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Document Name: ACRI 365: Commercial and Industrial Unitary Air-Conditioning Condensing Units

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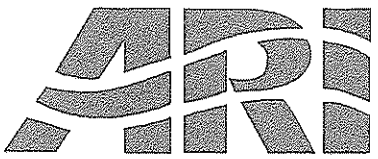
1994
STANDARD for

COMMERCIAL AND INDUSTRIAL UNITARY AIR-CONDITIONING CONDENSING UNITS



AIR-CONDITIONING &
REFRIGERATION
INSTITUTE

Standard 365

4301 NORTH FAIRFAX DRIVE • ARLINGTON, VIRGINIA 22203

IMPORTANT

SAFETY RECOMMENDATIONS

It is strongly recommended that the product be designed, constructed, assembled and installed in accordance with nationally recognized safety requirements appropriate for products covered by this standard.

ARI, as a manufacturers' trade association, uses its best efforts to develop standards employing state-of-the-art and accepted industry practices. However, ARI does not certify or guarantee safety of any products, components or systems designed, tested, rated, installed or operated in accordance with these standards or that any tests conducted under its standards will be non-hazardous or free from risk.

Note:

This standard supersedes ARI Standard 365-87.

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COMMERCIAL AND INDUSTRIAL UNITARY AIR-CONDITIONING CONDENSING UNITS

Section 1. Purpose

1.1 *Purpose.* The purpose of this standard is to establish for commercial and industrial air-conditioning condensing units: definitions and classifications; requirements for testing and rating; performance requirements; and conformance conditions.

1.1.1 This standard is intended for guidance of the industry, including manufacturers, engineers, installers, contractors and users.

1.1.2 *Review and Amendment.* This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 *Scope.* This standard applies to factory-made commercial and industrial unitary air-conditioning condensing units defined in Section 3.

2.1.1 *Energy Source.* This standard applies only to electrically-driven, mechanical compression type condensing units.

2.2 *Exclusions.* This standard does not apply to condensing units with capacities less than 135,000 Btuh [40 kW]. It also does not apply to the testing and rating of condensing units for refrigeration purposes, as defined in ARI Standard 520.

Section 3. Definitions

3.1 *Definitions.* All terms in this document will follow the standard industry definitions in the current edition of ASHRAE *Terminology of Heating, Ventilation, Air Conditioning, and Refrigeration* unless otherwise defined in this section.

3.2 *Commercial and Industrial Unitary Air-Conditioning Condensing Unit.* A commercial and industrial unitary air-conditioning condensing unit is a factory-made assembly of refrigerating components designed to compress and liquefy a specific refrigerant. It consists of one or more refrigerant compressors, refrigerant condensers, condenser fans and motors (where used) and factory-supplied accessories.

3.3 *Energy Efficiency Ratio (EER).* A ratio of the cooling capacity in Btu/h [W] to the power input in watts [W] at any given set of rating conditions expressed in Btu/W•h [W/W].

3.4 *Integrated Part Load Value (IPLV).* A single number part load efficiency figure of merit calculated per the method described in 5.2.2.

3.5 *Published Rating.* A statement of the assigned values of those performance characteristics, under stated rating conditions, by which a unit may be chosen to fit its application. These values apply to all units of like nominal size and type (identification) produced by the same manufacturer. As used herein, the term "published rating" includes the rating of all performance characteristics shown on the unit or published in specifications, advertising, or other literature controlled by the manufacturer, at stated rating conditions.

3.5.1 *Standard Rating.* A rating based on tests performed at Standard Rating Conditions.

3.5.2 *Application Rating.* A rating based on tests performed at application rating conditions (other than Standard Rating Conditions).

3.6 *Rating Conditions.* Any set of operating conditions under which a single level of performance results, and which causes only that level of performance to occur.

3.6.1 *Standard Rating Conditions.* Rating conditions used as the basis of comparison of performance characteristics.

3.7 *"Shall," "Should," "Recommended," or "It Is Recommended."* "Shall," "should," "recommended," or "it is recommended" shall be interpreted as follows:

3.7.1 *Shall.* Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.7.2 *Should, Recommended, or It Is Recommended.* "Should," "recommended," or "it is recommended" is used to indicate provisions which are not mandatory but which are desirable as good practice.

Section 4. Classification

4.1 *Classification.* Normally, equipment covered within the scope of this standard may be classified as follows:

Types of Commercial and Industrial Air-Conditioning Condensing Units

Designation	ARI Type	Heat Rejection	Arrangement
Condensing Unit	RCU-A	Air	
	RCU-E	Evaporative	
	RCU-W	Water	

Section 5. Testing and Rating Requirements

5.1 *Standard Ratings.* Standard Ratings of condensing units shall be established at the Standard Rating Conditions shown in 5.1.3. All Standard Ratings shall be verified by tests conducted in accordance with the ASHRAE Standard 14-1980 and with the test methods and procedures as described in this standard. An alternate method of verification may be used by tests conducted in accordance with ANSI/ASHRAE 37-1988 provided that the saturated suction temperature and actual suction vapor temperature is determined from this procedure.

Standard Cooling Capacities shall be that obtained under Standard Rating Conditions. Power input shall be the total power input to the compressor(s) and fan(s) plus controls and other items included as part of the condensing unit.

5.1.1 *Values of Standard Capacity Ratings.* These ratings shall be expressed only in terms of thousands of Btu per hour (Mbh) [kW] in multiples of 2 Mbh [0.6 kW] for units with standard ratings of 400 Mbh [117 kW] and under. For units with standard ratings of over 400 Mbh [117 kW], the ratings shall be expressed in multiples of 5 Mbh [1.5 kW].

5.1.2 *Values of Standard Efficiency Ratings.* Energy Efficiency Ratios (EER) in Btu/W•h and Integrated Part Load Values (IPLV) shall be expressed in multiples to the nearest 0.1.

5.1.3 *Standard Rating Conditions.* The conditions of test for Standard Rating for condensing units shall include the following:

5.1.3.1 *Standard Rating Temperatures.* Standard Capacity Ratings and corresponding power input shall be determined at the following temperature conditions as shown in Table 1.

5.1.3.2 *Single Number Rating.* Where single number ratings are required the reported values shall be determined by averaging the results of the following tests from Table 1:

For all units
Refrigerant entering condensing unit
Saturated suction
temperature.....50°F [10°C] and
40°F [4.4°C]
Actual suction
temperature.....65°F [18.3°C] and
55°F [12.8°C]

Air-cooled and evaporatively-cooled units
Air entering and surrounding
unit.....95°F [35°C] DB
75°F [23.9°C] WB*

Water-cooled units
Entering water temperature 85°F [29.4°C]
Leaving water temperature 95°F [35°C]

*Required for evaporatively-cooled units.

5.1.3.3 *Electrical Conditions.* Standard Rating tests shall be performed at the nameplate rated voltage(s) and frequency.

For condensing units with dual nameplate voltage ratings, Standard Rating tests shall be performed at both voltages, or at the lower of the two voltages, if only a single Standard Rating is to be published.

Table 1. Standard Rating Conditions

Air- and Evaporatively-Cooled Condensing Units							
Air Entering and Surrounding Unit				Refrigerant Entering Condensing Unit[1]			
Dry Bulb		Wet Bulb[2]		Saturated Suction Temp.		Actual Suction Temp.	
°F	°C	°F	°C	°F	°C	°F	°C
95	35	75	23.9	50	10	65	18.3
95	35	75	23.9	40	4.4	55	12.8
80	26.7	67	19.4	50	10	65	18.3
80	26.7	67	19.4	40	4.4	55	12.8
Water-Cooled Condensing Units							
Water Temperature							
Entering		Leaving					
°F	°C	°F	°C				
85	29.4	95	35	50	10	65	18.3
85	29.4	95	35	40	4.4	55	12.8
75	23.9	same flow rate as above		50	10	65	18.3
75	23.9			40	4.4	55	12.8

NOTES:
1 The liquid temperature and pressure leaving the condensing unit shall be reported by the manufacturer in his ratings.
2 Required for evaporatively-cooled condensing units only.

5.1.3.4 *Condenser Air Quantity.* All Standard Ratings for condensing units shall be determined at the condenser air quantity specified by the manufacturer where the fan drive is adjustable; or where the fan drive is direct-connected, they shall be determined at the condensing unit when operated with all of the resistance elements as associated with inlet louvres and any duct work and attachments considered by the manufacturer as normal installation practice. Once established, the condenser air circuit of the condensing unit shall remain unchanged throughout all tests prescribed herein, except as altered by automatic controls.

5.2 *Part-Load Rating.* Condensing units which are capable of capacity reduction shall be rated at 100% and at each step of capacity reduction provided by the condensing unit as published by the manufacturer. These rating points shall be used to calculate the IPLV (see 5.2.2).

5.2.1 *Part Load Rating Conditions.* The conditions of test for part load rating are the same for the Standard Ratings (see 5.1) except for the following:

5.2.1.1 *Part Load Rating Temperatures.*

For all units
Refrigerant Entering Condensing Unit
Saturated suction
temperature.....50°F [10°C]
Actual suction
temperature.....65°F [18.3°C]

For air-cooled units
Air temperature entering and surrounding
unit.....80°F [26.7°C] DB
(and 67°F [19.4°C] WB
when condensate is
rejected into the air
stream)

For evaporatively-cooled units
Air temperature entering and surrounding unit.....80°F [26.7°C] DB
67°F [19.4°C] WB

For water-cooled units
Water temperature entering condenser.....75°F [23.9°C]
Water flow rate (same as Standard Rating Conditions)

5.2.1.2 The capacity reduction means may be adjusted to obtain the specified step of unloading. No manual adjustment of condenser air quantities from those of the Standard Rating Conditions shall be made. However, automatic adjustment of condenser air quantities by condensing unit function is permissible.

5.2.2 *Integrated Part Load Value (IPLV).* For equipment covered by this standard, the IPLV (in EER) shall be calculated as follows:

a. Determine the capacity and EER at the conditions specified in 5.2.

b. Determine the part-load factor (PLF) from Figure 1, "Part-Load Factor Curve," at each rating point (see Example in Appendix B).

c. Use the following equation to calculate IPLV:

$$IPLV = (PLF1 - PLF2)\left(\frac{EER_1 + EER_2}{2}\right) + (PLF2 - PLF3)\left(\frac{EER_2 + EER_3}{2}\right) + \ldots\ldots\ldots + (PLF_n\text{-}1 - PLF_n)\left(\frac{EER_{n-1} + EER_n}{2}\right) + (PLF_n)\,(EER_n)$$

where: PLF = Part-Load Factor determined from Figure 1
n = Total number of capacity steps
Subscript 1 = 100% capacity and EER at part-load rating conditions

Subscript 2,3,etc.= Specific capacity and EER at part-load steps per 5.2

5.3 *Minimum Data Requirements for Published Ratings.* Wherever application ratings are published or printed, they shall include, or be accompanied by, the Standard Rating clearly designated as such, including a statement of the conditions at which the ratings apply.

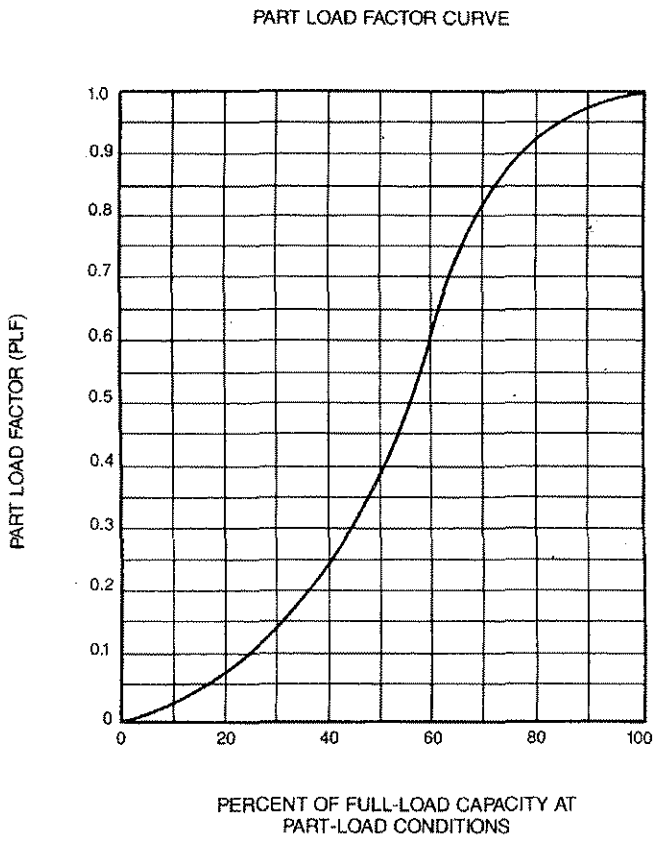
5.3.1 *Capacity Designations.* The capacity designations used in published specifications, literature or advertising, controlled by the manufacturer, shall be expressed only in Mbh [kW] at the Standard Rating Conditions specified in 5.1.3 and in the terms described in 5.1.1 and 5.1.2. Horsepower, tons or other units shall not be used as capacity designations.

5.4 *Tolerances.* To comply with this standard, published cooling capacity ratings and energy efficiency ratings shall be based on data obtained in accordance with this section, and shall be such that any production unit, when tested, will meet or exceed these ratings except for an allowance to cover testing and manufacturing variations; the amount of allowance to be -5%.

Section 6. Performance Requirements

6.1 *Performance Requirements.* To comply with this standard, commercial and industrial unitary air-conditioning condensing units shall be designed and produced in accordance with the provisions of this section in such a manner that any production unit will meet the appropriate requirements detailed herein.

6.2 *Maximum Operating Conditions Test.* Commercial and industrial unitary air-conditioning condensing units shall be designed and produced to pass the following maximum operating conditions tests. For multi-capacity units, this test shall be conducted with unit control set for maximum capacity.



Note: Curve is Based on Following Equation:

$$PLF = A0 + (A1 \times Q) + (A2 \times Q^2) + (A3 \times Q^3) + (A4 \times Q^4) + (A5 \times Q^5) + (A6 \times Q^6)$$

where: PLF = Part-Load Factor
Q = Percent of full-load capacity at part-load rating conditions.

$A0 = -0.12773917 \times 10^{-6}$
$A1 = -0.27648713 \times 10^{-3}$
$A2 = 0.50672449 \times 10^{-3}$
$A3 = -0.25966636 \times 10^{-4}$
$A4 = 0.69875354 \times 10^{-6}$
$A5 = -0.76859712 \times 10^{-8}$
$A6 = 0.28918272 \times 10^{-10}$

Figure 1. Part-Load Factor Curve

6.2.1 *Temperature Conditions.*

For all units
Air temperature surrounding unit.....115°F [46.1°C] DB

(For units or portions thereof intended to be installed only indoors, this temperature may be reduced to 95° F [35°C] DB.)

Refrigerant Entering Condensing Unit
Saturated suction temperature.....50°F [10°C]
Actual suction temperature.....65°F [18.3°C]

For water-cooled units
Water temperature entering condenser.....90°F [32.2°C]
Water temperature leaving condenser.....100°F [37.8°C]

For air-cooled units
Outside air temperature.....115°F [46.1°C] DB (and 75°F [23.9°C] WB when condensate is rejected to the condenser air stream) at the standard condenser air quantity specified and stated by the manufacturer.

For evaporatively-cooled units
Outside air temperature.....100°F [37.8°C] DB 80°F [26.7°C] WB

Make-up water temperature.....90°F [32.3°C]

6.2.2 *Voltages.*

6.2.2.1 Tests shall be run at 90% and 110% of the unit's nameplate rated voltage at the unit's service connection and at rated frequency, or at a lower than 90% minimum or a higher than 110 % maximum voltage, if listed on the nameplate.

6.2.3 *Procedure.*

6.2.3.1 The condensing unit shall be operated continuously for two hours at the temperature conditions and voltage(s) specified.

6.2.3.2 All power to the condensing unit shall be cut off for a period sufficient to cause the compressor to stop (not to exceed five seconds) and then restored.

6.2.4 *Requirements.*

6.2.4.1 During both entire tests, the condensing unit shall operate without failure of any of its parts.

6.2.4.2 The unit shall resume continuous operation within one hour of restoration of power and shall then operate continuously for one hour. Operation and resetting of safety devices prior to establishment of continuous operation is permitted.

6.2.4.3 Units with water-cooled condensers shall be capable of operation under these maximum conditions at a water-pressure drop not to exceed 15 psi [103.4 kPa], measured across the unit.

6.3 *Tolerances.* The conditions for the tests outlined in 6.2 are average values subject to tolerances of ±1.0°F [±0.56 K] for air wet-bulb and dry-bulb temperature, and ±1.0 % of the reading for voltages.

Section 7. Nameplate Data

7.1 *Nameplate Data.* The nameplate shall display the manufacturer's name, model designation, and electrical characteristics.

Recommended nameplate voltages for 60 Hertz systems shall include one or more of the utilization voltages shown in Table 1 of ARI Standard 110-90. Recommended nameplate voltages for 50 Hertz systems shall include one or more of the utilization voltages shown in Table 1 of IEC Standard Publication 38.

Section 8. Voluntary Conformance

8.1 *Voluntary Conformance.* While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within it's *Purpose* (Section 1) or *Scope* (Section 2) unless such claims meet all of the requirements of the standard.

APPENDIX A. REFERENCES

Listed here are all standards, handbooks, and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of this standard.

- ARI Standard 110-90, *Air-Conditioning and Refrigerating Equipment Nameplate Voltages*, Air-Conditioning and Refrigeration Institute.
- ASHRAE Standard 14-1980, *Methods of Testing for Rating Positive Displacement Condensing Units*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.
- ASHRAE Standard 37-1988, *Methods of Testing for Rating Unitary Air-Conditioning and Heat Pump Equipment*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.
- ASHRAE *Terminology of Heating, Ventilation, Air-Conditioning, Refrigeration, & Refrigeration*, Second Edition, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. 1991
- IEC Standard Publication 38, *IEC Standard Voltages*, International Electrotechnical Commission, 1983

APPENDIX B. METHOD AND EXAMPLE OF CALCULATING INTEGRATED PART LOAD VALUES (IPLV)

B1 *Purpose and Scope.*

B1.1 *Purpose.* This appendix shows example calculations for determining Integrated Part Load Values (IPLV).

B1.2 *Scope.* This appendix is for equipment covered by this standard.

B2 *Equations and Definitions of Terms.*

B2.1 *General Equation.*

$$IPLV = (PLF_1 - PLF_2)\left(\frac{EER_1 + EER_2}{2}\right)$$

$$+ (PLF_n\text{-}1 \quad PLF_n)\left(\frac{EER_n\text{-}1 + EER_n}{2}\right)$$

$$+ \ldots\ldots\ldots$$

$$+ (PLF_n\text{-}1\text{-}PLF_n)\left(\frac{EER_{n-1} + EER_n}{2}\right)$$

$$+ (PLF_n)\ (EER_n)$$

Where: PLF = Part-Load Factor determined from Figure 1

n = Total number of capacity steps

Subscript 1 = 100% capacity and EER at part-load rating conditions

Subscript 2, 3, etc. = specific capacity steps per 5.2

B3 *Calculation Example for a Four Capacity Step System.*

B3.1 *Unit Performance Data & Sample Calculation.*

$$IPLV = (1.0 - 0.9)\left(\frac{2.6 + 2.3}{2}\right)$$

$$+ (0.9 - 0.4)\left(\frac{2.3 + 2.1}{2}\right)$$

$$+ (0.4 - 0.1)\left(\frac{2.1 + 1.5}{2}\right)$$

$$+ (0.1 \times 1.5)$$

$$= (0.1 \times 2.45) + (0.5 + 2.2)$$

$$+ (0.3 \times 1.8) + .15$$

$$= .245 + 1.1 + .54 + .15$$

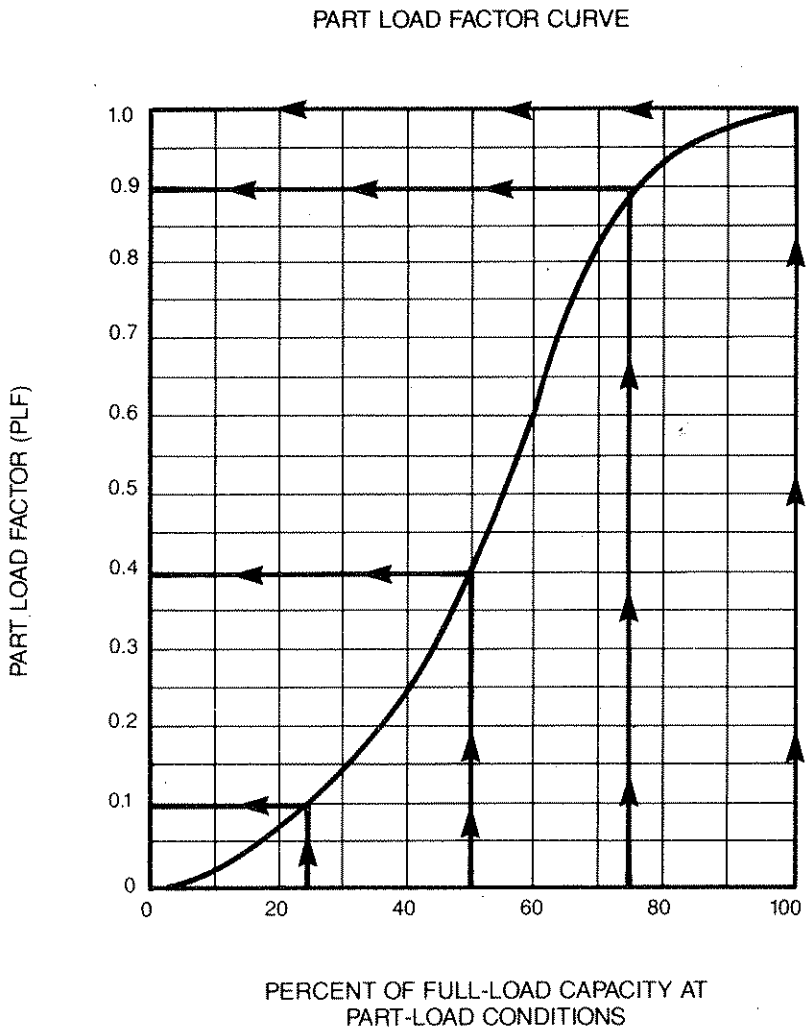
$$IPLV = 2.0$$

B3.1.1 Assume equipment has four capacity steps as follows:

- 100% (full load)
- 75% of full load
- 50% of full load
- 25% of full load

B3.1.2 Obtain part load factors from Figure 1 (see example Figure B1).

B3.1.3 Obtain EER at each capacity step per 5.2.



Note: Curve is Based on Following Equation:

$$PLF = A0 + (A1 \times Q) + (A2 \times Q^2) + (A3 \times Q^3) + (A4 \times Q^4) + (A5 \times Q^5) + (A6 \times Q^6)$$

where: PLF = Part-Load Factor

Q = Percent of full-load capacity at part-load rating conditions.

$A0 = -0.12773917 \times 10^{-6}$

$A1 = -0.27648713 \times 10^{-3}$

$A2 = 0.50672449 \times 10^{-3}$

$A3 = -0.25966636 \times 10^{-4}$

$A4 = 0.69875354 \times 10^{-6}$

$A5 = -0.76859712 \times 10^{-8}$

$A6 = 0.28918272 \times 10^{-10}$

Figure B1. Part-Load Factor Example

B3.1.4 Calculate IPLV using the general equation with:

$n = 4$

PLF_1	= 1.0	EER_1	= 8.9 [2.6]
PLF_2	= 0.9	EER_2	= 7.7 [2.3]
PLF_3	= 0.4	EER_3	= 7.1 [2.1]
PLF_4	= 0.1	EER_4	= 5.0 [1.5]

I-P Units Example.

Enter the above I-P Units values in the general equation (B2.1).

$$IPLV = (1.0 - 0.9)\left(\frac{8.9 + 7.7}{2}\right)$$

$$+(0.9 - 0.4)\left(\frac{7.7 + 7.1}{2}\right)$$

$$+(0.4 - 0.1)\left(\frac{7.1 + 5.0}{2}\right)$$

$$+0.1 \times 5.0$$

$$= (0.1 \times 8.3) + (0.5 \times 7.4)$$

$$+ (0.3 \times 6.0) + 0.5$$

$$= 0.83 + 3.70 + 1.80 + 0.5$$

IPLV = 6.83 (rounded to 6.8)

To further illustrate the calculation process, see example in Table B1.

SI Units Example.

Enter the above SI Unit values in the general equation (B2.1).

$$IPLV = (1.0 - 0.9)\left(\frac{2.6 + 2.3}{2}\right)$$

$$+(0.9 - 0.4)\left(\frac{2.3 + 2.1}{2}\right)$$

$$+(0.4 - 0.1)\left(\frac{2.1 + 1.5}{2}\right)$$

$$+ (0.1 \times 1.5)$$

$$= (0.1 \times 2.45) + (0.5 \times 2.2)$$

$$+ (0.3 \times 1.8) + .15$$

$$= .245 + 1.1 + .54 + .15$$

$$IPLV = 2.0$$

Using information from B3.1.1; B3.1.2 and B3.1.3

Table B1. Example IPLV Calculation (I-P Units)

Capacity Step	% Full Load Cap.[2]	PLF[3]	Mfrs. Part Load EER	Avg. Part Load EER	PLF Diff.	Avg. EER x PLF Diff.=	Weighted Avg.
1	100%	1.0	8.9[2]	8.3	(1.0 - 0.9) = 0.1	8.3 x 0.1 =	0.83
2	75%	0.9	7.7	7.4	(0.9 - 0.4) = 0.5	7.4 x 0.5 =	3.70
3	50%	0.4	7.1	6.0	(0.4 - 0.1) = 0.3	6.0 x 0.3 =	1.80
4	25%	0.1	5.0	5.0[1]	(0.1 - 0.0) = 0.1	5.0[1] x 0.1 =	0.50
	0%	0.0				Single number IPLV =	6.83[4]

NOTES:
[1]For the range between 0% capacity and the last capacity step, use EER of the last capacity step for the average EER.
[2]The 100% capacity and EER are to be determined at the part-load rating conditions.
[3]Part-load factor from Figure B1.
[4]Rounded to 6.8

Table B1. Example IPLV Calculations (SI Units)

Capacity Step	% Full Load Cap[2]	PLF[3]	Mfgs. Part Load EER	Avg. Part Load EER	PLF Diff.	Avg. EER xPLF Diff.	Weighted Avg.
1	100%	1.0	2.6 =	2.45	(1.0-0.9) = 0.1	2.45 x 0.1 =	.245
2	75%	0.9	2.3 =	2.2	(0.9-0.4) = 0.5	2.2 x 0.5 =	1.1
3	50%	0.4	2.1 =	1.8	(0.4-0.1) = 0.3	1.8 x 0.3 =	0.54
4	25%	0.1	1.5[1] =	1.5	(0.1-0.0) = 0.1	1.5[1] x 0.1 =	0.15
	0%	0.0				Single Number IPLV =	2.0

NOTES
[1]For the range between 0% capacity and the last capacity step, use EER of the last capacity step for the average EER.
[2]The 100% capacity and EER are to be determined at the part-load rating conditions.
[3]Part-load factor from Figure B1.