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

First Public Review Draft

Proposed Addendum b to Standard 90.4-2022, *Energy Standard for Data Centers*

First Public Review (February, 2025)
(Draft Shows Proposed Changes to Current Standard)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

This standard is under continuous maintenance. To propose a change to the current standard, use the change submittal form available on the ASHRAE website, www.ashrae.org.
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ASHRAE, 180 Technology Pkwy NW, Peachtree Corners, GA 30092

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

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 examples, they have not been clearly delineated in definitions, leading to confusion in the use of undefined terms. This Addendum 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.

[Note to Reviewers: This addendum makes proposed changes to the current standard. These changes are indicated in the text by underlining (for additions) and strikethrough (for deletions) except where the reviewer instructions specifically describe some other means of showing the changes. Changes shown where there is a complete replacement are shown in red and only for informative appendices. Only these changes to the current standard are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed changes.]

Addendum b to 90.4-2022

Modify the following definitions to Section 3.

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* 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*.~~

design electrical loss component (design ELC): the *design electrical loss component* for the *data center* or *data center addition* shall be the combined *losses* (or the *losses* 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.~~

essential facilities: those portions of a *data center*, whether on the same site or at a remote location, serving one of the following functions:

a. Hospitals and other health care facilities having surgery or emergency treatment facilities
b. Fire, rescue, and police stations and emergency-vehicle garages
c. Designated earthquake, hurricane, or other emergency shelters
d. Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response

e. Power generation, transmission, and distribution stations, and other public utility facilities required as emergency backup facilities for other *essential facilities*
f. Structures containing highly toxic materials where the quantity of the material exceeds the maximum allowable quantities
g. Aviation control towers, air traffic control centers, and emergency aircraft hangars
h. *Data centers* and other structures having critical national defense functions
i. Those *spaces* having a *mechanical cooling* or electrical design of Rating IV as defined by ANSI/TIA- 942-B
j. Those *spaces* classified under NFPA 70, Article 708, "Critical Operations Power Systems (COPS)"
k. Those *spaces* where core clearing and settlement *services* are performed such that failure to settle pending financial transactions could present systematic risk as described in "The Interagency Paper on Sound Practices to Strengthen the Resilience of the U.S. Financial System"

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* does 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 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 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 during the *loss* of the primary components, *equipment*, controls, or *systems* due to failure, maintenance, servicing, or other modification activities.

N: base number of capacity components needed to provide design *system* functional capacity.

N+1, N+2, etc.: single *system redundancy* having one or more additional capacity components.

2N, 2N+1 or 2(N+1), etc.: dual *system redundancy* having one or more additional capacity components.

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.

~~***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 US 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. How- ever, 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, ~~also known as "Eco Mode~~," in which power is fed to the load without going through power conversions to reduce *loss* during normal operation. ~~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 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: 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 between those two points. ~~*Transformers* and switchgear functioning as parts of the *UPS* but installed separately and not provided by the *UPS manufacturer* (such as custom-configured bypass) are not considered part of the *UPS segment* but are to 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 buildout: 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 is included.

Full buildout: design for the complete data center facility based on total *UPS Operational Design Load* and is permitted and constructed in-full as a single project.

Scaled buildout: design is for the complete facility (as if for a *full buildout*), 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 buildout: 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 the language in Section 4.2.1.3 and the Exceptions to 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 Buildout

4.2.1.4.1 Core and shell buildouts. Design and construction of *core and shell buildouts* 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* is designed and permitted for installation in *space* and shall be in accordance with the applicable form of design and buildout in Section 4.2.1.4.2 - 4.2.1.4.4.

4.2.1.4.2 Full buildout. Design and construction of *full buildouts* shall comply with the most recent applicable version of this Standard.

4.2.1.4.3 Scaled buildout. Design and construction of *scaled buildouts* 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 buildout* design.
b) Facility remains in compliance with the Standard if all stages of the buildout adhere to the original design and permit.
c) Initial stage of the *scaled buildout* 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 buildout, 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 Section 6.1.1.3.1 and 8.1.1.3.1, respectively.)

4.2.1.4.4 Modular buildout: *Modular buildout* and each subsequent *modular buildout* shall comply with the latest applicable version of this Standard at the time each module is designed and permitted.

Informative Note: More information on buildout types are found in Informative Appendix C.

Modify the language in Section 6.6.2.1as follows:
Note to reviewer: highlighted language was added by Published 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 ~~D~~describe the amount ~~amounts~~ of mechanical & 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 the language in Section 8.4.1 as follows:

8.4.1 **Electrical Distribution Systems for Mechanical Loads.** The electrical *distribution systems* serving…

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 calculation. However, all ~~components~~ transformers in the incoming 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*.

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 the language in 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 the language in Informative Appendix C as follows: changes in text boxes in charts are shown in red. Numbers in tables are highlighted for ease of review

INFORMATIVE APPENDIX C

TOOLS FOR ILLUSTRATING COMPLIANCE

Modify Figure C-3, C-4, and C-5 as shown – replace with new figures and new text in red.

SPC 90.4 APPLICABILITY

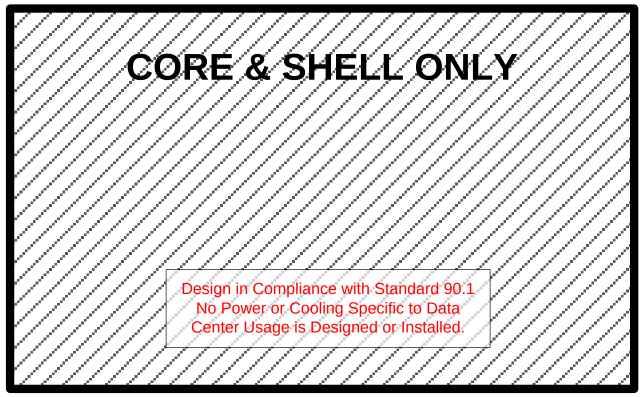
FORMS OF NEW CONSTRUCTION

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

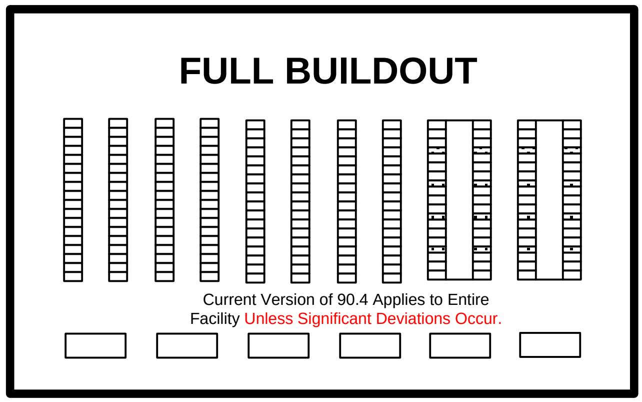
(See Options Below for Types of Build-outs)



FULL BUILDOUT

Design and Permitting Based on
Design Load for Full Buildout

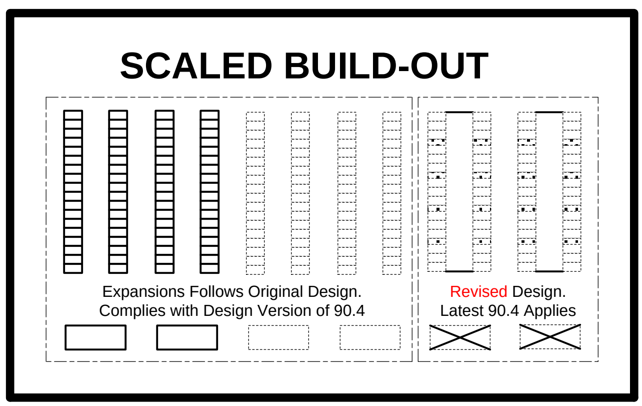
Current Applicable Version of 90.4
At Time of Design & Permit
(Continues to Apply Unless Deviations
Require Reverting to Latest Version)



SCALED BUILD-OUT

Calculate Based On Design Load
For Full Build-out

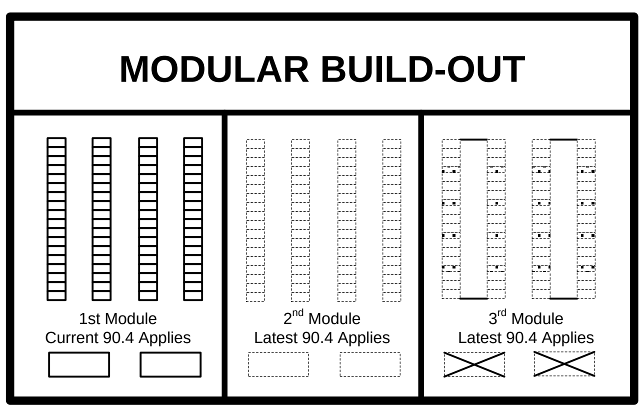
Current Applicable Version of 90.4
At Time of Design and Permitting.
Each Stage Shown as Complying on Design Documents.
(Deviations Revert to Latest Version)



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



SPC 90.4 APPLICABILITY

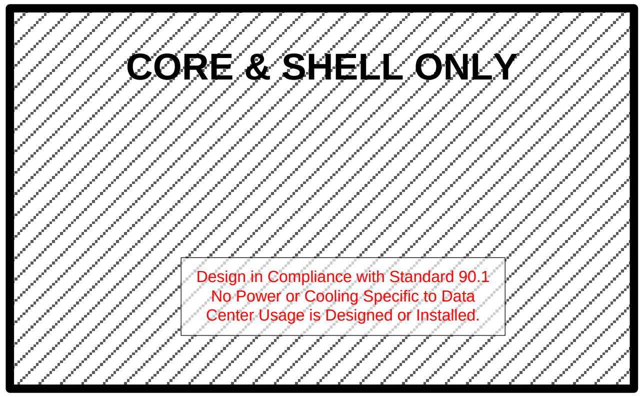
CHANGES TO HVAC SYSTEM DESIGN ONLY

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)

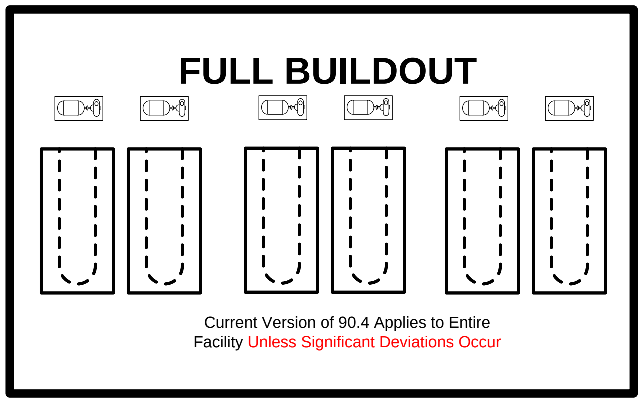


FULL BUILDOUT

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.)



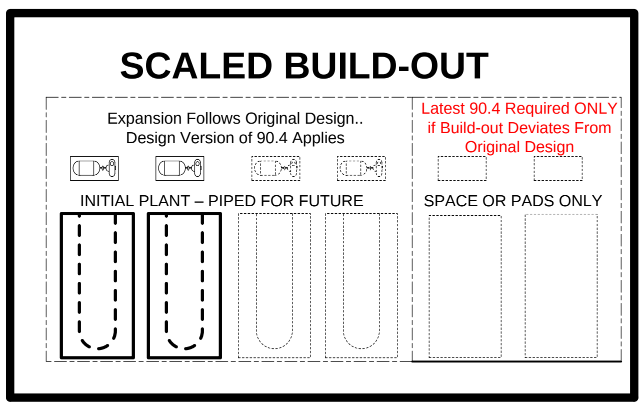
SCALED BUILD-OUT

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.

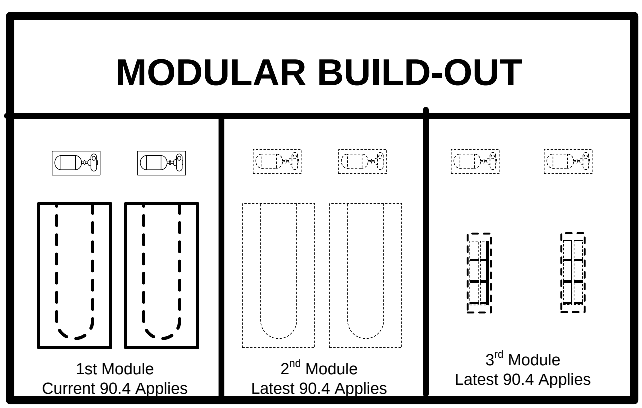
(Deviations Revert to Latest Version)



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



SPC 90.4 APPLICABILITY

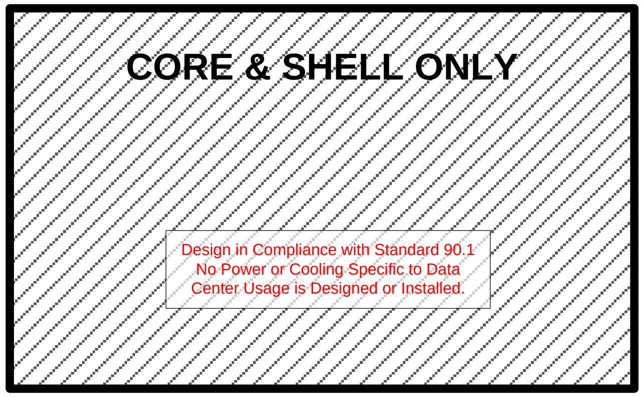
CHANGES TO ELECTRICAL POWER DESIGN ONLY

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)

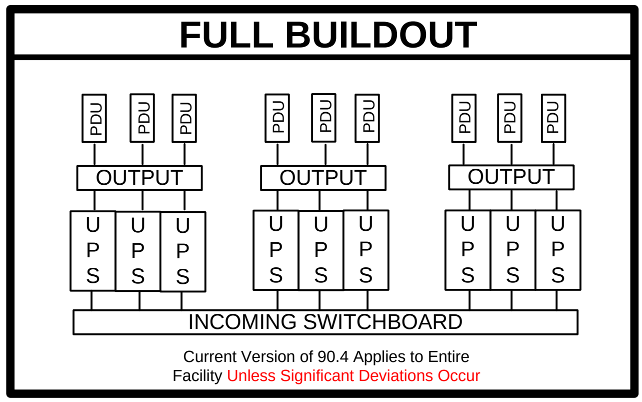


FULL BUILDOUT

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

Current Applicable Version of 90.4
At Time of Design & Permit

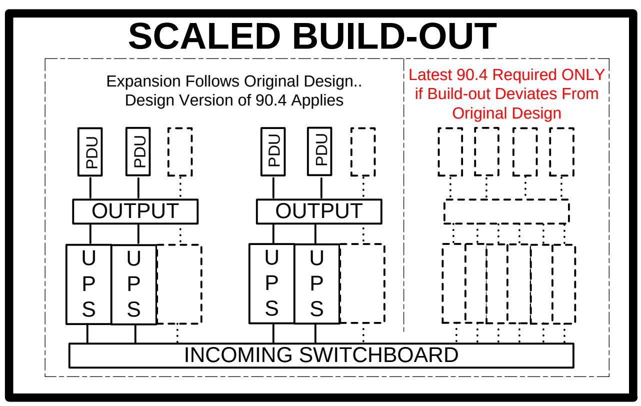
(Electrical System Upgrade is Completed as a Single Project In Accordance with Permitted Design.)



SCALED BUILD-OUT

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

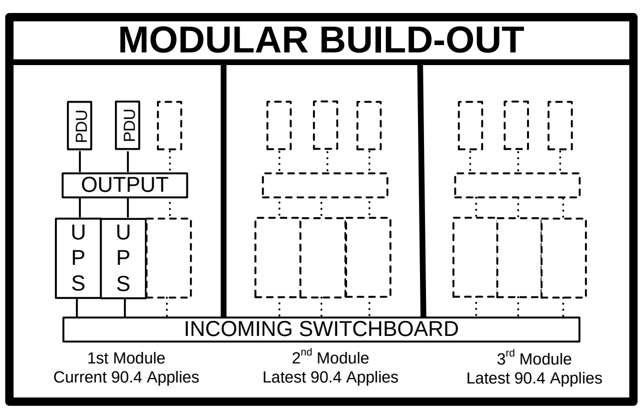
Current Applicable Version of 90.4
At Time of Design and Permitting.
Each Stage Shown as Complying on Design Documents.
(Deviations Revert to Latest Version)



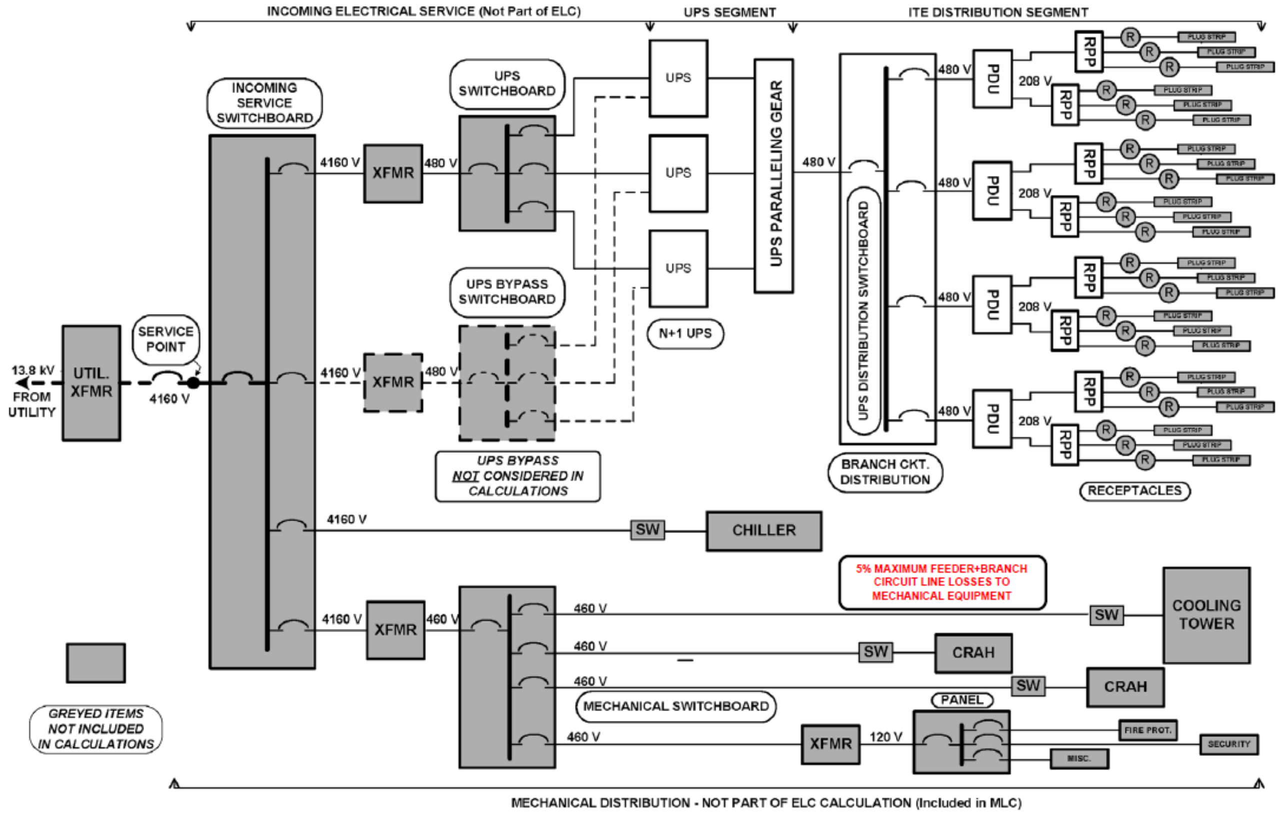
MODULAR BUILD-OUT

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



Modify text box in Figure C6 Electrical efficiency compliance path with new text in red



~~3% MAXIMUM LINE LOSSES TO MECHANICAL EQUIPMENT~~ changed to:
5% MAXIMUM FEEDER + BRANCH CIRCUIT LINE LOSSES TO MECHANICAL EQUIPMENT

Modify Informative Appendix C1

Note most changes are to italicize new defined terms. Numbers in the tables are highlighted for ease of review.

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*.

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]

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]

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 – 1,000 kW (2N)
Both *systems* are identical and share load equally. Calculate for one (1) *system* at half *UPS*

Operational ~~d~~Design ~~l~~Load.
[Two (2)modules of 250 *kW* = 500 *kW* ~~actual~~ *UPS rated capacity* per system or 1,000 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 x 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 Loa*d = 400 kW/2 x 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 / x 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* (❶*i*), which is the total of the *ITE* design load (❶g) 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 rated capacity* (capacity without *redundancy*)].
2	*UPS 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 *UPS rated capacity* plus *redundancy* when operated at full operational design load—that is, *UPS* operational design load (❶*i*) divided by total *UPS redundant* capacity. (❶*f*).

5 Likewise, (❶*o*) is actual *UPS* load percentage at fractional *UPS operational design loads* (100%, 75%, 50%, and 25%) devided 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 redundant capacity*

6 *UPS efficiencies* (❶*p*) determined from *manufacturer* data at actual percentage of total *UPS redundant capacity* calculated at 100%, 75%, 50%, and 25% of *UPS operational design load.*

7 *UPS* 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 *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 *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 Rated Capacity, kW	UPS Redund. Modules kW	UPS Redundant Capacity, kW [2]	ITE ITE Design Load kW [1]	Additional UPS Loads, kW [1]	Operational UPS 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	550	**390**	10	**400**	480	3	0.9	611
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*		*k*	*l*
				$d = a \times b$	$e = a \times c$	$f = d + e$			$i = g + h$				$l = f/k$

Efficiencies at Full and Partial Loads

% Design Load, %	Design Load, kW [1]	UPS Actual Oper. % [4,5]	UPS Effic., %	UPS Input, kW	Power Loss, kW	UPS Loss, %	UPS Segment of ELC [4]	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*
	$n = m \times i$	$p = n/f \times 100\%$		$q = n/p$	$r = q - n$	$s = 1 - p$	$t = \lvert s \rvert$	$u = n/k$	$v = u \times 1000/j/\sqrt{3}$

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*
	$b =$ ❶u			$e = b/c$	$f =$ ❶j	$g = e \times 1000/f/\sqrt{3}$				$k = j/1000 \times h$	$l = g^2$	$m = 1 \times k$		$o = m \times n$	$p = e - o$	$q = o/e \times 100\%$	$r = (1 - q) \times 100\%$

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^2, 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/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* × *c* × *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*t*	*c* = ❺*g*	*d* = *b* + *c*		*f* = *e* – *d*	*f* ≥ 0

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