ASHRAE®

ADDENDA

ANSI/ASHRAE Addendum b to
ANSI/ASHRAE Standard 90.4-2022

Energy Standard for Data Centers

Approved by ASHRAE and the American National Standards Institute on September 30, 2025.

This addendum was approved by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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FOREWORD

The UPS segment of the ELC calculation requires knowing three different load numbers. While those numbers have always been described in the Informative Appendix C examples, they have not been clearly delineated in definitions, leading to confusion in the use of undefined terms. Addendum b adds a definition for "UPS redundant capacity" to clarify the fact that UPS efficiency must be based on the total available capacity of the UPS, including its redundant capacity, even though that additional capacity is not intended to be used under normal operating conditions.

Terminology throughout Section 8, "Electrical," as well as in the informative appendices, has also been updated to correspond with the revised definitions terminology.

Informative Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum b to Standard 90.4-2022

Modify Section 3 as follows.

data center ITE design power: the combined power in *kilowatts* of all the *ITE* loads for which the *ITE system* was designed. The *data center ITE design* ~~power~~ *power* ~~shall~~ does not include any additional loads. See *UPS operational design load.*~~, such as *cabinet fans* or other devices unless they are inherent parts of the *ITE*, even if the loads are part of the *UPS operational design load*.~~

design electrical loss component (design ELC): the *design electrical loss component* for the *data center* or *data center addition* ~~shall be~~ is the combined *loss~~es~~* (or the *loss~~es~~* calculated from *efficiencies*) of two segments of the electrical chain: *UPS segment* and *ITE distribution segment*. ~~The *design ELC* shall be calculated using the highest *loss* (lowest efficiency) parts of each segment of the power chain in order to demonstrate a minimum level of electrically efficient design. The *design ELC* does not, and is not intended to, integrate all electrical *losses* in the facility.~~

incoming electrical service point (service point): the point of connection between the ~~facilities of the~~ serving utility wiring and the premises wiring, also known as the point of demarcation between where the serving utility wiring ends and the premises wiring begins, as defined by the National Electrical Code (NFPA 70). (***Informative Note:*** Any power generation source [e.g., microgrids] can be considered the serving utility to the data center.)

incoming electrical service ~~segment~~: *incoming electrical service ~~segment~~* includes all elements of the electrical *power chain* ~~power chain~~ prior to the *UPS segment*, beginning with the load side of the *incoming electrical service point* supplying the *building*, continuing through all other intervening *transformers*, wiring, and switchgear, and ending at the *manufacturer*-provided input *terminals* of the *UPS* or its equivalent location in the *power chain* ~~circuit~~.

~~***ITE adds, moves, and changes:*** the normal and somewhat perpetual additions, moves, and changes to *ITE*, such as a server moving from one *ITE enclosure* to another.~~

ITE distribution segment: the segment of the *design ELC* that includes all elements of the ~~power chain~~ *power chain*, beginning at the *manufacturer*-provided output-load *terminals* of the *UPS segment*; extending through all *transformers*, wiring, and switchgear; and continuing to and including the receptacles to which *ITE* or power distribution strips for connection of multiple pieces of *ITE* to a circuit are intended to be connected. ~~The *ITE distribution segment* shall not include the actual *ITE*, its power cords, or any accessory part of the *ITE*. In cases where power is to be hardwired into self-contained, *manufacturer* configured *cabinets*, the calculation path shall terminate at the power input *terminals* provided by the *manufacturer* within that *equipment*. The *ITE distribution segment* used to calculate the *design ELC* is the highest *loss* (lowest *efficiency*) path. This is normally the longest path that also contains the largest numbers of *loss*-producing devices, such as *transformers*.~~

~~***ITE room:*** a room dedicated for *ITE*.~~

loss: the difference between the power or *energy* entering a device or *system* segment and the power or *energy* leaving that device or *system* segment. ~~The *loss* may be measured in physical units (volts, watts, psi, etc.) or may be calculated as one (1) minus the *efficiency* of the device or *system* segment.~~ (***Informative Note:*** The *loss* may be measured in physical units [volts, watts, psi, etc.] or may be calculated as one [1] minus the efficiency of the device or system segment.)

power chain: the contiguous series of electrical devices and interconnecting wiring between a power source and a load.

redundancy (redundant): duplication of components, *equipment*, controls, or *systems* and their interconnections to enable continued operation ~~at needed functional capacities~~ during the failure ~~and after the *loss*~~ of the primary components, *equipment*, controls, or *systems* due to failure, maintenance, servicing, or other modification activities.

~~***service point:*** the point of connection between the facilities of the serving utility and the premises wiring. The *service point* can be described as the point of demarcation between where the serving utility ends and the premises continuation begins. The serving utility generally specifies the location of the *service point* based on the conditions of *service*.~~

terminal: a device by which *energy* from a *system* is finally delivered (e.g., UPS, transformers, receptacles ~~registers, diffusers, lighting fixtures, faucets~~) prior to the interface with the *ITE* or *ITE enclosure*. For devices used for other purposes or in other *systems*, the definition of *terminal* in ANSI/ASHRAE/IES Standard 90.1 applies ~~(see Annex 1)~~.

telephone exchange: a telecommunication *service* facility that provides telecommunication *services* to the public and that has operations regulated via the U.S. Communications Act of 1934, Title II (Common Carriers), and 47 CFR Chapter 1 (Federal Communications Commission). (***Informative Note:*** See Informative Appendix D for additional guidance.)

uninterruptible power supply (UPS): also known as an "uninterruptible power *system*," a *system* primarily intended to continue delivering power to the critical load during ~~after~~ a utility power disturbance or interruption. It may also serve to deliver continuous, stable power when anomalies occur in the incoming power source, which may be the utility or an alternate power source, such as a *generator*. ~~*UPS systems* are defined by three internationally recognized classifications:~~ (***Informative Note:*** See Appendix A for references to the IEC standards for the different types of UPSs: VFD, VI, VFI, battery, rotary, and diesel rotary.)

~~***voltage and frequency dependent (VFD) systems:*** also known as "offline" or "standby" *UPS systems,* which are offline until a power interruption occurs and then rapidly switch into the circuit to maintain power to the critical load.~~

~~***voltage independent (VI) systems:*** also known as "line interactive," which are similar to *VFD systems* in that they rapidly switch backup power to the critical load when a power interruption occurs. However, a *VI UPS* continually passes incoming power to the output while also using the stored *energy* source to filter incoming power, suppress voltage spikes, and provide a degree of voltage regulation.~~

~~***voltage and frequency independent (VFI) systems:*** also known as "double conversion," "dual conversion," or "full time" *UPS*, which use incoming utility or generator power solely to drive an electronic or mechanical mechanism that regenerates power and delivers it to the critical load without the need to switch anything into or out of the circuit. This results in total isolation of the critical load from incoming power and no break of any duration in the delivered power.~~

~~Two physical types of *UPS systems* are in general use:~~

~~a. Battery *UPS*, in which incoming AC power maintains battery charge, and an AC to DC converter, known as an "inverter," delivers power to the critical load on either a continuous or noncontinuous basis.~~

~~b. Rotary *UPS*, in which incoming AC power drives a propulsion unit that turns a generating device, with a heavy flywheel storing kinetic *energy* that continues to turn the generating portion when incoming power fails or anomalies occur. Batteries are also sometimes used to supplement the kinetic *energy* storage to extend "ride-through" time. Rotary *UPS systems* may also include a driven engine for emergency backup (commonly referred to as a "diesel rotary *UPS*" [DRUPS], regardless of fuel type), which is decoupled from the rotary *UPS* components during normal operation and is not included in *efficiency* calculations.~~

~~Either type can be made up of one or more modules running in parallel to add capacity or *redundancy* or both. DC *UPS systems*, which eliminate the inverter and deliver DC power to the *ITE*, are also used.~~

UPS economy mode: a mode of *UPS* operation in which power is ~~normally~~ fed to the load without going through power conversions ~~within the *UPS* for the purpose of reducing~~ in order to reduce *loss* during normal operation~~ so as to save *energy*~~. ~~Circuitry is incorporated to rapidly switch the load to the rectifier/battery/inverter in the event of a power failure or voltage drop below a preset threshold. Economy mode is normally a configurable option that can be used or overridden at user discretion.~~

UPS operational design load: the load in *kilowatts* at which the *UPS* is intended to operate by design~~. This will be~~ that includes the *data center ITE design power* plus any other loads, such as *cabinet* door fans or refrigerant pumps, that will be connected to the *UPS*. The *UPS operational design load* is typically less than the *UPS rated capacity*.

UPS segment: ~~the *UPS segment* of the *design ELC* shall include the *manufacturer* provided UPS system~~ segment from the input *terminals* to the output *terminals* of the *manufacturer*-provided *UPS system,* including all *transformers*, switchgear, rectifiers, inverters, rotary propulsion units, and wiring ~~provided by the manufacturer~~ between those two points. ~~*Transformers* and switchgear provided by the *UPS manufacturer* but housed in different *cabinets* from the actual *UPS* capacity components shall be considered parts of the *UPS segment* along with associated wiring. *Transformers* and switchgear functioning as parts of the *UPS* but installed separately and not provided by the *UPS manufacturer* (such as custom-configured bypass) shall not be considered part of the *UPS segment*. All such associated components shall be included with the *incoming electrical service segment* and/or the *ITE distribution segment* in accordance with their specific design logic.~~

UPS rated capacity: the maximum load in *kilowatts* or *kilovolt-amperes* at which an individual *UPS* is designed and specified by the *manufacturer* to operate on a continuous basis under specified ~~environmental~~ conditions.

UPS redundant capacity: the *UPS rated capacity* plus the capacities of *redundant* online modules. For non-*redundant UPS systems*, this will be the same as the *UPS rated capacity*.

core and shell build-out: site work, walls, floor slabs and roof structure including utilities necessary to obtain a Certificate of Occupancy. Infrastructure such as raised access floors, communications ducts, header piping, or primary switchboards may be installed, but no power or *HVAC systems* specific to data center usage are included.

full build-out: design for the complete data center facility based on total *UPS operational design load* and as permitted and constructed in full as a single project.

scaled build-out: design for the complete facility (as if for a *full build-out*), based on total *UPS operational design load*, where the *ITE* cabinets and associated power and *HVAC systems* are initially installed for only a portion of the facility, with the remainder of the facility left to be built out as future phases. Each intended phase is delineated on design documents.

modular build-out: design, permitting, and construction are "per module", based on the *UPS operational design load* for each module. Each module is delineated by demising walls.

Modify Section 4.2.1.3 as follows.

4.2.1.3 Alterations to Existing Buildings. *Alterations* of existing *data center spaces* shall comply with the provisions of Sections 5, 7, 9, and 10 and with either Sections 6 and 8 or Section 11, provided such compliance will not result in the increase of *energy* consumption of the *building*.

Component or *system* replacements or modifications that result in changes in either capacity or type of technology require compliance with the applicable sections and versions of this standard in accordance with Chart 1 (see Informative Appendix C).

Alterations of other *spaces* shall comply with ANSI/ASHRAE/IES Standard 90.1, Section 4.2.1.3.

Exceptions to 4.2.1.3:

1. *ITE* adds, moves, and changes ~~*ITE adds, moves and changes*~~ are excluded.

Informative Note: *ITE* adds, moves, and changes are the normal and somewhat perpetual additions, moves, and changes to *ITE*.

[. . .]

Add new Section 4.2.1.4 as follows:

4.2.1.4 Applicable Editions of Standard for Various Forms of Design and Build-Out

4.2.1.4.1 Core and Shell Build-Outs. Design and construction of *core and shell build-outs* shall be in accordance with the most recent applicable version of Standard 90.1. Compliance with Standard 90.4 is required when *data center* power and *HVAC systems equipment* are designed and permitted for installation in the *space* and shall be in accordance with the applicable form of design and build-out in Sections 4.2.1.4.2 to 4.2.1.4.4.

4.2.1.4.2 Full Build-Out. Design and construction of *full build-outs* shall comply with the most recent applicable version of this standard.

4.2.1.4.3 Scaled Build-Out. Design and construction of *scaled build-outs* shall comply in accordance with the most recent applicable version of this standard at the time of design and permitting, with the following requirements:

a. Permitting shall be based on the *full build-out* design.
b. Facility remains in compliance with the standard if all stages of the build-out adhere to the original design and permit.
c. Initial stage of the *scaled build-out*, and each subsequent stage, shall comply with the latest applicable version of this standard at the time each stage is designed and permitted.
d. If deviations from the original power or *HVAC systems* designs occur in any stage of the remaining build-out, they shall be considered *additions*, require new permitting, and comply with the latest applicable version of this standard.

Exception to 4.2.1.4.3: If power or *HVAC system* deviations are newer models of the originally specified *equipment* and meet or exceed the energy efficiencies of those systems, they are considered compliant with the original design. (See exception 2 to Sections 6.1.1.3.1 and 8.1.1.3.1, respectively.)

4.2.1.4.4 Modular Build-Out: *Modular build-out* and each subsequent *modular build-out* shall comply with the latest applicable version of this standard at the time each module is designed and permitted.

Informative Note: More information on build-out types are found in Informative Appendix C.

Modify Section 6.6.2.1as follows. Note to reviewer: This section includes language added by Addendum g to Standard 90.4-2022.

6.6.2.1 Drawings. *Construction documents* shall require that, within 90 days after the date of *system* acceptance, *record drawings* of the actual installation be provided to the *building* owner or the designated representative of the *building* owner. *Record drawings* shall include, as a minimum, the location and performance data on each piece of *equipment*; general configuration of the duct and pipe *distribution system*, including sizes; and the ~~*terminal*~~ air or water design flow rates. Plans shall show the location of *equipment* to be installed and locations for all deferred *equipment*. Plans shall describe ~~Describe~~ the amount ~~amounts~~ of mechanical and electrical *equipment* assumed (in each part-load MLC calculation) to be installed and operating during the 25%, 50%, 75%, and 100% *ITE* power level in the associated MLC compliance calculation.

Modify Section 8.4.1 as follows.

8.4.1 Electrical Distribution Systems for Mechanical Loads.

[. . .]

8.4.1.2 Minimum Efficiency or Maximum Loss. The *design ELC* calculations shall use the minimum operating *efficiency* or maximum operating *loss* of each segment of the *power chain* ~~component~~ unless a specific mode of operation (with higher *efficiency* or lower *loss*) is designated on the approved design documents.

Informative Note: The *design ELC* does not, and is not intended to, integrate all electrical *losses* in the facility.

[. . .]

8.4.1.4 Incoming Electrical Service ~~Segment~~. The *incoming electrical service* ~~*segment*~~ is not part of the ~~ELC~~ *design ELC* calculation. However, all ~~components~~ *transformers* in the incoming ~~power chain~~ *power chain* shall meet or exceed published U.S. DOE minimum *efficiencies* for *transformers* or the equivalent international standards, and ~~U.S. National Electrical Code® (NFPA 70) maximum *losses* for service conductors or the equivalent international electrical codes~~ shall comply with all related applicable codes.

~~**Exception to 8.4.1.4:** Emergency or stand-by power systems are not considered a part of the incoming electrical service segment, with the exception of individual elements such as associated transfer switches, transformers, or other devices that are also included between the design ELC demarcation and the UPS. Diesel rotary UPS (DRUPS) systems shall be calculated as part of the UPS segment with the engine element decoupled.~~

8.4.1.5 UPS Segment Efficiency. *Efficiency* and resulting *loss* through the *UPS segment* shall be calculated at both full and partial loads as follows:

a. *UPS* configuration *losses* shall be based on the *manufacturer*'s stated *efficiencies* at 100%, 75%, 50%, and 25% of the *operational design load* at *efficiencies* based on the *UPS redundant capacity* ~~*UPS operational design load*~~.
b. For *2N*, *2N+1*, *2(N+1)* or other dual-feed *UPS* configurations where *UPS systems* are identical, only one of the *systems* shall be used in the calculation. Where *UPS systems* are not identical, both *systems* shall be calculated, and the *system* with the lowest *efficiency* shall be used to compute the *UPS segment* of the *design ELC*.
c. Where a *UPS* has more than one mode of operation (e.g., normal and *UPS economy modes*), the mode used in these calculations shall be the same as the mode used as the Basis of Design and so designated on the approved *construction documents*.
d. Where nonrated *UPS systems* are used, the *efficiencies* and *losses* shall be as published or provided in writing by the *manufacturer*.
e. Diesel rotary UPS (DRUPS) systems shall be calculated as part of the *UPS segment* with the engine element decoupled.

8.4.1.6 ITE Distribution Segment Efficiency. Where significant numbers of power paths exist between the *UPS* and the many *equipment cabinets*, the *ITE distribution segment efficiency* shall be that with the lowest path *efficiency*. This shall be the longest path with the largest numbers of *loss* producing components, such as *transformers*, switchgear, and/or panelboards. Calculations are required to determine the path with the greatest *loss* or lowest *efficiency*, which shall be used in developing the total *design ELC*.

Informative Note: The *ITE distribution segment* does not include the actual *ITE*, its power cords, or any accessory part of the *ITE*. In cases where power is to be permanently installed or hardwired into self-contained, *manufacturer*-configured *cabinets*, the calculation path terminates at the power input *terminals* provided by the *manufacturer* within that *equipment*. The *ITE distribution segment* used to calculate the *design ELC* is the highest *loss* (lowest *efficiency*) path. This is normally the longest path that also contains devices producing a *loss* (e.g. *transformers*).

Modify Informative Appendix A as follows.

International Electrotechnical Commission (IEC)
IEC Secretariat
3 rue de Varembé, PO Box 131
CH-1211 Geneve 20, Switzerland
www.iec.ch

IEC 62040-3 (2021)
Uninterruptible Power Systems (UPS)—Part 3: Method of Specifying the Performance and Test Requirements

IEC 62040-5-3 (2016)
Uninterruptible Power Systems (UPS)—Part 5-3: DC Output UPS—Performance and Test Requirements

IEC 88528-11 (2004)
Reciprocating Internal Combustion Engine Driven Alternating Current Generating Sets—Part 11: Rotary Uninterruptible Power Systems—Performance and Test Methods

Modify Informative Appendix C as follows.

Replace Figures C-3, C-4, C-5, and C-6 with the new figures provided.

CORE & SHELL ONLY

Designed for Required Space Only. Data Center Electrical and HVAC Systems are NOT Part of Design

Complies with Current Applicable Version of Std. 90.1

(See Options Below for Types of Build-Outs)

FULL BUILD-OUT

Design and Permitting Based on Design Load for Full Build-Out

Current Applicable Version of 90.4 At Time of Design & Permit

(Continues to Apply Unless Deviations Require Reverting to Latest Version)

SCALED BUILD-OUT

Calculate Based On Design Load For Full Build-out

Current Applicable Version of 90.4 At Time of Design and Permitting. Each Stage Shown as Complying on Design Documents.

(Deviations Revert to Latest Version)

MODULAR BUILD-OUT

Each Module Designed and Permitted Separately Based On Design Load For Each Module

Latest Applicable Version of 90.4 At Time of Build-Out of Each Module

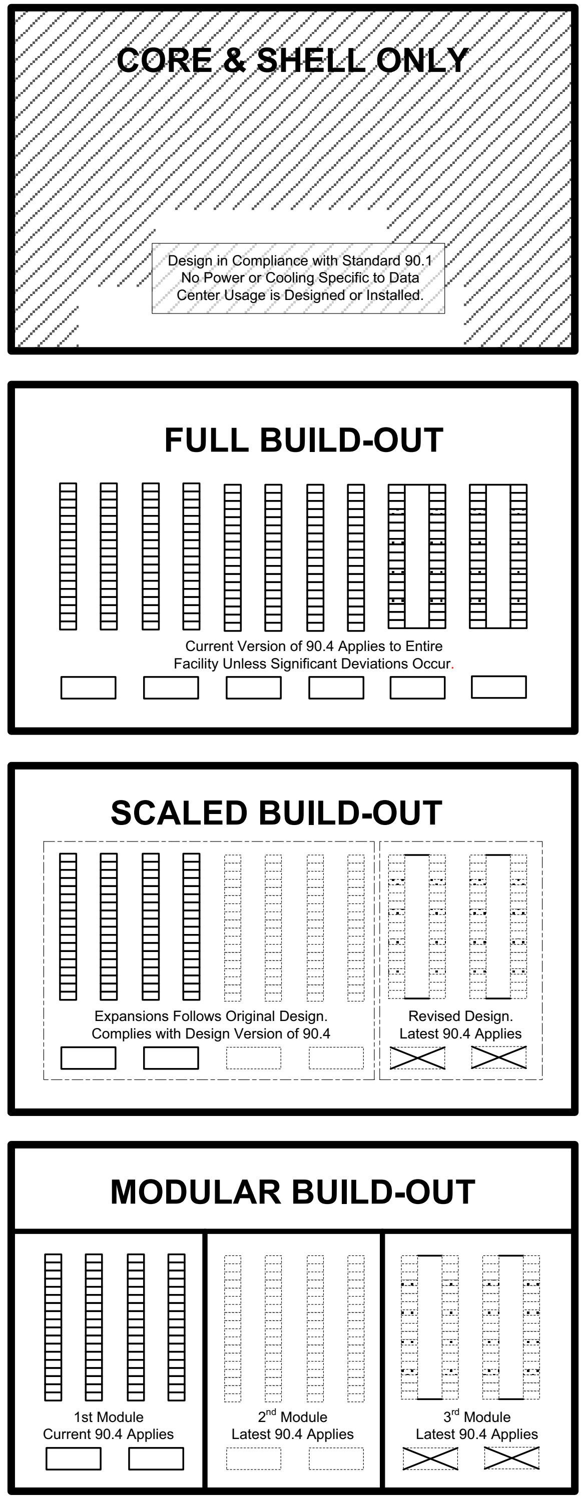


Figure C-3 Applicability for datacom equipment in new construction.

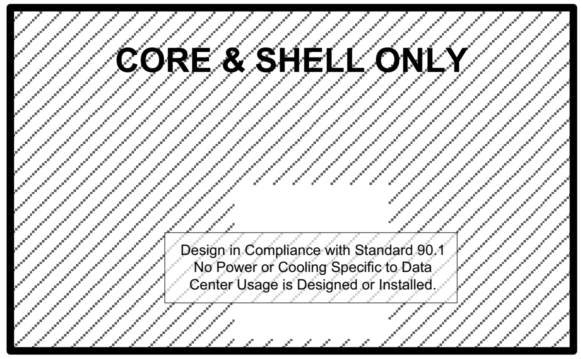
NOTE: Figure C-3 illustrates the applicability of Standard 90.4 to different types of construction, expansions, and existing facility alterations. The specifics of each project will differ. This illustration is provided only to exemplify how different versions of Standard 90.4 would apply to typical situations.

CORE & SHELL ONLY

Not Applicable.
No Data Center HVAC
or Electrical Systems Involved

Complies with Current Applicable Version of Std. 90.1

(See Options Below for Types of Build-Outs)

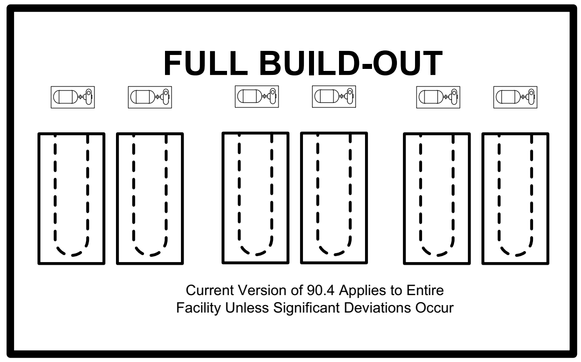


FULL BUILD-OUT

Design and Permitting are for Full
HVAC System Upgrade.
(Electrical System NOT Modified)

Current Applicable Version of 90.4 At Time of Design & Permit

(HVAC System Upgrade is Completed as a Single Project In Accordance with Permitted Design.)

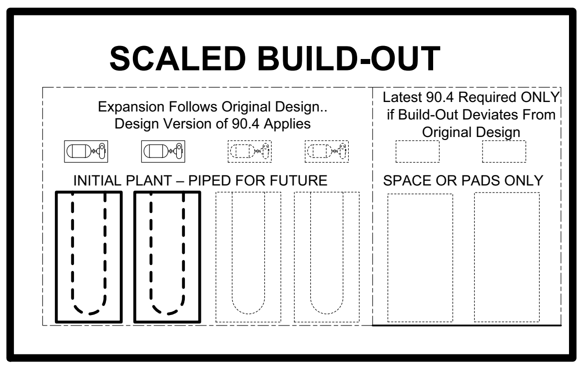


SCALED BUILD-OUT

Design and Permitting are for Full HVAC
System Upgrade.
(Electrical System NOT Modified)

Current Applicable Version of 90.4 At Time of Design and Permitting. Each Stage Shown as Complying on Design Documents.

(Deviations Revert to Latest Version)



MODULAR BUILD-OUT

Design and Permitting are for
Single Module HVAC System Upgrades
(Electrical Systems NOT Modified)

Latest Applicable Version of 90.4 At Time of Design & Permitting of Each Module

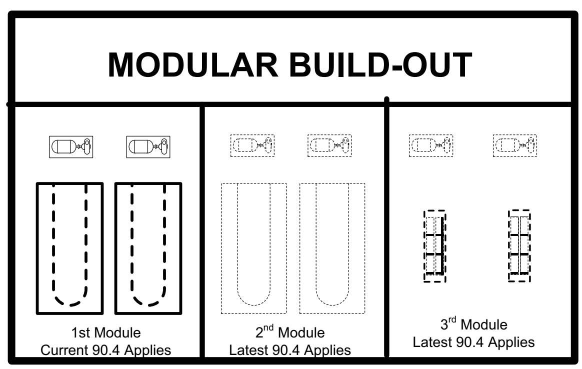


Figure C-4 Applicability for mechanical equipment in new construction.

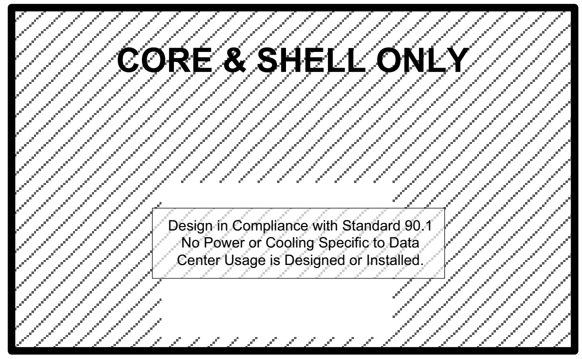
NOTE: Figure C-4 illustrates the applicability of Standard 90.4 to different types of construction, expansions, and existing facility alterations. The specifics of each project will differ. This illustration is provided only to exemplify how different versions of Standard 90.4 would apply to typical situations.

CORE & SHELL ONLY

Not Applicable
No Data Center Electrical
or HVAC Systems Involved

Complies with Current Applicable Version of Std. 90.1

(See Options Below for Types of Build-Outs)

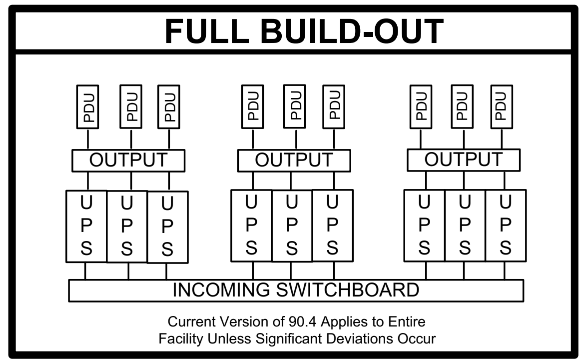


FULL BUILD-OUT

Design and Permitting are for Full
Electrical System Upgrade.
(HVAC System NOT Modified)

Current Applicable Version of 90.4 At Time of Design & Permit

(Electrical System Upgrade is Completed as a Single Project In Accordance with Permitted Design.)

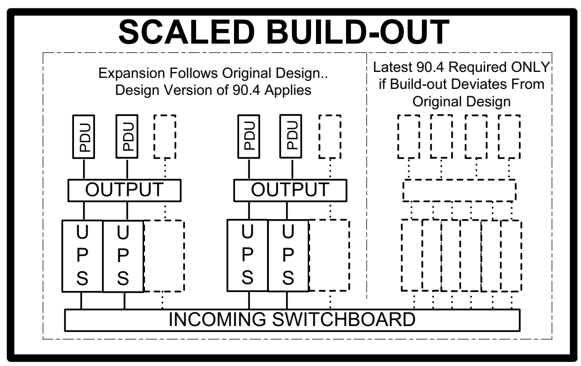


SCALED BUILD-OUT

Design and Permitting are for Full
Electrical System Upgrade.
(HVAC System NOT Modified)

Current Applicable Version of 90.4 At Time of Design and Permitting. Each Stage Shown as Complying on Design Documents.

(Deviations Revert to Latest Version)



MODULAR BUILD-OUT

Design and Permitting are for
Single Module Electrical System Upgrades
(HVAC Systems NOT Modified)

Latest Applicable Version of 90.4 At Time of Design & Permitting of Each Module

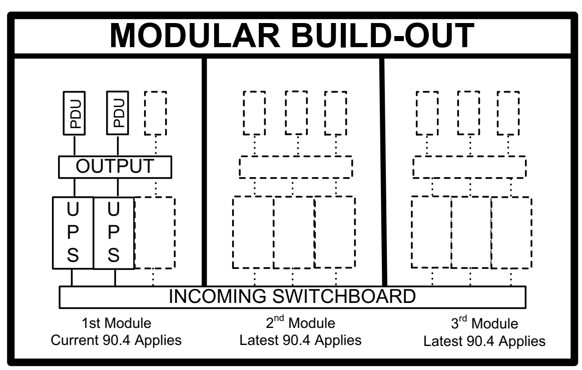


Figure C-5 Applicability for electrical equipment in new construction.

NOTE: Figure C-5 illustrates the applicability of Standard 90.4 to different types of construction, expansions, and existing facility alterations. The specifics of each project will differ. This illustration is provided only to exemplify how different versions of Standard 90.4 would apply to typical situations.

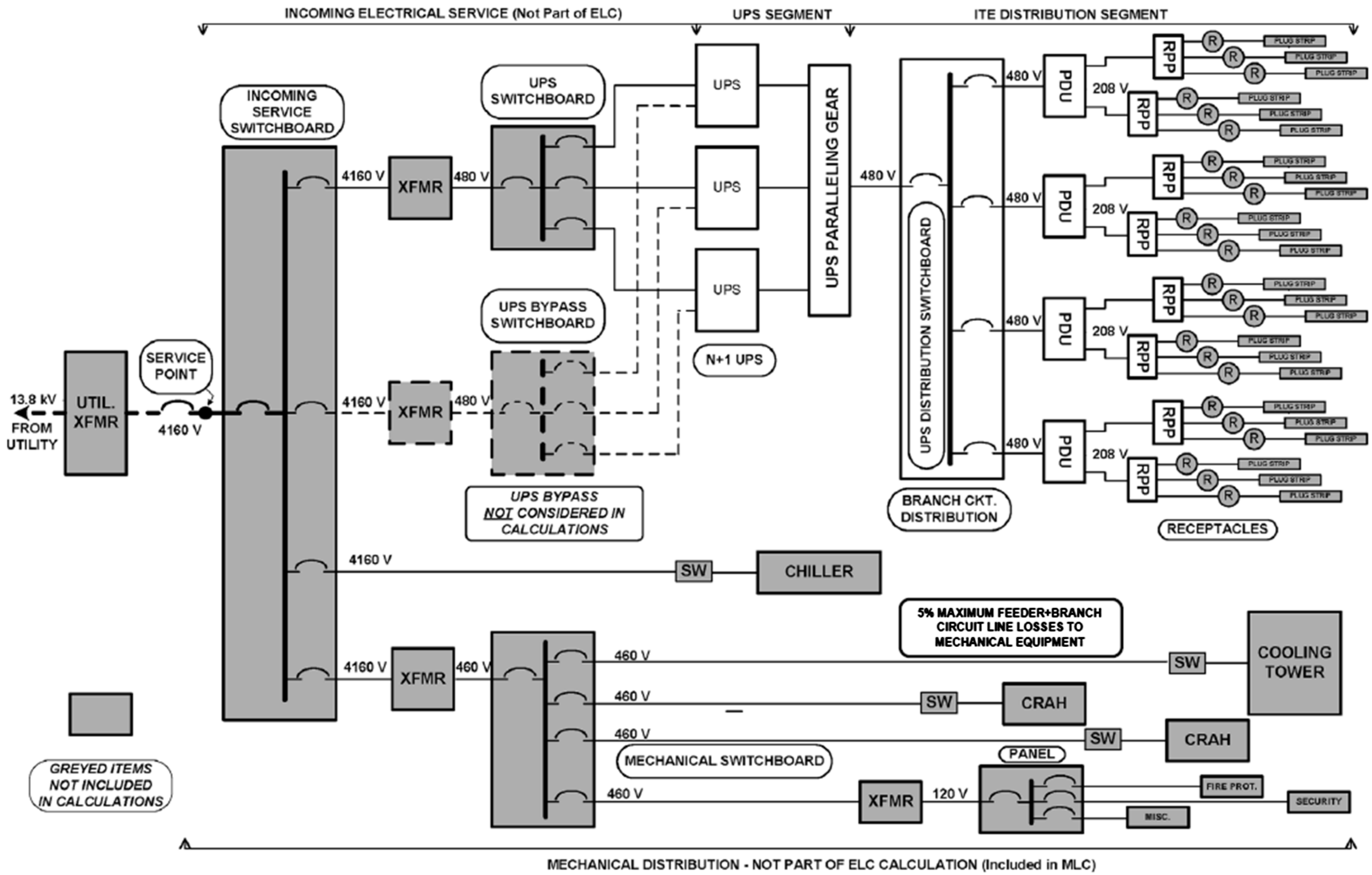


Figure C-6 Electrical efficiency compliance path.

NOTE: Figure C-6 illustrates the design electrical loss component (design ELC) compliance path for the electrical power system serving the ITE. This diagram is not in any way intended to recommend or dictate any particular electrical design, and not all of the devices shown will be present in every data center or connected in the same order or in the same way. This diagram is provided only to illustrate the electrical loss component compliance path using components of the ITE electrical system that typically appear in many designs.

Modify Section C1 as follows. Note that most changes are to italicize new defined terms.

C1. EXAMPLES: UPS SEGMENT OF DESIGN ELC CALCULATIONS

The electrical *loss* component is calculated in two segments—the *UPS segment* and the distribution segment. Following are four examples of *UPS segment* calculations illustrating the substantive differences among four different levels of *UPS redundancy*. Examples are given below for "N", "N+1", and "2N" *UPS* configuration calculations.

Following these examples is a detailed step-by-step example in chart form of a complete ELC computation for an *N+1 UPS system* of greater than 100 *kW* capacity through all four load levels of both ELC segments.

Following the *UPS* calculation example charts is an example of the distribution segment *loss* calculations based on the *N+1* modular *UPS* example. Lastly, the *UPS* and distribution segment calculations are combined into the total ELC.

UPS calculations are based on *kW*. Remaining ELC calculations are based on *kVA*. *UPS* output voltage in these examples is 480V three-phase, and *UPS* power factor is 0.9. *UPS efficiencies* are from representative *manufacturers*' data sheets.

Sample Calculation for an *N* (nonredundant) UPS

~~Operational Design Load~~ *UPS Operational Design Load* = 400 *kW* (usually approximately 80% of *UPS rated capacity* ~~*UPS* design *capacity*~~)

Nonredundant *UPS* *Rated Capacity* ~~Design Capacity~~= 500 *kW*

[Two (2) modules of 250 *kW*, ten (10) modules of 50 *kW*, or equivalent]

100% of *UPS Operational Design Load* = 400 *kW*
Operational Load Percentage = 400 *kW*/500 *kW* × 100% = 80%
UPS Efficiency at 80% Load = 95.67% (*Efficiency* Factor = 0.9567)
Input Power = 400 *kW*/0.9567 = 418.1 *kW*
Resulting *Loss* = 418.1 *kW* – 400 *kW* = 18.1 *kW*; 18.1 *kW*/418.1 *kW* × 100% = 4.33%
Standard 90.4 Max. Power *Loss* = 5.5%
(*UPS* MEETS STANDARD REQUIREMENTS AT 100% DESIGN LOAD.)
Output is 400 *kW*/0.9 pf = 444.4 *kVA*.
Output current is 444.4 *kVA* × 1000/√3/480V = 535 A.

75% of *UPS Operational Design Load* = 300 *kW*
Operational Load Percentage = 300 *kW*/500 *kW* × 100% = 60%
UPS Efficiency at 60% Load = 95.68% (*Efficiency* Factor = 0.9568)
Input Power = 300 *kW*/0.9568 = 313.5 *kW*
Resulting *Loss* = 313.5 *kW* – 300 *kW* = 13.5 *kW*; 13.5 *kW*/313.5 *kW* × 100% = 4.32%
Standard 90.4 Max. Power *Loss* = 5.5%
(*UPS* MEETS STANDARD REQUIREMENTS AT 75% DESIGN LOAD.)
Output is 300 *kW*/0.9 pf = 33.3 *kVA*.
Output current is 333.3 *kVA* × 1000/√3/480V = 400.9 A.

50% of *UPS Operational Design Load* = 200 *kW*
Operational Load Percentage = 200 *kW*/500 *kW* × 100% = 40%
UPS Efficiency at 40% Load = 95.20% (*Efficiency* Factor = 0.9520)
Input Power = 200 *kW*/0.9520 = 210.1 *kW*
Resulting *Loss* = 210.1 *kW* – 200 *kW* = 10.1 *kW*; 10.1 *kW*/210.1 *kW* × 100% = 4.80%
Standard 90.4 Max. Power *Loss* = 6.0%
(*UPS* MEETS STANDARD REQUIREMENTS AT 50% DESIGN LOAD.)
Output is 200 *kW*/0.9 pf = 33.3 *kVA*.
Output current is 222.2 *kVA* × 1000/√3/480V = 267.3 A.

25% of *UPS Operational Design Load* = 100 *kW*
Operational Load Percentage = 100 *kW*/500 *kW* × 100% = 20%
UPS Efficiency at 20% Load = 94.00% (*Efficiency* Factor = 0.9400)
Input Power = 100 *kW*/0.9400 = 106.4 *kW*
Resulting *Loss* = 106.4 *kW* – 100 *kW* = 6.4 *kW*; 6.4 *kW*/106.4 *kW* × 100% = 6.00%
Standard 90.4 Max. Power *Loss* = 7.0%
(*UPS* MEETS STANDARD REQUIREMENTS AT 25% DESIGN LOAD.)

Output is 100/0.9 *kW* pf = 111.1 *kVA*.
Output current is 111.1 *kVA* × 1000/√3/480V = 133.6 A.

UPS SEGMENT FOR NONREDUNDANT *UPS* IS WITHIN TABLE 8.6 VALUES AT ALL LOAD LEVELS.

Sample Calculations for Two Different Configurations of N+1 Redundant UPS

***N+1* Option #1**

UPS Operational Design Load = 400 *kW* (usually approximately 80% of *UPS* ~~design~~ *rated capacity*)

UPS Rated ~~Design~~ *Capacity* = 500 *kW*~~, *N+1*~~

UPS Redundant Capacity (N+1)

[Three (3) modules of 250 *kW* = 750 *kW* *redundant* ~~actual~~ *capacity* ~~capacity~~]

100% of *UPS Operational Design Load* = 400 *kW*
Operational Load Percentage = 400 *kW*/750 *kW* × 100% = 53%
UPS Efficiency at 53% Load = 95.62% (*Efficiency* Factor = 0.9562)
Input Power = 400 *kW*/0.9562 = 418.3 *kW*
Resulting *Loss* = 418.3 *kW* – 400 *kW* = 18.3 *kW*; 18.3 *kW*/418.3 *kW* × 100% = 4.38%
Standard 90.4 Max. Power *Loss* = 5.5%
(*UPS* MEETS STANDARD REQUIREMENTS AT 100% DESIGN LOAD.)
Output is 400 *kW*/0.9 pf = 444.4 *kVA*.
Output current is 444.4 *kVA* × 1000/√3/480V = 535 A.

75% of *UPS Operational Design Load* = 300 *kW*
Operational Load Percentage = 300 *kW*/750 *kW* × 100% = 40%
UPS Efficiency at 40% Load = 95.20% (*Efficiency* Factor = 0.9520)
Input Power = 300 *kW*/0.9520 = 315.1 *kW*
Resulting *Loss* = 315.1 *kW* – 300 *kW* = 15.1 *kW*; 15.1 *kW*/315.1 *kW* × 100% = 4.80%
Standard 90.4 Max. Power *Loss* = 5.5%
(*UPS* MEETS STANDARD REQUIREMENTS AT 75% DESIGN LOAD.)
Output is 300 *kW*/0.9 pf = 333.3 *kVA*.
Output current is 333.3 *kVA* × 1000/√3/480V = 400.9 A.

50% of *UPS Operational Design Load* = 200 *kW*
Operational Load Percentage = 200 *kW*/750 *kW* × 100% = 27%
UPS Efficiency at 27% Load = 94.55% (*Efficiency* Factor = 0.9455)
Input Power = 200 *kW*/0.9455 = 211.5 kW
Resulting *Loss* = 211.5 *kW* – 200 *kW* = 11.5 *kW*; 11.5 *kW*/211.5 *kW* × 100% = 5.45%
Standard 90.4 Max. Power *Loss* = 56.0%
(*UPS* MEETS STANDARD REQUIREMENTS AT 50% DESIGN LOAD.)
Output is 200 *kW*/0.9 pf = 222.2 *kVA*.
Output current is 222.2 *kVA* × 1000/√3/480V = 267.3 A.

25% of *UPS Operational Design Load* = 100 *kW*
Operational Load Percentage = 100 *kW*/750 *kW* × 100% = 13%
UPS Efficiency at 13% Load = 92.71% (*Efficiency* Factor = 0.9271)
Input Power = 100 *kW*/0.9271 = 107.9 *kW*
Resulting *Loss* = 107.9 *kW* – 100 *kW* = 7.9 *kW*; 7.9 *kW*/107.9 *kW* × 100% = 7.29%
Standard 90.4 Max. Power *Loss* = 7.0%
(*UPS* DOES NOT MEET STANDARD REQUIREMENTS AT 25% DESIGN LOAD.)
Output is 100 *kW*/0.9 pf = 111.1 *kVA*.
Output current is 111.1 *kVA* × 1000/√3/480V = 133.6 A.

UPS segment for *n+1* redundant *UPS* is within Table 8.6 values EXCEPT at 25% load level. Meeting ELC of the standard requires higher-*efficiency UPS*, smaller module *redundancy*, or offset with higher *efficiency* distribution segment and/or higher *efficiency* mechanical load component (MLC).

***N+1* Option #2**

UPS Operational Design Load = 400 *kW* (usually approximately 80% of *UPS* ~~design~~ *rated capacity*)

UPS ~~Design~~ *Rated Capacity* = 500 *kW*~~, *N+1*~~

UPS Redundant Capacity = 550 kW (N+1)

[Eleven (11) modules of 50 *kW* = 550 *kW* *redundant* ~~actual~~ *capacity* ~~capacity~~]

100% of *UPS Operational Design Load* = 400 *kW*
Operational Load Percentage = 400 *kW*/550 *kW* × 100% = 73%
UPS Efficiency at 73% Load = 95.78% (*Efficiency* Factor = 0.9578)
Input Power = 400 *kW*/0.9578 = 417.6 *kW*
Resulting *Loss* = 417.6 *kW* – 400 *kW* = 17.6 *kW*; 17.6 *kW*/417.6 *kW* × 100% = 4.22%
Standard 90.4 Max. Power *Loss* = 5.5%
(*UPS* MEETS STANDARD REQUIREMENTS AT 100% DESIGN LOAD.)
Output is 400 *kW*/0.9 pf = 444.4 *kVA*.
Output current is 444.4 *kVA* × 1000/√3/480V = 535 A.

75% of *UPS Operational Design Load* = 300 *kW*
Operational Load Percentage = 300 *kW*/550 *kW* × 100% = 55%
UPS Efficiency at 55% Load = 95.63% (*Efficiency* Factor = 0.9563)
Input Power = 300 *kW*/0.9563 = 313.7 *kW*
Resulting *Loss* = 313.7 *kW* – 300 *kW* = 13.7 *kW*; 13.7 *kW*/313.7 *kW* × 100% = 4.37%
Standard 90.4 Max. Power *Loss* = 5.5%
(*UPS* MEETS STANDARD REQUIREMENTS AT 75% DESIGN LOAD.)
Output is 300 *kW*/0.9 pf = 333.3 *kVA*.
Output current is 333.3 *kVA* × 1000/√3/480V = 400.9 A.

50% of *UPS Operational Design Load* = 200 *kW*
Operational Load Percentage = 200 *kW*/550 *kW* × 100% = 36%
UPS Efficiency at 36% Load = 95.85% (*Efficiency* Factor = 0.9585)
Input Power = 200 *kW*/0.9585 = 208.7 *kW*
Resulting *Loss* = 208.7 *kW* – 200 *kW* = 8.7 *kW*; 8.7 *kW*/208.7 *kW* × 100% = 4.15%
Standard 90.4 Max. Power *Loss* = 6.0%
(*UPS* MEETS STANDARD REQUIREMENTS AT 50% DESIGN LOAD.)
Output is 200 *kW*/0.9 pf = 222.2 *kVA*.
Output current is 222.2 *kVA* × 1000/√3/480V = 267.3 A.

25% of *UPS Operational Design Load* = 100 *kW*
Operational Load Percentage = 100 *kW*/550 *kW* × 100% = 18%
UPS Efficiency at 18% Load = 93.50% (*Efficiency* Factor = 0.9350)
Input Power = 100 *kW*/0.9350 = 107.0 *kW*
Resulting *Loss* = 107.9 *kW* – 100 *kW* = 7.0 *kW*; 7.0 *kW*/107.0 *kW* × 100% = 6.5%
Standard 90.4 Max. Power *Loss* = 7.0%
(*UPS* MEETS STANDARD REQUIREMENTS AT 25% DESIGN LOAD.)
Output is 100 *kW*/0.9 pf = 111.1 *kVA*.
Output current is 111.1 *kVA* × 1000/√3/480V = 133.6 A.

UPS SEGMENT FOR *N+1* REDUNDANT *UPS* IS WITHIN TABLE 8.6 VALUES AT ALL LOAD LEVELS.

2N Redundant *UPS*

UPS Operational Design Load = 400 *kW* (usually approximately 80% of *UPS* ~~design~~ *rated capacity*)

UPS Rated ~~Design~~ *Capacity* = 500 *kW*

UPS Redundant Capacity = 1000 *kW* (2N)

Both *systems* are identical and share load equally. Calculate for one (1) *system* at half *UPS Operational Design Load* ~~*design load*~~.

[Two (2) modules of 250 *kW* = 500 *kW* ~~actual~~ *UPS rated capacity* per system or 1000 *kW UPS redundant capacity*]

100% of SHARED *UPS Operational Design Load* = 400 *kW*/2 ~~*kW*~~ = 200 *kW*
Operational Load Percentage = 200 *kW*/500 *kW*× 100% = 40%
UPS Efficiency at 40% Load = 95.20% (*Efficiency* Factor = 0.9520)
Input Power = 200 *kW*/0.9520 = 210.1 *kW*
Resulting *Loss* = 210.1 *kW* – 200 *kW* = 10.1 *kW*; 10.1 *kW*/210.1 *kW* × 100% = 4.80%
Standard 90.4 Max. Power *Loss* = 5.5%
(*UPS* MEETS STANDARD REQUIREMENTS AT 100% DESIGN LOAD.)
Output is 200 *kW*/0.9 pf = 222.2 *kVA*.
Output current is 222.2 *kVA* × 1000/√3/480V = 267.3 A.

75% of SHARED *UPS Operational Design Load* = 400 *kW*/2 × 75% = 150 *kW*
Operational Load Percentage = 150 *kW*/500 *kW* × 100% = 30%
UPS Efficiency at 30% Load = 94.50% (*Efficiency* Factor = 0.9450)
Input Power = 150 *kW*/0.9450 = 158.7 *kW*
Resulting *Loss* = 158.7 *kW* – 150 *kW* = 8.7 *kW*; 8.7 *kW*/150 *kW* × 100% = 5.50%
Standard 90.4 Max. Power *Loss* = 5.5%
(*UPS* MEETS STANDARD REQUIREMENTS AT 75% DESIGN LOAD.)
Output is 150 *kW*/0.9 pf = 166.7 *kVA*.
Output current is 166.7 *kVA* × 1000/√3/480V = 200.5 A.

50% of SHARED *UPS Operational Design Load* = 400 *kW*/2 × 50% = 100 *kW*
Operational Load Percentage = 100 *kW*/500 *kW* × 100% = 20%
UPS Efficiency at 20% Load = 94.00% (*Efficiency* Factor = 0.9400)
Input Power = 100 *kW*/0.9400 = 106.4 *kW*
Resulting *Loss* = 106.4 *kW* – 100 *kW* = 6.4 *kW*; 6.4 *kW*/106.4 *kW* × 100% = 6.00%
Standard 90.4 Max. Power *Loss* = 6.00%
(*UPS* MEETS STANDARD REQUIREMENTS AT 50% DESIGN LOAD.)
Output is 100 *kW*/0.9 pf = 111.1 *kVA.*
Output current is 111.1 *kVA* × 1000/√3/480V = 133.6 A.

25% of SHARED *UPS Operational Design Load* = 400 *kW*/2 × 25% = 50 *kW*
Operational Load Percentage = 50 *kW*/500 *kW* × 100% = 10%
UPS Efficiency at 10% Load = 92.12% (*Efficiency* Factor = 0.9212)
Input Power = 50 *kW*/0.9212 = 54.3 *kW*
Resulting *Loss* = 54.3 *kW* – 50 *kW* = 4.3 *kW*; 4.3 *kW*/54.3 *kW* × 100% = 7.88%
Standard 90.4 Max. Power *Loss* = 7.00%
(*UPS* DOES NOT MEET STANDARD REQUIREMENTS AT 25% DESIGN LOAD.)
Output is 50 *kW*/0.9 pf = 55.6 *kVA.*
Output current is 55.6 *kVA* × 1000/√3/480V = 66.8 A.

UPS segment for *2N* redundant *UPS* is within Table 8.6 values EXCEPT at 25% load level. Meeting ELC of the standard requires higher-*efficiency UPS*, or offset with higher *efficiency* distribution segment and/or higher-*efficiency* MLC.

Table C-1 Superscript Notes from Charts 1 through 6

Superscript	
1	The ELC calculation begins with the *UPS* segment and starts with the establishment of the *UPS* ~~operational design load~~ *operational design load* (❶*i*), which is the total of the *ITE* design load (❶*g*) plus any additional *UPS* loads (❶*h*) such as *cabinet* fans, auxiliary pumps, etc. [*UPS* operational design percentage (❶*j*) is usually around 80% of *UPS* ~~design capacity~~ *rated capacity* (capacity without *redundancy*)].
2	*UPS* ~~total capacity~~ *redundant capacity* (❶*f*) is determined by overhead capacity (usually about 20% above design load), modularity, and *redundancy*.
3	*UPS* electrical data obtained from *manufacturer* data sheets.
4	*UPS* actual operating load percentage (❶*o*) based on ~~design capacity~~ *UPS rated capacity* plus *redundancy* when operated at full operational design load—that is, *UPS* operational design load (❶*i*) divided by total *UPS* ~~capacity with *redundancy*~~ *redundant capacity* (❶*f*).
5	Likewise, (❶*o*) is actual *UPS* load percentage at fractional operational *UPS* ~~design load~~ *operational design loads* (100%, 75%, 50%, and 25%) ~~of full loading percentage, and is dependent on *UPS redundancy*~~ divided by total *UPS redundant capacity*. In the example, 400 *kW* is 80% of 500 *kW UPS* design capacity but only 73% of 550 *kW* total *UPS* capacity with *redundancy*.
6	*UPS efficiencies* (❶*p*) determined from *manufacturer* data at actual percentage of total *UPS* ~~capacity (including *redundancy*)~~ *redundant capacity*, calculated at 100%, 75%, 50%, and 25% of *UPS* operational design load.
7	*UPS* ~~segment~~ *segment loss* values of the ELC (❶*t*) are absolute values of *UPS* power *loss* percentages (❶*s*) at 100%, 75%, 50%, and 25% of ~~design loads~~ *UPS operational design loads*, and are transferred to Chart ❻ for calculation of total ELC.
8	Actual *UPS* output *kVA* (❶*u*) at each design load level transferred to Chart ❷ for calculation of PDU feeder *loss* portion of ELC distribution segment.
9	Input to PDU feeder is output *kVA* of *UPS* at 100%, 75%, 50%, and 25% of ~~design load~~ *UPS operational design load*.
10	*UPS* output power is assumed to be equally divided between equal-sized PDUs in this example. Actual calculation must use worst-case condition (longest and highest power loss feeder).
11	PDU feeder sized for input amperage per code.
12	Power factor is assumed to be close to 1.0. Therefore, most loads are expressed in or converted to volt-amperes or *kilovolt-amperes* for consistency throughout the example, and using DC resistance for uncoated copper wires from NFPA 70 Table 8, rather than calculating impedance, is considered sufficient for this standard. Alternatively, the engineer may use NFPA 70 Table 9, "Alternating Current Resistance for Uncoated Copper Wires" when feeder is three single conductors in conduit for three-phase circuit.
13	I^2R Method is used in the example for calculating single conductor *losses*, and then multiplied by the number of conductors in order to apply to both single-phase and three-phase conditions. Alternately, the engineer may use other accepted methods so long as actual calculations are shown on submitted design documents. (***Note*:** Superscript "2" in "I^2R" is an exponent, not a table note.)
14	Calculated PDU feeder *efficiency* (❷*r*) transferred to Chart ❺*b* for calculation of distribution segment of ELC.
15	Nominal two-wire, single-phase *transformer* output voltage in the U.S. Calculations must use actual output voltage to *branch circuit* wiring.
16	*Transformer efficiencies* (❻*e*) from *manufacturer* load vs. *efficiency* curves at 100%, 75%, 50%, and 25% load levels. (Single DOE *efficiencies* at 35% load are not acceptable for this standard.)
17	Calculated PDU *efficiency* (❸*r*) transferred to Chart ❺*c* for calculation of distribution segment of ELC.
18	80% of breaker trip rating in example for continuous current per NFPA 70. Use ratings applicable to installation.
19	Wire gage selected for maximum current per code [NFPA 70, Table B.2(1)].
20	Calculated PDU *efficiency* (❹*r*) transferred to Chart ❺*d* for calculation of distribution segment of ELC.
21	Distribution segment *efficiency* is product of PDU feeder, PDU, and *branch circuit* conductor *efficiencies*.
22	Total power *loss* percent can also be calculated as algebraically combined *loss* percentages: $$Loss\ \% = [\{(((a + b) - (a \times b)) + c) - (c \times (a + b)\} - (c^2 \times a \times b)]$$ where *a*, *b*, and *c* are PDU feeder (❷*q*), PDU (❸*o*), and *branch circuit* conductor (❹*q*) power *losses*.
23	Distribution segment *loss* values of the ELC (❺*f*) are absolute values of distribution power *loss* percentages (❺*r*) at 100%, 75%, 50%, and 25% of design loads, and are transferred to Chart ❻ for calculation of total ELC.
24	ELC segments from Charts ❶ and ❺ are added to calculate ELC.
25	ELC values from Table 8.5 (less than 100 *kW* design load) or Table 8.6 (greater than or equal to 100 *kW* design load) of the standard.
26	If any part of the ELC fails to meet Section 8 table values, use Section 11 Trade-Off Method to see if the standard can be met.

Chart ❶ Calculation of UPS Segment of ELC
(Example Based on Modular UPS with N+1 Redundancy Designed at 80% Normal Loading)

Capacity, Design Loads, and Output Feeder Current

UPS Redund.	UPS Module Size, kW [3]	Base UPS Module Quant.	Redundant UPS Module Quant.	UPS Design Capacity, kW	UPS Redund. Capacity, kW	UPS Total Capacity, kW [2]	ITE Design Load kW [1]	Additional UPS Loads, kW [1]	Operational Design Load, kW [1]	UPS Input: Volts [3]	UPS Input: Phases [3]	UPS Input: Power Factor (pf)	UPS Input: kVA [12]
N+1	50	10	1	500	50	550g	**390**	10	**400**	480	3	0.9	611
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*		*k*	*l*
				d = *a* × *b*	*e* = *a* × *c*	*f* = *d* + *e*			*i* = *g* + *h*				*l* = *f*/*k*

Efficiencies at Full and Partial Loads

% Design Load, %	Design Load, kW [1]	UPS Actual Oper. % [4, 5]	UPS Effic., % [6]	UPS Input, kW	Power Loss, kW	UPS Loss, % [7]	UPS Segment of ELC [7]	Output: kVA [8, 12]	Output: A
100%	**400**	72.73%	95.78%	417.62	17.62	4.22%	**0.042**	**444.44**	534.58
75%	300	54.55%	95.63%	313.71	13.71	4.37%	**0.044**	**333.33**	400.94
50%	200	36.36%	95.85%	208.66	8.66	4.15%	**0.042**	**222.22**	267.29
25%	100	18.18%	93.50%	106.95	6.95	6.50%	**0.065**	**111.11**	133.65
m	*n*	*o*	*p*	*q*	*r*	*s*	*t*	*u*	*v*
	n = *m* × *i*	*p* = *n*/*f* × 100%		*q* = *n*/*p*	*r* = *q* – *n*	*s* = 1 – *p*	*t* = |*s*|	*u* = *n*/*k*	*v* = *u* × 1000/*j*/√3

See Table C-1 for a description of superscript notes.

Chart ❷ Calculation of UPS-to-PDU Feeder Segment of ELC—Step #1

Loss and Efficiency of Worst-Case UPS Feeder to PDU Using I^2R Method

% Design Load	UPS Output, kVA [9, 12]	PDU Quant. [10]	PDU Size, kVA [12]	PDU Actual, kVA [10, 12]	PDU Input, V	PDU Input, 3 φ A	Wire Length, ft	Wire Gage, AWG [11]	Ohms/ 1000', 75°C [12]	Wire Resist., Ohms	I^2, Amps [2]	I^2R Loss per Cond., kVA [12, 13]	No. Cond. [13]	Total Loss, kVA [12, 13]	Output Power, kVA [12]	Power Loss, %	Feeder Effic., % [14]
100%	**444.44**	4	150	111.11	480	133.65	100	1/0	0.122	0.0122	17,861	0.22	3	0.65	**110.46**	0.59%	**99.41%**
75%	**333.33**	4	150	83.33	480	100.23	100	1/0	0.122	0.0122	10,047	0.12	3	0.37	**82.97**	0.44%	**99.56%**
50%	**222.22**	4	150	55.56	480	66.82	100	1/0	0.122	0.0122	4465	0.05	3	0.16	**55.39**	0.29%	**99.71%**
25%	**111.11**	4	150	27.78	480	33.41	100	1/0	0.122	0.0122	1116	0.01	3	0.04	**27.74**	0.15%	**99.85%**
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*	*r*
~~*a* = ❶*v*~~	*b* = ❶*u*			*e* = *b*/*c*	*f* = ❶~~*k*~~ *j*	*g* = *e* × 1000/*f*/√3				*k* = *j*/1000 × *h*	*l* = *g* [2]	*m* = 1 × *k*		*o* = *m* × *n*	*p* = *e* – *o*	*q* = *o*/*e* × 100%	*r* = (1 – *q*) × 100%

See Table C-1 for a description of superscript notes.

Chart ❸ Calculation of PDU Portion of Distribution Segment of ELC—Step #2

Loss and Efficiency of Worst-Case PDU								
% Design Load, %	**Xfmr. Rating, kVA[12]**	**Xfmr. Input, kVA[12]**	**Xfmr. Output, V[15]**	**Xfmr. Effic., %[16]**	**Xfmr. Loss, %**	**Xfmr. Output, kVA[12]**	**Xfmr. Loss, kVA[12]**	**PDU Effic., %[17]**
100%	150	**110.46**	208	97.50%	2.50%	107.70	2.76	**97.50%**
75%	150	**82.97**	208	97.80%	2.20%	81.14	1.83	**97.80%**
50%	150	**55.39**	208	98.00%	2.00%	54.28	1.11	**98.00%**
25%	150	**27.74**	208	98.40%	1.60%	27.29	0.44	**98.40%**
a	*b*	*c*	*d*	*e*	*o*	*p*	*q*	*r*
	b = ❷*d*	*c* = ❷*p*			*o* = 100% – *e*	*p* = *c* × *e*	*q* = *c* – *p*	*r* = *p*/*c* × 100%

See Table C-1 for a description of superscript notes.

Chart ❹ Calculation of Branch Circuit Portion of Distribution Segment of ELC—Step #3

Loss and Efficiency of Worst Case Branch Circuit from PDU Branch Breakers to Cabinets																
% Design Load, %	**Distrib. Volts, 1Ph**	**Breaker Rating, A**	**Max. Current, A[18]**	**Current @ Load %, A**	**Per Cond. Power, VA[12]**	**No. Cond.**	**Total Power, VA[12]**	**Wire Size, AWG[19]**	**Wire Length, ft**	**Ohms/ 1000', 75°C[12]**	**Wire Resist., ohms**	**I^2R, Amps[2]**	**I^2r Loss Per Cond., VA[12, 13]**	**Total Loss, VA[12, 13]**	**Power Loss, %**	**Segment Effic., %[20]**
100%	**208**	**30**	**24**	**24**	~~2882~~ 2496	2	~~5764~~ 4994	#10	50	1.21	0.0605	576.00	34.85	69.70	~~1.21~~ 1.40%	~~**98.79**~~ **98.60%**
75%	**208**	**30**	**24**	**18**	~~2162~~ 1872	2	~~4323~~ 3744	#10	50	1.21	0.0605	324.00	19.60	39.20	0.91 1.05%	~~**99.09**~~ **98.95%**
50%	**208**	**30**	**24**	**12**	~~1441~~ 1248	2	~~2882~~ 2496	#10	50	1.21	0.0605	144.00	8.71	17.42	~~0.60~~ 0.70%	~~**99.40**~~ **99.30%**
25%	**208**	**30**	**24**	**6**	~~721~~ 624	2	~~1441~~ 1248	#10	50	1.21	0.0605	36.00	2.18	4.36	~~0.30~~ 0.35%	~~**99.70**~~ **99.65%**
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*q*	*r*
	b = ❸*d*		*d* = *c* × 80%	*e* = *a* × *d*	~~*f* = *b* × *e* = √3~~ *f* = *b* × *e*/2		*h* = *f* × *g*				*l* = *k*/1000 × *j*	$m = e^2$	*n* = *m* × *l*	*o* = *g* × *n*	*q* = *o*/*h* × 100%	*r* = 100% – *q*

See Table C-1 for a description of superscript notes.

Chart ❺ Calculation of Distribution Segment of ELC—Step 4

Combined UPS, PDU, and Branch Ckt. Efficiencies for Distribution Segment of ELC						
% Design Load, %	**PDU Feeder, %** [14]	**PDU, %** [17]	**Branch Circuit, %** [20]	**Combined Efficiencies, %** [21]	**Loss, %** [22]	**Distrib. Segment of ELC** [23]
100%	**99.41%**	**97.50%**	**~~98.79~~ 98.60%**	~~95.75~~ 95.57%	~~4.25~~ 4.43%	**~~0.042~~ 0.044**
75%	**99.56%**	**97.80%**	**~~99.09~~ 98.95%**	~~96.49~~ 96.35%	~~3.51~~ 3.65%	**~~0.035~~ 0.037**
50%	**99.71%**	**98.00%**	**~~99.40~~ 99.30%**	~~97.12~~ 97.03%	~~2.88~~ 2.97%	**~~0.029~~ 0.030**
25%	**99.85%**	**98.40%**	**~~99.70~~ 99.65%**	~~97.96~~ 97.91%	~~2.04~~ 2.09%	**~~0.020~~ 0.021**
a	***b***	*c*	*d*	*e*	*f*	***g***
	b = ❷*r*	*c* = ❸*r*	*d* = ❹*r*	$e = b \times c \times d$	$f = 100\% - e$	$g = \|f\|$

See Table C-1 for a description of superscript notes.

Chart ❻ ELC Calculation Based on Losses

Single Output UPS (*N*, *N+1*, etc.) or No UPS: 100 kW or Greater						
% Design Load, %	**UPS Segment** [7]	**ITE Distrib. Segment** [23]	**ELC** [24]	**ELC Standard Values** [25]	**Diff. from Standard**	**Pass or Fail**
100%	0.042	~~0.042~~ 0.044	~~0.085~~ 0.086	0.110	~~0.025~~ 0.024	Pass
75%	0.044	~~0.035~~ 0.037	~~0.079~~ 0.080	0.098	~~0.019~~ 0.018	Pass
50%	0.042	~~0.029~~ 0.030	~~0.070~~ 0.071	0.094	~~0.024~~ 0.023	Pass
25%	0.065	~~0.020~~ 0.021	~~0.085~~ 0.086	0.093	~~0.008~~ 0.007	Pass
a	*b*	*c*	*d*	*e*	*f*	*g*
	b = ❶~~*q*~~*t*	*c* = ❺~~*i*~~*g*	$d = a + b + c$		$f = e - d$	~~$g \geq f$~~ $f \geq 0$

See Table C-1 for a description of superscript notes.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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About ASHRAE

Founded in 1894, ASHRAE is a global professional society committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields.

As an industry leader in research, standards writing, publishing, certification, and continuing education, ASHRAE and its members are dedicated to promoting a healthy and sustainable built environment for all, through strategic partnerships with organizations in the HVAC&R community and across related industries.

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