher part load ration. Can result in significant under calculation of power consumption if incorrectly specified.
52. Change code to allow condenser fan pwr-fPLR curve to apply to regular (non-gas powered) DX equipment.
53. Fix bug that caused FC (fan coil) system unconditioned zones to get fan energy assigned equal to the fan energy of the next previous conditioned zone value due to lack of initialization of the zone fan energy to zero in the hourly zone loop.
54. Baseboards could be assigned heat when the BBRD-LOOP was off or limited in capacity; this could cause unaccounted heating.
55. Staged-volume economizer did not work properly with intermittent fan.
56. For INDOOR-FAN-MODE = INTERMITTENT, TEMDEV did not calculate the during-the-hour temperature/extraction swing terms (X,Y,Z) correctly. Also problems with CONTINUOUS in some routines such as PIU, RESVVT. Solution: Prior to calling TEMDEV, each routine should set XC,ZC, XH,ZH simultaneously with the ERMAX, ERMIN, ERMAXM, ERMINM terms. Tests show small changes in fan energy (2%-5%); varies w/ floating hours.
57. In the case when the circulation pump is attached to the DW heater rather than directly to the loop, the DHW loop operation failed to specify when recirculation exists.
58. Change some default expressions for PSZ/PVAVS/PVVT/RESYS2 for keywords that apply differently for water cooled vs. air cooled condensers. 1) Turn off defaults (make unused) crankcase heating keyword (but put them in for PMZS systems - they were missing) 2) Change PVVT zone thermostat to be proportional rather than reverse action when the min-flow-ratio is less than 1.0 3) Lower the MIN-UNLOAD-RATIO to 0.1 4) Set MIN-HP-T to MIN-ALARM-T for water cooled HP's Also change default for MIN-UNLOAD-RATIO to 0.15 (from 0.25) for non WLHP systems and set MIN-HGB-RATIO to 0 for PSZ when indoor fan is not intermittent (used to equal M-U-L) and also make M-H-R equal to M-U-R for PVVT when intermittent indoor fan used to be zero.
59. The LOOP-FLOW-RESET keyword default was not looking at HEAT-SETPT-CONTROL for pipe2 and hw.
60. Fix bug in 044d (thru 44e2) where unset variable IL (layer number) and ETA (sun angle on window) were 0 causing GTC glass types to have incorrect angular absorption and thus low angle glass conduction was low by up to 4X. This would have the largest effect when sun angles were closest to 0 (winter sunny days)
61. When a 2-pipe heating coil was used with DX cooling, or a 2-pipe cooling coil was used with electric/gas heating, the design coil capacity of the non-2pipe coil could be improperly resized, or set to zero. If reset to zero, then energy consumption could be substantially under calculated.
62. New DX-PIU was setting up report SS-P when it should not, causing the IUNIQ count to be thrown off and then the report generator would throw error messages into the .sim file and then usually cause a program crash.

63. A BDL keyword default expression change was implemented. For WLHP loops, COOL-SETPT-T was changed to default to the design cool T when the cooling control is LOAD-RESET (similar to what is done for CW loops.)
64. Fix typo in 44e2 that causes an incorrect extraction rate calculation for HVSYS and can cause the program to crash in some circumstances.
65. In the EVAP-COOL economizer, OA damper stayed open anytime DBT > TR; this was changed so that the OA damper is fully open anytime DBT > TC. Also allow EVAP-COOL to be variable-flow, like PVVT
66. New daylight savings keywords were added to handle both old and new US as well as custom selections.
67. For PS-C, change the DHW to use only format 6 (if HIR>0) or format 8, like the boiler. No impact on results unless the AUX-KW is specified, in which case the aux kW was not reported here (already included in meter).
68. Force loops to calculate required supply temperature during a startup hour. Otherwise, for a 2-pipe loop, startup hour temperature will be unrealistic and may result in a negative coil capacity. Add PS-H report for ground-loop heat-exchanger.
69. Fix a bug in the staged-volume system where capacity is incorrectly limited when the MIN-SUPPLY-T (or COOL-SET-T if defaulted) is set unrealistically low.
70. Fix a bug introduced in variable-flow exhaust tracking that caused the min-flow-ratio of a PIU terminal to be calculated too high; possibly > 1. This bug can cause major differences in results. (Possibly 100+% difference in fan energy or heating energy.)
71. If HUMIDIFIER-TYPE = NONE, force MIN-HUMIDITY = 0. Otherwise humidification load would be calculated regardless. By default the load would be assigned to a HW loop if one exists, else would be lost. Heating energy could be off by more than 100%.
72. Improve accuracy of Heat Exchanger mode 3 convergence check. May have 10% effect on annual drycooler energy.
73. Drycooler did not size properly when more than one cell. This normally causes a design error (air temperature rise too great) rather than a simulation error.
74. Fix divide by zero bug in PS-H for lake/well GLHX's that was caused by the number of well being used but not defined for this type of HX
75. Add capability to specify convective/radiative split for equipment loads (rather than old custom weighting factor assumed split for each class of load.) Allow equipment loads to be modified by (a function of) hourly calculated zone temperature.
76. Add curve-fit command to LOADS, Enable edtt variables for CURVE-FIT and include name in data passed to simulation to improve curve-fit warning and error messages.
77. Add DHW process end-use T to simulate mixing of hot/cold.
78. Duct losses to an unconditioned space did not cause the design OA fraction to increase proportionately. Typically results in a small increase in heating/cooling loads.
79. When COOL-CONTROL=WARMEST, HEAT-CONTROL=COLDEST disregarded the COOL-MAX-RESET-T. This allowed the supply temperature to be warmer than user-specified; typically underestimating cooling energy by a small amount.
80. Duct loss report block variable included conduction but not air loss
81. Allow natural ventilation to exhaust to unconditioned zone, such as a whole-house fan to the attic.
82. Add photocell-ctrl to SCHEDULE
83. New GLHX would divide-by-zero if GROUT-COND same as GROUND-COND



84. DKTEMP was not correctly estimating heating flow for control/subzone when HMIN-FLOW-RATIO specified.
85. Do not allow a subzone to have variable-flow independent of the control zone.
86. Allow duct leakage to vary by airflow (not just cycling.)
87. If EQUIP-CTRL has no equipment or meter specified, then no equipment runs but coils continue to produce demands. Generate error.
88. Add a CONDENSING-UNIT condenser type.
89. Add hi/lo temperature limit checks to the GLHX to prevent extreme fluid temperatures from causing unreal results. ABORT if found.
90. For heat-driven chillers, the design HIR was specified incorrectly causing design condenser heat rejection to be too low.
91. System type SUM with only unconditioned zones will divide by zero when attempting to calc average temperatures of conditioned zones.
92. Enable hourly reports during initialization if DUMP-OPTIONS = DEBUG
93. Enhance photocell control to take into account the fraction of the hour the sun is up.
94. Add condensing boiler TYPE.
95. Modify BDLKEY BOILER:CAPACITY-FT to allow a QUADRATIC-T for condensing boiler. Change condensing boiler, CAPACITY-FT default curve to be QUADRATIC-T, not QUADRATIC. This was causing an error message due to an incorrect curve type being referenced in the library.
96. Modify condensing boiler to eliminate need for CAPACITY-FT curve. Detect point at which HIR-f(PLR,HWR) curve inverts and limit HWR accordingly. Output boiler capacity at rated conditions in report. Add condensing boiler type to PS-H report. For condensing boiler, CAPACITY-FT should use QUADRATIC-T, not QUADRATIC; change library entry.
97. Add CONDUCT-TMAX-SCH and MIN-SOLAR-SCH keywords to the WINDOW command to allow additional outside temperature and solar gain trigger controls to the deployment of window shades; this was mainly added to facilitate modeling of greenhouses where the deployment of the shading devices is done for both heating and cooling considerations.
98. Fix problem where pv-modules caused curve-invert error when modules produced more DC than inverter could convert to AC.
99. Condensing boiler would not work if simulated with another boiler
100. The SYSTEM temperature correction to the INF-METHOD = S-G did not calculate the wind speed contribution correctly (omitted WSHGTL(IMO)). Neither the S-G or RESIDENTIAL correction included the infiltration schedule; serious errors could result if a schedule was used.
101. Add EXHAUST-SOURCE to zone command.
102. Add ASHRAE enhanced infiltration correction
103. 1) Duct leakage exfiltrated to unconditioned zone, and not returned via infiltration to the return duct, was being double counted. Increases hourly OA fraction, if required OA is less than duct loss to outdoors. 2) Duct loss to plenum was always lost to outdoors, rather than always returned to AHU. Return fan energy less than required. Also, OA fraction was inflated, if OA reqt was otherwise less than duct leakage. 3) Take exfiltrated duct leakage out of MIN-OUTSIDE-AIR calc, as this could force a fixed high hourly OA flow when the duct loss was variable.

104. PIU system did not include MIN-FLOW/AREA in min-cfm calc.
105. PS-E, F mods for electric peak, increase decimal precision to 3 digits. Clean up some hourly report variables: DTREC is unused, QCR is actually RfanPumpKW, no generator surplus for non-elec meters, QHR should not be incremented for zonal reheat in SZCI.
106. For ASHRAE-enhanced infiltration: 1) Correct the FLOW-COEFF and WIND-COEFF to be correct English values; 2) Add SHELTER-FACTOR and use instead of SHIELDING-COEFF; convert wind from knots to mph and modify by shelter factor. Restore SHIELDING-COEFF to previous value – the keyword will be used only with S-G method.
107. Disable INDOOR-FAN-MODE for system types PMZS, PVAVS, PTAC, HP, UVT, RESVVT, RESYS, and PTGSD; as these systems do not reference this keyword. For EVAP-COOL, disable EVAP-CL+M-SUP as it does not apply.
108. Baseboard heating can be under estimated in PTAC system with HEAT-SOURCE = NONE, or single-zone system w/o ahu coil, or reheat systems w/o zone reheat coil. Baseboard calc in TEMDEV was using the wrong value for ERMINM when calculating the baseboard load. More than 20% of the baseboard load could be improperly shifted to the HVAC coil. If no HVAC coil existed, shifted heating load is lost.
109. In an earlier change the RESYS-Cool-EIR-fPLR curve was deleted because of unrealistic very high cycling penalty. This change restores that curve for backwards compatibility, but makes it a copy of TypicalCyclingAC-EIR-fPLR to ensure reasonable results.
110. S-G natural ventilation was not working for version 46. The modifications for ASHRAE-enhanced infiltration eliminated the monthly wind-speed correction for weather station height, but failed to remove it for the S-G natural ventilation algorithm, causing the wind speed component to be zero.
111. S-G infiltration was using VOLUME/AREA as an approximation for space HEIGHT (in most cases, an exact approximation). Use the space HEIGHT directly. In a like manner, use the space HEIGHT as the parameter in the modification terms to local wind speed defined in the SITE-PARAMETERS command.
112. In BDL input a problem with references to library fetched components was fixed. When a component that is "pre-defined" in the library has its data fetched by a reference the component was not being correctly marked as being defined. This causes future references such as LIKE to cause an error saying that the symbol had not yet been defined.
113. -046 Exhaust mods introduced a bug in minimum outside air calculation when SUPPLY-FLOW was set together with a zone ASSIGNED-FLOW; in that case the zone's outside air requirement was dropped from OUTA summation resulting in the system outside air amount be low by that zone amount.
114. The new expression for zonal HMIN-FLOW-RATIO in -045f set the value to the SYSTEM MIN-FLOW-RATIO rather than the SYSTEM HMIN-\* This causes a problem when the user sets the SYSTEM:MIN-FLOW-RATIO, but also sets the ZONE:MIN-FLOW-RATIO to a different value. HMIN is then the SYSTEM value rather than the zonal value.
115. The expression for THERMOSTAT-TYPE looks at the SYSTEM level min flow ratio which causes an incorrect decision for reverse acting in heating mode when zone and system flow and reheat settings differ; it was changed to preferentially look at the zonal level value
116. In version 47e: 1) Chiller condenser flow was reduced by chiller cycling, but this was not carried through properly to CW loop pump, or dedicated chiller CW pump. More common is for condenser flow to continue during time the compressor is cycled off. Results in small

- changes in condensing temperature, increase in CW loop pumping energy. 2) Add an error check if 3-way valves consume all loop flow so that thermal storage can never charge. 3) add information of hours a zone overheated or undercooled to the BEPS/BEPU reports.
117. In version 47f: 1) add HMAX-FLOW-RATIO for reverse-action VAV boxes; default is 0.5 which may significantly affect heating loads in colder climates 2) if loop overloaded, drop max airflow for VAV reverse-action boxes. 2) increase limit on interior walls to 12288.
118. In version 47g: If energy-recovery ventilator used a purge, calculation of very small flows might not successfully converge successfully
119. In version 47h: 1) Fix bug in calculation of space lighting heat gain to return air that caused the gain to be too large. This happens when there are lighting systems in a space and ANY lighting system has a light-to-return value not equal to zero. In this case the sum of all lighting systems (up to and including the current one) times light-to-return of the current one were added to the return air heat gain rather than just the one lighting system. This can cause a very large error for the case of multiple lighting systems with one or more light-to-return with a value that is not very small. 2) In LOADS and SYSTEMS, the curve-fit interpretation routine CVAL was called with the wrong number of arguments; no change in results expected. 3) The common block "PtrSys" was being initialized to zero beyond the end of the block; no impact found.
120. In version 47i: 1) The cooling tower capacity was not normalized properly when the user specified the capacity; also applies to fluid coolers. The tower energy could be off by as much as 50% depending on the specific design conditions and their deviation from CTI conditions. 2) Loop capacitance doesn't work consistently for CW loops when using LOAD-RESET tower control. As loop capacitance (the change in load due to a change in loop temperature) is not significant for condenser loops, eliminate capacitance. Could impact cooling tower energy by approximately 10% 3) Single zone systems incorrectly limited the hourly supply temperature to be not less than the MIN-SUPPLY-T. This is incorrect, as most systems do not have a discharge air controller, and integrated economizer operation may often result in depressed supply temperatures. Let COOL-SET-T be the limit. 4) Original implementation of pipe and duct losses did not cover all cases and could give incorrect results, particularly when floating. Reimplemented in a simpler, more robust solution. 5) In a single zone system, when MAX-HUMIDITY forced down the supply temperature, an incorrect value of MIN-FLOW-RATIO could be used if supply-cfm was specified. 6) For PVVT 2-speed system, the MIN-FLOW-RATIO was changed to default to be the same as the low-speed compressor cooling stage. 7) For variable-speed cooling tower fans, the default fan power curve inverted below  $PLR = 0.4$ , and power increased below this point. Annual tower fan energy could be more than 50% higher than correct. 8) For vertical ground-loop heat exchangers, the number of boreholes in G-FUNCTIONS was incorrect for non-linear and non-rectangular configurations.
121. In version 47j: 1) For a 2-speed PVVT system, the MIN-FLOW-RATIO default, rather than defaulting based on ventilation, was changed to be the same as the low-speed cooling capacity fraction. 2) Chiller condenser calculations could fail to converge for variable-flow or off-rated flow. Errors typically small. 3) Chiller condenser calculations for variable-flow or off-rated flow could fail to converge.
122. In version 47k: 1) The default fan curve for a variable-speed cooling tower inverted around  $PLR=0.4$ ; below this point power increased as  $PLR$  decreased. The error in fan energy could be greater than 50% of the reported value, primarily depending on the setpoint of the

condenser loop (lower setpoints would generate less error, as the tower would be working harder most hours).

123. In version 47l: 1) Related to the bug in 47i, the condenser loop could have zero fluid capacitance, which would produce a "divide by zero". Simulation would either abort or generate a "nan". A very rare situation, with no significant impact on results. 2) Single zone systems (SZHR, PSZ, PVVT, etc.) incorrectly limited the hourly discharge temperature to not less than the MIN-SUPPLY-T. This is incorrect, as most systems, especially packaged systems, do not have a discharge air controller. As a result, latent cooling energy may be undercalculated, and fans with cycling control may run longer than otherwise. Impact on cooling/fan energy consumption is small in most cases; < 5%. Let the COOL-SET-T be the limit in DKTEMP. 3) Original implementation of pipe and duct losses did not completely cover all cases, and could give incorrect results, particularly when floating. Net effect on energy not assessed, but typically small.
124. In version 47m: 1) For cogeneration systems consisting of multiple engine-generators, the Jpe pointer was not being calculated correctly for the second and following generators. Typically results in a program crash. 2) For vertical ground-loop heat-exchangers, the number of boreholes in G-FUNCTIONSs is incorrect for non-linear or non-rectangular configurations. The net effect was not determined, but heating/cooling power consumption could be in error by 20% or more. 3) The check for SS-Q failed to recognize that HEAT-SOURCE could be changed from NONE (after the initial report records were written) to another value which would trigger SS-Q monthly writes; throwing off the increment of Iuniq and causing the report generator to crash.
125. In version 47n: 1) When MAX-HUMIDITY control forces down the supply temperature of a single zone system, an incorrect value of the MIN-FLOW-RATIO could be used if the user also specified the SUPPLY-FLOW. Impact not assessed, but normally small, and only for those rare single zone systems that utilize MAX-HUMIDITY control.
126. In version 47o: 1) A bug fix in 042L2 BDL inadvertently deleted the line which calculates NGShade, the sum of building and fixed shades. This variable was used in the algorithm to create dummy exterior walls for shading surfaces requesting a shading report. No impact on simulation results. 2) For a multi-layer window, a misspelled variable (ngap) in the shading coefficient calculation caused the inward flowing fraction of absorbed radiation to not take into account the resistance of the airgap(s). This affects the estimated shading coefficient in the reports; it does not affect the hourly calculation. 3) When EXHAUST-SOURCE = AIR-HANDLER, exhaust fan CFM would be left on when the air handler was off. No impact on energy usage as this variable was ignored in this situation, but would show up as non-zero in zonal hourly report.
127. In version 48: Conversion to Intel Fortran and C compilers; add polygons to the BUILDING-SHADE command.
128. In version 48a: Increase limits on total storage and SPACES to 9999; increase limits on total storage to 75 and 300 million word (4 byte words) in the DLL and exe versions respectively.
129. In version 48b: Add PROJECT-DATA command for temporary keyword expressions for use in BDL only.
130. In version 48d: 1) Modify window convective calculations per NREL document "Identifying and Resolving Differences in DOE-2 and E+ ..." December 2011 2) Secondary DHW loop process loads were not adjusted for mixing. DHW heating loads were then

larger than actual. 3) For DHW loops with recirculation pumps, the return temperature was not adjusted for makeup water. For heat pump DHW heaters where the loop supply setpoint is greater than what the heat pump produces, this affects the split between heat pump compressor energy and supplementary heat.

131. In version 48e: Add C-SFAN-MOTOR-SUB, C-RFAN-MOTOR-SUB and C-HFAN-MOTOR-SUB keywords to SYSTEM command, add C-XFAN-MOTOR-SUB, C-XFAN-QTY, C-XFAN-MTR-TYPE, C-XFAN-MTR-SNC-SPD, and C-XFAN-MTR-ENC to ZONE command; add SHAPE to BUILDING-SHADE and FIXED-SHADE.
132. In version 48f: Electric baseboard with OA-RESET did not sum power to elec meter. 2) SS-N relative humidity scatter plot was not completely initialized. 3) The PV module calculation for Vmp included an adjustment for the number of cells in series AND MODULES IN SERIES, where the latter was in error.
133. In version 48g: Put Compliance expressions into a separate file.
134. In version 48i: ; Allow 2500 PARAMETER's; do not let emissivities be zero.
135. In version 48j: 1) The relatively new keyword, HMAX-FLOW-RATIO, was not fully implemented for hot-deck reset. 2) ERV was having convergence failures in some cases. 3) change GLASS-PROP-CALC default from QUICK-FIT to INTERPOLATION. 4) allow fractional values for PV modules in series and parallel. 5) allow 512 report blocks and 128 hourly reports. 6) Air and evaporative cooled chillers could have 0F for entering condenser temperature due to an error introduced for Tcond in version -047j.
136. In version 48k: 1) Version 47k incorrectly checked for LEAK-AREA for the S-G method, such that the infiltration was not corrected for zone temperature. 2) The head of water-cooled DX equipment was assigned to a CW or WLHP loop in LoopCoilFlow, but then zeroed in LoopPrimLoads. Loop pump head was under calculated by the head of the DX condenser.
137. In version 48l: In the fan coil (FC) system, zone volume was not correctly taken into account in the moisture balance calculations. The result was that latent gains due to internal space loads were undercalculated by at least a factor of 10.
138. In version 48m: If OA-CONTROL was set to anything other than FIXED or OA-TEMP, then the ECONO-LIMIT-T does not work properly in DKTEMP and may cause the minimum supply temperature to be calculated too high. This can falsely cause zones to overheat and cause cooling energy to be undercalculated.
139. In version 48n: Once converted to the Intel Parallel Studio Fortran compiler, file names and/or paths could no longer be modified via environment variables; affected users who ran DOE-2 .exe's in the batch mode using the file DOE22.bat or similar.
140. In version 48o: The fluid cooler curve for capacity as a function of range broke down for ranges below 4°F. The bi-quadratic curve was almost linear; replaced with linear fit.
141. In version 48q: 1) Hourly report processing modified to suppress the double-printing of the GLOBAL report block in both LOADS and HVAC simulations. If the rest of the REPORT-BLOCKS in the hourly report are LOADS related, then the GLOBAL block is not repeated in the HVAC output; similarly, if associated with HVAC report blocks, the GLOBAL block does not print in the LOADS output. 2) Polygon vertices limited to 52,800 feet (10 miles) to prevent precision errors in calculating segment lengths and/or polygon area.
142. In version 48r: 1) The LOAD-MANAGEMENT commands did not properly set several DO loop end boundaries; could result in a circulation-loop or other component pointer having a zero value which could result in memory being overwritten; most likely in a

SCHEDULE block but possibly elsewhere. 2) Hourly report binary output files forced to have zero length if not used. 3) Global report block not output after the HVAC simulation unless there are also HVAC-related report blocks in the same hourly report. 4) In BEPS and BEPU reports, the "HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE" or below the heating throttling range could be over counted.

143. In version 48s: 1) A Watcom/Intel compiler incompatibility could cause BDL to crash when a BLOCK-CHARGE was defined but not attached to a UTILITY-RATE. 2) In the .dll version (eQUEST or WinDOE2) when WIN-SPEC-METHOD was not defined BDL should have thrown an error, but crashed instead. 3) Environment path name including length of file name, has been increased from 64 characters to 256 (useful in .exe batch mode).
144. In version 48t: 1) The number of PARAMETERS is increased from 2,500 to 6,000.
145. In version 48u: 1) DX cycling loss calculations are modified to skip over the calculations if not cycling; previously the cycling calcs were always made and relied upon the CLOSS curve to give the correct result when not cycling. This modification allows more flexibility in the use of the CLOSS curve (initiated for DEER purposes).
146. In version 48v: 1) SCHEDULE:GROUP keywords were previously replaced with PHOTOCELL-CTRL keywords, but former keyword remained active in the same group.
147. In version 48x: 1) For a window, CONDUCT-TMAX-SCH and MIN-SOLAR-SCH would be ignored unless CONDUCT-TMIN-SCH and/or MAX-SOLAR-SCH were also specified. 2) The WALL-PARAMETERS output routine in BDL was writing over the 3<sup>rd</sup> data array (display area) rather than the 4<sup>th</sup>.
148. In version 48y: 1) A new expression function, SymIndexType( ), has been added to resolve expression handling in "negative TYPE" commands pertaining to different sets of keywords and/or code words in one type of the command vs. another. 2) The optimization for the REP.F module was turned off in the hope this resolves the issue of the report generator format errors that would get randomly generated. 3) Pipe and duct losses were not zeroed hourly for CHW loops. Affects only hourly reports.
149. In version 48z: 1) For the HEAT-REJECTION:AUX-MODE and AUX-SCHEDULE keywords, expressions were fixed to avoid a program abort. No impact on results.