Staying Ahead of the DOE 2017 Walk-In Cooler and Freezer Energy Efficiency Ratings

October 21, 2014

Presented By:

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Webinar Objectives

- **WICF & AWEF Rulemaking Overview: Ani Jayanth**
  1. Understand WICF rulemaking
  2. Understand specifics of TSD
  3. Understand cost-efficiency design options
- **Alternative Refrigerants Note: Ani Jayanth**
- **AWEF Calculation & Technology Guidance: Brian Buynacek**
  1. AWEF for indoor and outdoor condensing units
  2. BIN temperature analysis
  3. AWEF minimums for 2017
  4. Differences between AHRI 1250 and DOE interpretation
  5. Importance of floating head pressure
  6. Example pass/fail calculations

WICF & AWEF Rulemaking Overview

Ani Jayanth

- **WICF & AWEF Rulemaking Overview**

1. Understand WICF rulemaking
2. Understand specifics of TSD
3. Understand cost-efficiency design options

Definitions

Walk-in Cooler and Freezer (WICF)	*The Energy Policy and Conservation Act (EPCA) defines "walk-in cooler" and "walk-in freezer" as* ***an enclosed storage space refrigerated to temperatures, respectively, above, and at or below 32 °F that can be walked into****, and has a total chilled storage area of less than 3,000 ft^2.The definition excludes products designed and marketed exclusively for medical, scientific or research purposes. (42 U.S.C. 6311[20])*
Notice of Public Rulemaking (NOPR)	*Federal document released to inform parties of intensions of altering or offering new rulemaking*
Supplemental Notice of Public Rulemaking (SNOPR)	*Further information collected from stakeholders and additional supporting information attached to original NOPR*
Final Rule	*Federal document released to inform stakeholders of new mandated regulatory compliance standards*
Technical Support Document (TSD)	*Document released to justify rulemaking with engineering and economic analyses*
Trial Standard Level (TSL)	*The level adopted for final rule which determines the acceptable energy efficiency with respect to operational and capital costs*
Annual Walk-in Energy Factor (AWEF)	*Ratio of heat removed from the envelope to the total energy input of the refrigeration system*

Source: Department of Energy

WICF & AWEF Documents

	Key Documents			
	Type	**Description**	**Key Piece of Information in Relation to AWEF**	**Location**
1	**Final Rule**	Summary of rulemaking, TSD, test procedure and framework for understanding and rulemaking	Table I.1 Table V.10 Table V.47	http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0015-0141
2	**Technical Support Document (TSD)**	Technical analysis and results supporting information presented in NOPR leading to final rule	Chapter 5 – Refrigeration System Chapter 7 – Refrigeration Energy Use	http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0015-0131
3	**Support Documents**	Public commentary, webinars, component calculators, other	Industry Commentary	http://www.regulations.gov/#!docketBrowser;rpp=25;so=DESC;sb=postedDate;po=0;D=EERE-2011-BT-TP-0024
4	**Final Rule Engineering Analysis Refrigeration Spreadsheet**	XLS spreadsheet with all components related to determining AWEF for the refrigeration system and content loaded from TSD	Calculation Tab	http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0015-0137
5	**Walk-in Standards**	AHRI 1250-2009 test requirements; rating requirements; minimum data requirements for Published Ratings	Procedures and Test Standards for AWEF	http://www.ari.org/App_Content/ahri/files/standards%20pdfs/AHRI%20standards%20pdfs/AHRI_1250_(I-P)-2014.pdf
6	**AWEF Calculator**	AHRI 1250-2009	Calculations for AWEF	http://www.ari.org/App_Content/ahri/files/standards%20pdfs/AHRI%20standards%20pdfs/AHRI_1250_(I-P)-2014.pdf

Source: Department of Energy

A Note on Technical Support Document

Research & Analysis

- **Ernest Orlando Lawrence Berkeley National Laboratory**
- **Navigant Consulting, Inc.**

Table 1.4.1 Analyses Under the Process Rule

Preliminary Analyses	NOPR	Final Rule
Market and technology assessment	Revised preliminary analyses	Revised NOPR analyses
Screening analysis	Life-cycle cost sub-group analysis	
Engineering analysis	Manufacturer impact analysis	
Markups for equipment price determination	Environmental assessment	
Life-cycle cost and payback period	Employment impact analysis	
Shipment analysis	Regulatory impact analysis	
National impact analysis		
Preliminary manufacturer impact analysis		

September 2013
- NOPR

February 2014
- SNOPR

April 2014
- Public Commentary Extension

June 2014
- Final Rule

June 5, 2017
- Compliance

Refrigeration System Classification

Dedicated Condensing

- **Refrigeration system means the mechanism (including all controls and other components integral to the system's operation) used to create the refrigerated environment in the interior of a walk-in cooler or freezer, consisting of any of the following:**
  - Indoor/outdoor
  - Single walk-in feed
  - A packaged dedicated system where the unit cooler and condensing unit are integrated into a single piece of equipment
  - A split dedicated system with separate unit cooler and condensing unit sections

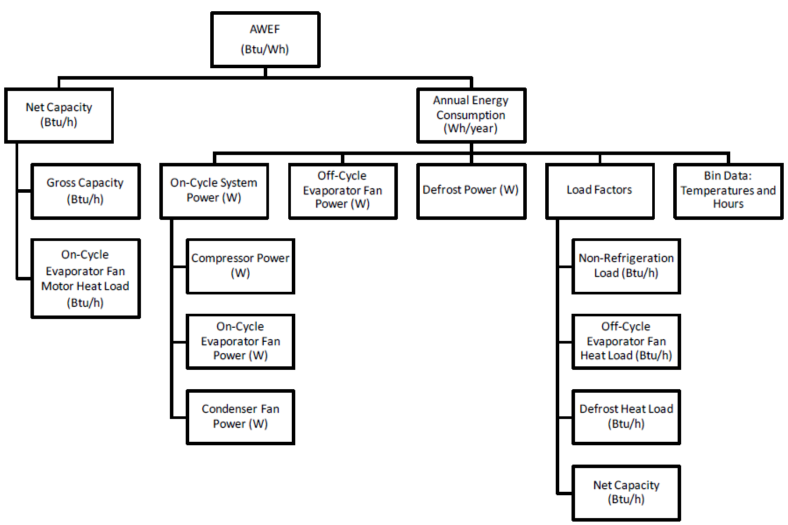

Table 5.3.4 Analysis Points: Dedicated Condensing Refrigeration Systems

Condensing Type	Temperature	Condenser Location	Size *Btu/h*	Class Code	Compressor Type	Capacity *Btu/h*	Analysis Point Code
Dedicated Condensing	Medium	Indoor	<9,000	DC.M.I-<9,000	Hermetic	6,000	DC.M.I.HER.006
					Semihermetic	6,000	DC.M.I.SEM.006
			≥9,000	DC.M.I-≥9,000	Hermetic	18,000	DC.M.I.HER.018
					Scroll	18,000	DC.M.I.SCR.018
					Semihermetic	18,000	DC.M.I.SEM.018
					Scroll	54,000	DC.M.I.SCR.054
					Semihermetic	54,000	DC.M.I.SEM.054
					Scroll	96,000	DC.M.I.SCR.096
					Semihermetic	96,000	DC.M.I.SEM.096
	Low		<9,000	DC.L.I-<9,000	Hermetic	6,000	DC.L.I.HER.006
					Scroll	6,000	DC.L.I.SCR.006
					Semihermetic	6,000	DC.L.I.SEM.006
			≥9,000	DC.L.I-≥9,000	Hermetic	9,000	DC.L.I.HER.009
					Scroll	9,000	DC.L.I.SCR.009
					Semihermetic	9,000	DC.L.I.SEM.009
					Scroll	54,000	DC.L.I.SCR.054
					Semihermetic	54,000	DC.L.I.SEM.054
	Medium	Outdoor	<9,000	DC.M.O-<9,000	Hermetic	6,000	DC.M.O.HER.006
					Semihermetic	6,000	DC.M.O.SEM.006
			≥9,000	DC.M.O-≥9,000	Hermetic	18,000	DC.M.O.HER.018
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					Scroll	54,000	DC.L.O.SCR.054
					Semihermetic	54,000	DC.L.O.SEM.054
					Semihermetic	72,000	DC.L.O.SEM.072

Source: Department of Energy

Refrigeration System Classification

Multiplex Condensing

- **Refrigeration system means the mechanism (including all controls and other components integral to the system's operation) used to create the refrigerated environment in the interior of a walk-in cooler or freezer, consisting of any of the following:**
  – Unit Coolers Matched To Multiplex Condensing Rack System

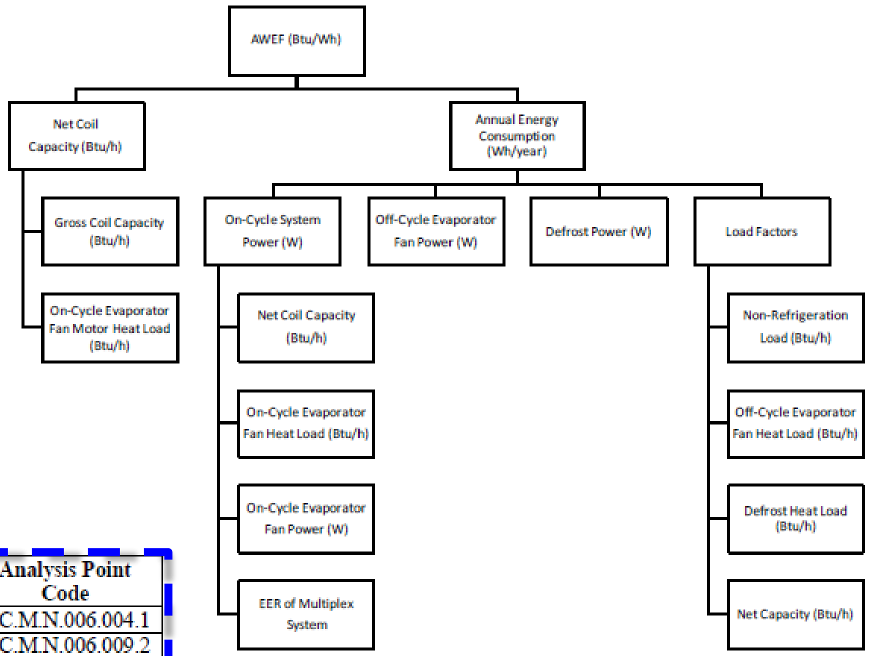


Table 5.3.5 Analysis Points: Multiplex Condensing Refrigeration Systems

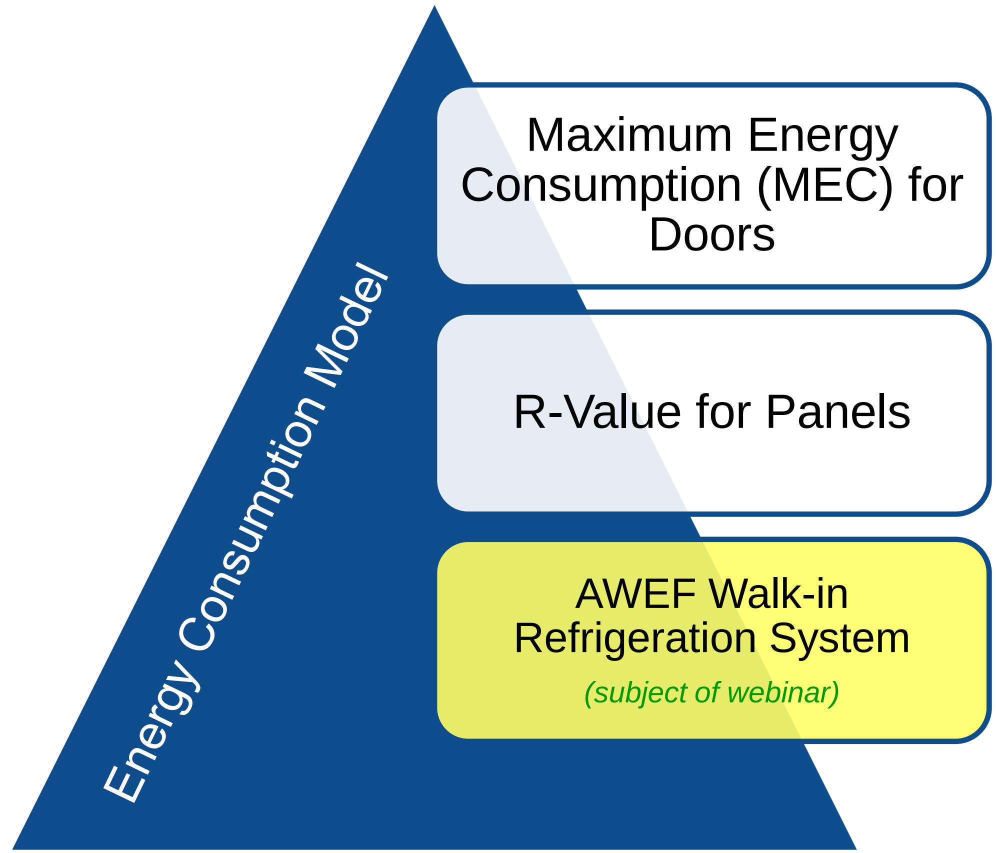
Condensing Type	Temperature	Class Code	Number of Fins per Inch	Capacity *Btu/h*	Number of Fans	Analysis Point Code
Multiplex Condensing	Medium	MC.M	6	4,000	1	MC.M.N.006.004.1
			6	9,000	2	MC.M.N.006.009.2
			6	24,000	6	MC.M.N.006.024.6
			4	4,000	1	MC.M.N.004.004.1
			4	9,000	2	MC.M.N.004.009.2
	Low	MC.L	6	4,000	1	MC.L.N.006.004.1
			6	9,000	2	MC.L.N.006.009.2
			6	18,000	2	MC.L.N.006.018.2
			4	4,000	1	MC.L.N.004.004.1
			4	9,000	2	MC.L.N.004.009.2
			4	18,000	2	MC.L.N.004.018.2
			4	40,000	2	MC.L.N.004.040.2

Source: Department of Energy

Making Sense

Walk-in Cooler & Freezer Energy Conservation Standards

- **Standards for WICF**
  1. Cost Model
     - Market baseline information
     - Material, labor, depreciation, other costs
  2. Energy Model
     - Existing technology assessment
     - Technology options from screening analysis
     - Energy consumption model
       - Output of energy model: cost-efficiency curve for each equipment class and for each component analyzed



"…shall be designed to achieve the maximum improvement in energy efficiency that DOE determines is both technologically feasible and economically justified…the new or amended standard must result in the significant conservation of energy."

Source: Department of Energy

Final Rule Methodology

Dedicated Condensing & Multiplex Condensing

Table 5.3.4 Analysis Points: Dedicated Condensing Refrigeration Systems

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					Scroll	6,000	DC.L.I.SCR.006
					Semihermetic	6,000	DC.L.I.SEM.006
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					Semihermetic	54,000	DC.L.I.SEM.054
	Medium	Outdoor	<9,000	DC.M.O-<9,000	Hermetic	6,000	DC.M.O.HER.006
					Semihermetic	6,000	DC.M.O.SEM.006
			≥9,000	DC.M.O-≥9,000	Hermetic	18,000	DC.M.O.HER.018
					Scroll	18,000	DC.M.O.SCR.018
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					Scroll	96,000	DC.M.O.SCR.096
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					Semihermetic	6,000	DC.L.O.SEM.006
			≥9,000	DC.L.O-≥9,000	Hermetic	9,000	DC.L.O.HER.009
					Scroll	9,000	DC.L.O.SCR.009
					Semihermetic	9,000	DC.L.O.SEM.009
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					Semihermetic	72,000	DC.L.O.SEM.072

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			4	4,000	1	MC.M.N.004.004.1
			4	9,000	2	MC.M.N.004.009.2
	Low	MC.L	6	4,000	1	MC.L.N.006.004.1
			6	9,000	2	MC.L.N.006.009.2
			6	18,000	2	MC.L.N.006.018.2
			4	4,000	1	MC.L.N.004.004.1
			4	9,000	2	MC.L.N.004.009.2
			4	18,000	2	MC.L.N.004.018.2
			4	40,000	2	MC.L.N.004.040.2

1

Technology Exploration / Cost Model Analysis / Baseline Model Analysis

2

TABLE V.10—AWEFS FOR ALL REFRIGERATION SYSTEM TSLS

Equipment class	Equations for minimum AWEF (Btu/W-h)*			
	Baseline	TSL 1	TSL 2	TSL 3
DC.M.I, <9,000	3.51	5.61	5.61	5.61
DC.M.I, ≥9,000	3.51	5.61	5.61	5.61
DC.M.O, <9,000	3.14	6.99	7.60	7.60
DC.M.O, ≥9,000	3.14	6.99	7.60	7.60
DC.L.I, <9,000	$1.39 \times 10^{-4} \times Q + 0.98$	$8.67 \times 10^{-5} \times Q + 2.00$	$5.93 \times 10^{-5} \times Q + 2.33$	$5.93 \times 10^{-5} \times Q + 2.33$
DC.L.I, ≥9,000	2.23	2.78	3.10	3.10
DC.L.O, <9,000	$1.96 \times 10^{-4} \times Q + 0.82$	$3.21 \times 10^{-4} \times Q + 1.29$	$2.30 \times 10^{-4} \times Q + 2.73$	$2.30 \times 10^{-4} \times Q + 2.73$
DC.L.O, ≥9,000	2.57	4.17	4.79	4.79
MC.M	6.11	10.89	10.89	10.89
MC.L	3.29	5.58	6.57	6.57

*Q represents the system gross capacity as calculated in AHRI 1250.

3

TABLE I.1—ENERGY CONSERVATION STANDARDS FOR WALK-IN COOLERS AND WALK-IN FREEZERS

Class descriptor	Class	Standard level
Refrigeration Systems		Minimum AWEF (Btu/W-h)*
Dedicated Condensing, Medium Temperature, Indoor System, <9,000 Btu/h Capacity	DC.M.I, <9,000	5.61
Dedicated Condensing, Medium Temperature, Indoor System, ≥9,000 Btu/h Capacity	DC.M.I, ≥9,000	5.61
Dedicated Condensing, Medium Temperature, Outdoor System, <9,000 Btu/h Capacity	DC.M.O, <9,000	7.60
Dedicated Condensing, Medium Temperature, Outdoor System, ≥9,000 Btu/h Capacity	DC.M.O, ≥9,000	7.60
Dedicated Condensing, Low Temperature, Indoor System, <9,000 Btu/h Capacity	DC.L.I, <9,000	$5.93 \times 10^{-5} \times Q + 2.33$
Dedicated Condensing, Low Temperature, Indoor System, ≥9,000 Btu/h Capacity	DC.L.I, ≥9,000	3.10
Dedicated Condensing, Low Temperature, Outdoor System, <9,000 Btu/h Capacity	DC.L.O, <9,000	$2.30 \times 10^{-4} \times Q + 2.73$
Dedicated Condensing, Low Temperature, Outdoor System, ≥9,000 Btu/h Capacity	DC.L.O, ≥9,000	4.79
Multiplex Condensing, Medium Temperature	MC.M	10.89
Multiplex Condensing, Low Temperature	MC.L	6.57

Q = system gross capacity

Meeting AWEF

Example: *Dedicated Condensing-Low Temp-Outdoor-Scroll-54K Btu/H*

1

TABLE I.1—ENERGY CONSERVATION STANDARDS FOR WALK-IN COOLERS AND WALK-IN FREEZERS

Class descriptor	Class	Standard level
Refrigeration Systems		Minimum AWEF (Btu/W-h) *
Dedicated Condensing, Medium Temperature, Indoor System, <9,000 Btu/h Capacity	DC.M.I, <9,000	5.61
Dedicated Condensing, Medium Temperature, Indoor System, ≥9,000 Btu/h Capacity	DC.M.I, ≥9,000	5.61
Dedicated Condensing, Medium Temperature, Outdoor System, <9,000 Btu/h Capacity	DC.M.O, <9,000	7.60
Dedicated Condensing, Medium Temperature, Outdoor System, ≥9,000 Btu/h Capacity	DC.M.O, ≥9,000	7.60
Dedicated Condensing, Low Temperature, Indoor System, <9,000 Btu/h Capacity	DC.L.I, <9,000	$5.93 \times 10^{-5} \times Q + 2.33$
Dedicated Condensing, Low Temperature, Indoor System, ≥9,000 Btu/h Capacity	DC.L.I, ≥9,000	3.10
Dedicated Condensing, Low Temperature, Outdoor System, <9,000 Btu/h Capacity	DC.L.O, <9,000	$2.30 \times 10^{-4} \times Q + 2.73$
Dedicated Condensing, Low Temperature, Outdoor System, ≥9,000 Btu/h Capacity	DC.L.O, ≥9,000	4.79
Multiplex Condensing, Medium Temperature	MC.M	10.89
Multiplex Condensing, Low Temperature	MC.L	6.57

2

Table 5A.5.43 Cost-Efficiency Data for DC.L.O.SCR.054.H

Efficiency Level	AWEF [Btu/Wh]	Manufacturer Production Cost (MPC) [$]	Manufacturer Selling Price (MSP) [$]	Design Option
L0	2.00	$6,819	$10,564	Baseline
L1	2.28	$6,849	$10,605	L0 + FHP
L2	2.58	$6,899	$10,672	L1 + DFC1
L3	2.78	$6,949	$10,740	L2 + MEF
L4	2.93	$6,999	$10,807	L3 + VEF
L5	3.69	$7,239	$11,131	L4 + HGD
L6	4.17	$7,389	$11,334	L5 + FHPEV
L7	4.38	$7,489	$11,469	L6 + VSCF
L8	4.43	$7,506	$11,491	L7 + EC
L9	4.47	$7,588	$11,602	L8 + EB2
L10	5.22	$9,668	$14,411	L9 + CMP2
L11	5.23	$9,693	$14,444	L10 + CB2
L12	5.26	$9,839	$14,703	L11 + ASC

3

Table 5.5.29 Design Option Codes and Descriptions for Refrigeration Systems

Design Option Code	Description
	High-Efficiency Compressor
CMP1	Baseline Compressor
CMP2	Variable Speed Compressor
	Improved Condenser Coil
CD1	Baseline Coil
CD2	Improved Coil
	High-Efficiency Condenser Fan Motors
PSC	Permanent Split Capacitor Motors
EC	Electronically Commutated Motors
	Improved Condenser Fan Blades
CB1	Baseline Condenser Fan Blades
CB2	Improved Condenser Fan Blades
	Condenser Fan Control
SSCF	Single Speed Condenser Fans
VSCF	Variable Speed Condenser Fans
	Ambient Sub-cooling
NOASC	No Ambient Sub-cooling
ASC	Ambient Sub-cooling
	Improved Evaporator Fan Blades
EB1	Baseline Evaporator Fan Blades
EB2	Improved Evaporator Fan Blades
	Evaporator Fan Controls
SSEF	Single Speed Evaporator Fans
MEF	Modulating Evaporator Fans
VEF	Variable Speed Evaporator Fans
	Defrost Controls
NODFC	Time-initiated, Temperature-terminated Defrost
DFC1	Temperature-initiated, Temperature-terminated Defrost
	Hot Gas Defrost
ELD	Electric Defrost
HGD	Hot Gas Defrost
	Head Pressure Control
FXHP	Fixed Head Pressure
FHP	Floating Head Pressure
FHPEV	Floating Head Pressure with Electronic Expansion Valve

4

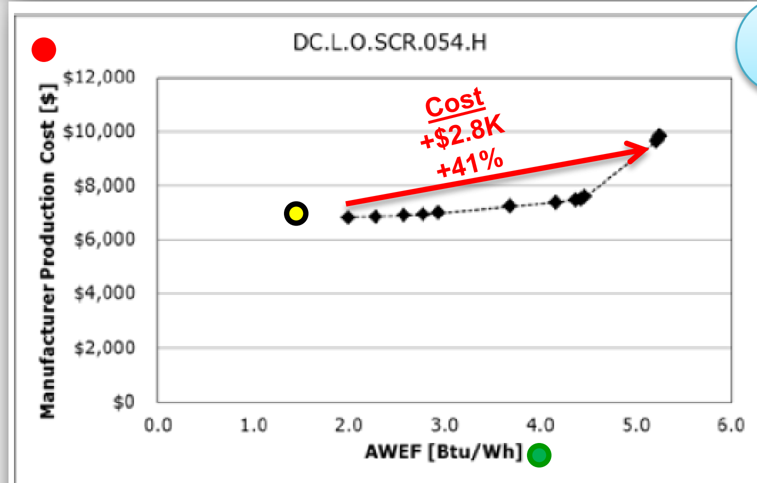


Figure 5A.5.43 Cost-Efficiency Curve for DC.L.O.SCR.054.H

DOE Design Options to Meet AWEF Summary

Option	DC Outdoor LT/MT	DC Indoor LT/MT	MC LT/MT
1	Floating Head Pressure	Modulating Evaporator Fans	Modulating Evaporator Fans
2	Floating Head Pressure With Electronic Expansion Valve	Variable Speed Evaporator Fans	Variable Speed Evaporator Fans
3	Modulating Evaporator Fans	Improved Coil	Improved Evaporator Fan Blades
4	Electronically Commutated Motors	Improved Condenser Fan Blades	Temperature-initiated, Temperature-terminated Defrost
5	Improved Evaporator Fan Blades	Electronically Commutated Motors	Hot Gas Defrost
6	Improved Condenser Fan Blades	Improved Evaporator Fan Blades	
7	Improved Coil	Temperature-initiated, Temperature-terminated Defrost	
8	Hot Gas Defrost	Hot Gas Defrost	
9	Temperature-initiated, Temperature-terminated Defrost		
10	Variable Speed Compressor		
11	Variable Speed Condenser Fans		
12	Variable Speed Evaporator Fans		
13	Ambient Sub-cooling		

Polling Question #1

What part of the refrigeration will you place the most importance on for improvement to meet AWEF?

a. **Compressor**
b. **Condenser coil**
c. **Condenser fan motors**
d. **Controls**
e. **Defrost**
f. **Evaporator coil**
g. **Evaporator fan motors**

Alternative Refrigerants Note

Ani Jayanth

- **In 2013 and early 2014, the EPA held stakeholder meetings to get input on which HFCs, if any, could be delisted**

- **The NOPR to delist was published on August 6**
  - Comments due on **October 20**

- ***Making Sense* Webinar on Refrigerants**

  - http://www.emersonclimate.com/en-US/About_Us/industry_stewardship/Pages/Making-Sense.aspx

- **Links to documents on the EPA website:**

  Rule:
  http://www.epa.gov/ozone/downloads/SAN_5750_SNAP_Status_Change_Rule_NPRM_signature_version-signed_7-9-2014.pdf

  Fact sheet:
  http://www.epa.gov/ozone/downloads/SAN_5750_SNAP_Status_Change_Rule-Fact_Sheet_070714.pdf

  NOPR:
  http://www.gpo.gov/fdsys/pkg/FR-2014-08-06/pdf/2014-18494.pdf

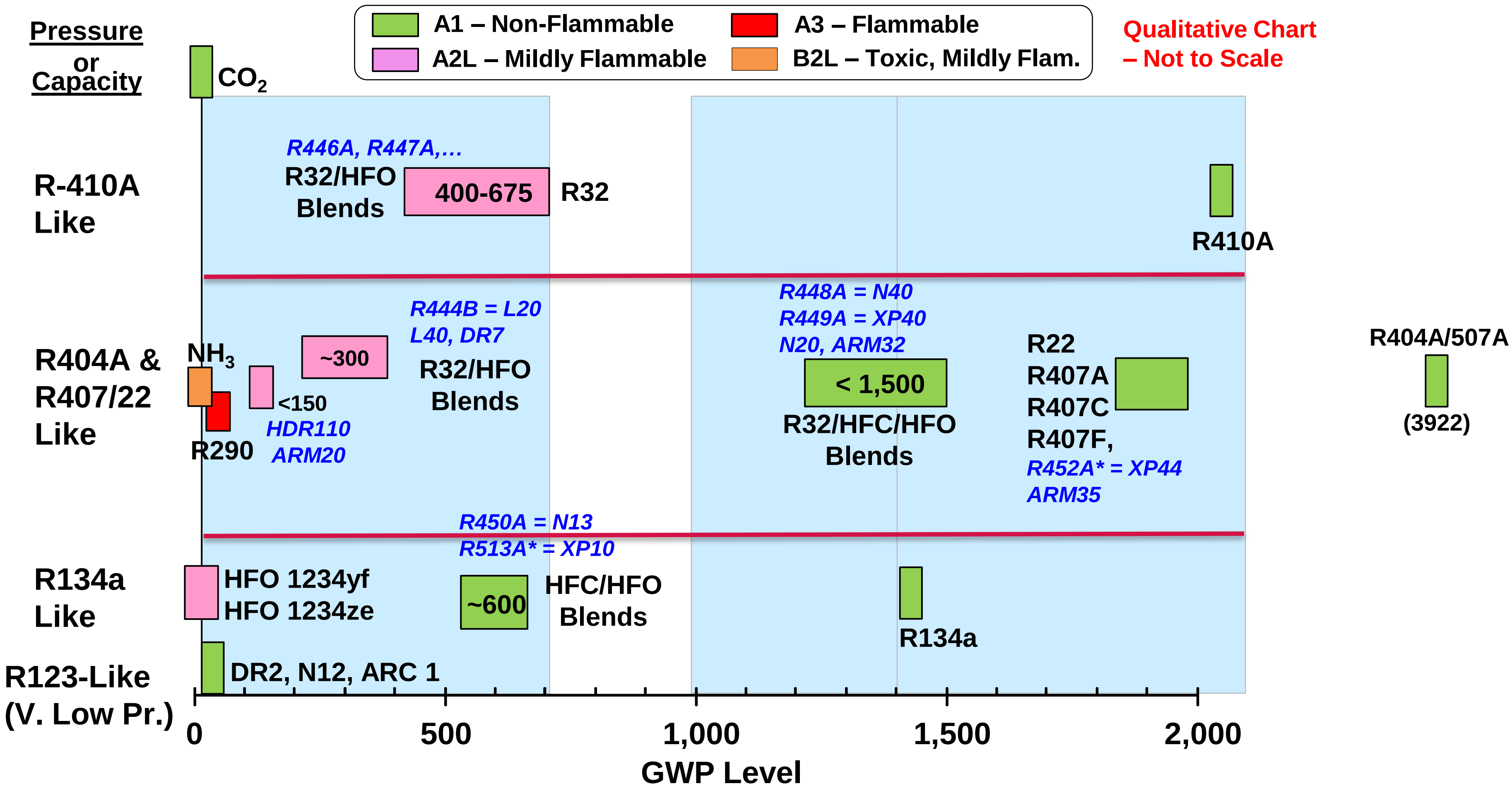
EPA's Proposed Rule on Delisting HFCs by Application

Refrigerant	Supermarket*		Condensing Units* *(field charged)*	Standalone Self Contained Comm. Ref. Eqpt* *(factory charged sealed systems)*	Vending Machines*	Foam	Auto AC
	Direct	Sec.					
R404A/507A	Jan 2016	Jan 2016	Jan 2016	Jan 2016	Jan 2016		
HFC-227ea, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A	Jan 2016	Jan 2016					
R407A, R407F				Jan 2016 (New)			
R134a				Jan 2016 (New)	Jan 2016 (New)	Jan 2017	2021 Model (New)
Various Blends, GWP 600-3990**				Jan 2016 (New)			
Various Foam Refs**						Jan 2017	
Various Auto Blends**							2017 Model (New)

* New And Retrofit Only; Service Is Allowed
** Check EPA Documents For Details
Aerosol Application Not Shown In Above Table
Industrial, Ice Making Heads, Warehouses and Transport Applications Are Not Included In This NOPR But Comments Have Been Requested

Source: Emerson Climate Technologies

Refrigerant Options for Air Conditioning and Refrigeration Applications



** Pending ASHRAE final approval*

Emerson View on Available Options (Not a Comprehensive List)

Retail Food Refrigeration	Today	Alternates Today	Future Alternative(s)
Supermarket	R404A/R507A	R407A/F* CO_2	R448A*, R449A* ARM32*
Condensing Unit *(field charged)*	R404A/R507A	R407A/F*	R448A*, R449A* ARM32*
Standalone Self Contained Comm. Ref. Equipment *(factory charged sealed systems)*	R404A/R507A	R290***	R448A(?), L40** R449A(?), DR7** HDR-110**, ARM20**
	R134a	R290[1]	R450A(?) R513A(?) HFO-1234yf** HFO-1234ze**

** May Have Disch. Temp Issues For Compressor*
*** A2L – Mildly Flammable*
**** A3 – Highly Flammable*

? – Some Clarifications Required From EPA
1 – Total System Redesign Required

Source: Emerson Climate Technologies

Polling Question #2

Before seeing the last several slides, how clear were you on the DOE's Final Rule on AWEF?

a. **Very clear**
b. **Clear**
c. **Somewhat clear**
d. **I did not know about them**

AWEF Calculation & Technology Guidance

Brian Buynacek

- **AWEF Calculation & Technology Guidance**
  1. AWEF for indoor and outdoor condensing units
  2. BIN temperature analysis
  3. AWEF minimums for 2017
  4. Differences between AHRI 1250 and DOE interpretation
  5. Importance of floating head pressure
  6. Example pass/fail calculations

What Is AWEF?

- **Ratio of heat removed from the envelope to the total energy input of the refrigeration system**
- **Metric based on efficiency rather than energy use because of walk-in system sizing and heat load produced**
- **Assumption that the system is sized appropriately to the load, regardless of envelope characteristics**

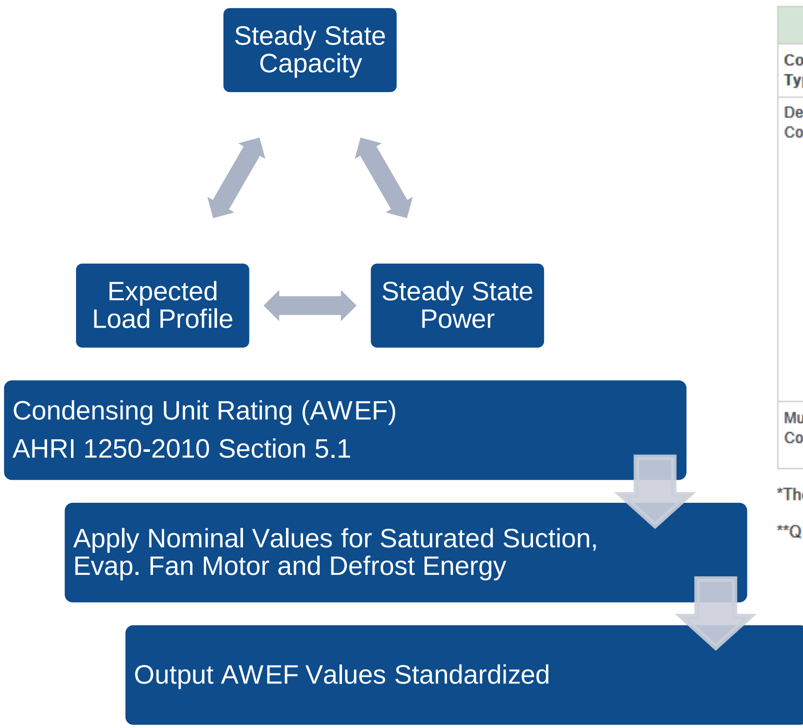


Table 2. Standards for Refrigeration Systems Effective August 4, 2014

Condensing Type	Internal Rating Temp. (°F)	Operating Temp. (°F)	Condensing Location	Capacity Range (Btu/h)	Equipment Class Designation*	Minimum AWEF (Btu/W-h)**
Dedicated Condensing	35 (M)	≥ 32	Indoor (I)	<9,000	DC.M.I, < 9,000	5.61
				>9,000	DC.M.I, = 9,000	5.61
			Outdoor (O)	<9,000	DC.M.O, < 9,000	7.60
				>9,000	DC.M.O, = 9,000	7.60
	-10 (L)	≤ 32	Indoor (I)	<9,000	DC.L.I, < 9,000	$5.93 \times 10^{-5} \times Q + 2.33$
				>9,000	DC.L.I, = 9,000	3.10
			Outdoor (O)	<9,000	DC.L.O, < 9,000	$2.30 \times 10^{-4} \times Q + 2.73$
				>9,000	DC.L.O, = 9,000	4.79
Multiplex Condensing	35 (M)	≥ 32	N/A	N/A	MC.M	10.89
	-10 (L)	≤ 32	N/A	N/A	MC.L	6.57

*The meaning of the letters in this column is indicated in the columns to the left.

**Q represents the system gross capacity as calculated by the test procedure.

Source: Department of Energy

Making Sense

DOE vs. AHRI 1250

DOE

TABLE III.5—CALCULATIONS FOR UNIT COOLER SATURATED SUCTION TEMPERATURE AND ENERGY USE FACTORS

	Medium temperature	Low temperature
Saturated Suction Temperature (°F)	25	−20.
On-cycle evaporator fan power (W)	0.013 × Q*	0.016 × Q.
Off-cycle evaporator fan power (W)	0.2 × on-cycle evaporator fan power.	
Electric defrost energy per cycle (W-h/cycle)	0	$8.5 \times 10^{-3} \times Q^{1.27}$
Electric defrost heat contribution per cycle (Btu/cycle)	0	0.95 × electric defrost energy use per cycle × 3.412.
Hot gas defrost energy per cycle (W-h/cycle)	0	0.5 × hot gas defrost heat contribution per cycle/3.412.
Hot gas defrost heat contribution per cycle (Btu)	0	0.18 × Q.
Number of cycles per day	As specified in installation instructions or, if no instructions, 2.5	

*Q represents the gross capacity at the highest ambient rating condition in Btu/h.

AHRI 1250-2014

Table 18. Unit Cooler Nominal Values for Condensing Unit Energy Calculations

Description	Cooler	Freezer
Saturated Suction Temperature, °F	25	-20
On-cycle evaporator fan power, per Btu/h of gross capacity at ambient condition, W-h/Btu	0.016	0.016
Off-cycle evaporator fan power, W	0.2 · on-cycle evaporator fan power	
Electric defrost energy per cycle, per Btu/h of gross capacity, W-h/cycle per Btu/h	0	0.12
Number of cycles per day	N/A	4
Daily electric defrost contribution, Btu	0.95 · daily defrost energy use · 3.413	

Minimum AWEF 2017

	Indoor Condensing Unit	Outdoor Condensing Unit
Medium Temp	5.61	7.60
Low Temp (<2 HP)	0.0000593Q + 2.33	0.00023Q + 2.73
Low Temp (>2 HP)	3.10	4.79

Q is the unit capacity at -20 °F evap.

Indoor AWEF Example Calculations

1. **Low-Temperature Indoor R404A (Freezer)**
   - ¾ HP Q = 3,330 Btu/H E = 875 W
   - AWEF (indoor LT -20 °F evap) = 0.502Q / (0.605 E +0.0309 Q) = 2.65
   - Min AWEF = 0.0000593 Q + 2.33 = 2.53 "PASS"
2. **Medium-Temperature Indoor R134a (Cooler)**
   - 2 HP Q = 9,990 Btu/H E = 1,425 W
   - AWEF (indoor MT +25 °F evap) = 0.285 Q / (0.304 E + 0.0057 Q) = 5.81
   - Min AWEF = 5.61 "PASS"

Indoor AWEF Example Condensing Unit Improvements

- **Small Indoor Medium Temp Cooler R134a**
  - ½ HP   Q=5000 Btu/H   E=900W (140W fan motor + 760W compressor)
  - AWEF (indoor MT +25F evap) = 0.285Q / (0.304E + 0.0057Q) = 4.71
  - Min AWEF = 5.61   "FAIL" – needs 19% improvement
- **Possible improvements: CSR compressor, larger condenser coil, improved airflow, ECM fan motor, alternative refrigerant.**
  - If condensing unit power can be reduced to 741W (from 900W) this unit will pass, assuming capacity holds at 5000 Btu/H.
  - Capacitor Start / Capacitor Run compressor model is available and would only draw 706W (not 760W)
  - ECM fan motor would draw less than 40W (not 140W).
  - Better condenser will reduce TD, and compressor will run more efficiently. TD=28.6F in this example.
- **Get TD down to 25F and CSR compressor will only draw 693W**
  - Now AWEF = 5.67   Pass!

Low-Temp Outdoor Calculation (6 HP)

System Input			
Ambient [F]	Qgrosss [btu/h]	Ecomp (W)	Econd (W)
95	27600	5400	330
59	43200	3430	330
35	43200	3430	330

	Net Capacity and System Watts			Evap Fan Output		Defrost Output		
Ambient [F]	qss [btu/h]	Ess [W]	EER [btu/w.h]	EF_comp_on [W]	EF_comp_off [W]	W-h/defrost	DF [W]	Q_DF [btu/h]
95	26093	6172	4.23	442	88.3	3312	552.0	1789.3
59	41693	4202	9.92					
35	41693	4202	9.92					

Temp [F]	Bin Hour [hr]	qss [btu/h]	Ess [W]	BLH [btu/h]	BLL [btu/h]	LFH	LFL	WLH [btu/h]	WLL [btu/h]	q [btu]	E [W-hr]	BL[Btu's]
100.4	9	23753	6467	21210	10773	0.97	0.53	23009	12702	144930.6263	44683.03	127954
95	74	26093	6172	20875	10437	0.87	0.47	22703	12385	1168449.658	319791.4	1027239
89.6	257	28433	5876	20539	10102	0.79	0.42	22392	12065	3976495.171	974004.4	3481355
84.2	416	30773	5581	20204	9766	0.72	0.38	22078	11742	6303590.215	1391411	5495628
78.8	630	33113	5285	19868	9431	0.66	0.34	21761	11418	9343399.675	1869750	8111351
73.4	898	35453	4990	19533	9095	0.60	0.31	21441	11092	13027258.18	2375977	11260629
68	737	37793	4694	19197	8760	0.56	0.28	21119	10765	10451922.01	1745668	8994489
62.6	943	40133	4399	18862	8424	0.52	0.26	20796	10437	13065521.39	2007048	11192190
57.2	628	41693	4202	18526	8089	0.49	0.24	20469	10106	8494365.142	1240139	7242863
51.8	590	41693	4202	18191	7753	0.48	0.23	20136	9773	7783859.236	1145711	6606665
46.4	677	41693	4202	17855	7418	0.47	0.23	19803	9440	8706155.258	1292409	7353744
41	576	41693	4202	17520	7082	0.47	0.22	19470	9107	7215452.342	1080670	6063418
35.6	646	41693	4202	17184	6747	0.46	0.21	19137	8774	7877162.239	1190774	6583568
30.2	534	41693	4202	16849	6411	0.45	0.20	18803	8441	6333598.96	966776.8	5262996
24.8	322	41693	4202	16513	6076	0.44	0.19	18470	8108	3711885.533	572381.9	3065541
19.4	305	41693	4202	16178	5741	0.44	0.19	18137	7775	3414327.818	532140.7	2801372
14	246	41693	4202	15842	5405	0.43	0.18	17804	7442	2671914.252	421118.4	2176938
8.6	189	41693	4202	15507	5070	0.42	0.17	17471	7109	1989860.543	317331.7	1609119
3.2	78	41693	4202	15171	4734	0.41	0.16	17138	6776	795232.2516	128399.2	637913
-2.2	5	41693	4202	14836	4399	0.40	0.15	16805	6443	49311.03945	8066.418	39214
									Total	116524691.5	19624252	99134187
											AWEF	5.05

Note: DOE minimum AWEF for this system is 4.79

1. Low-Temp Outdoor R404A (Freezer)
   1. 6 HP Q = 27,600 Btu/H
   2. AWEF (outdoor LT -20 °F evap) = 5.05
   3. Min AWEF = 4.79 "PASS"

Source: Emerson Climate Technologies
With AHRI 1250-2014 AWEF XLS Calculator

Medium-Temp Outdoor Calc (2 HP)

	System Input		
Ambient [F]	Qgrosss [btu/h]	Ecomp (W)	Econd (W)
95	17400	2005	300
59	23600	1215	300
35	25200	1055	300

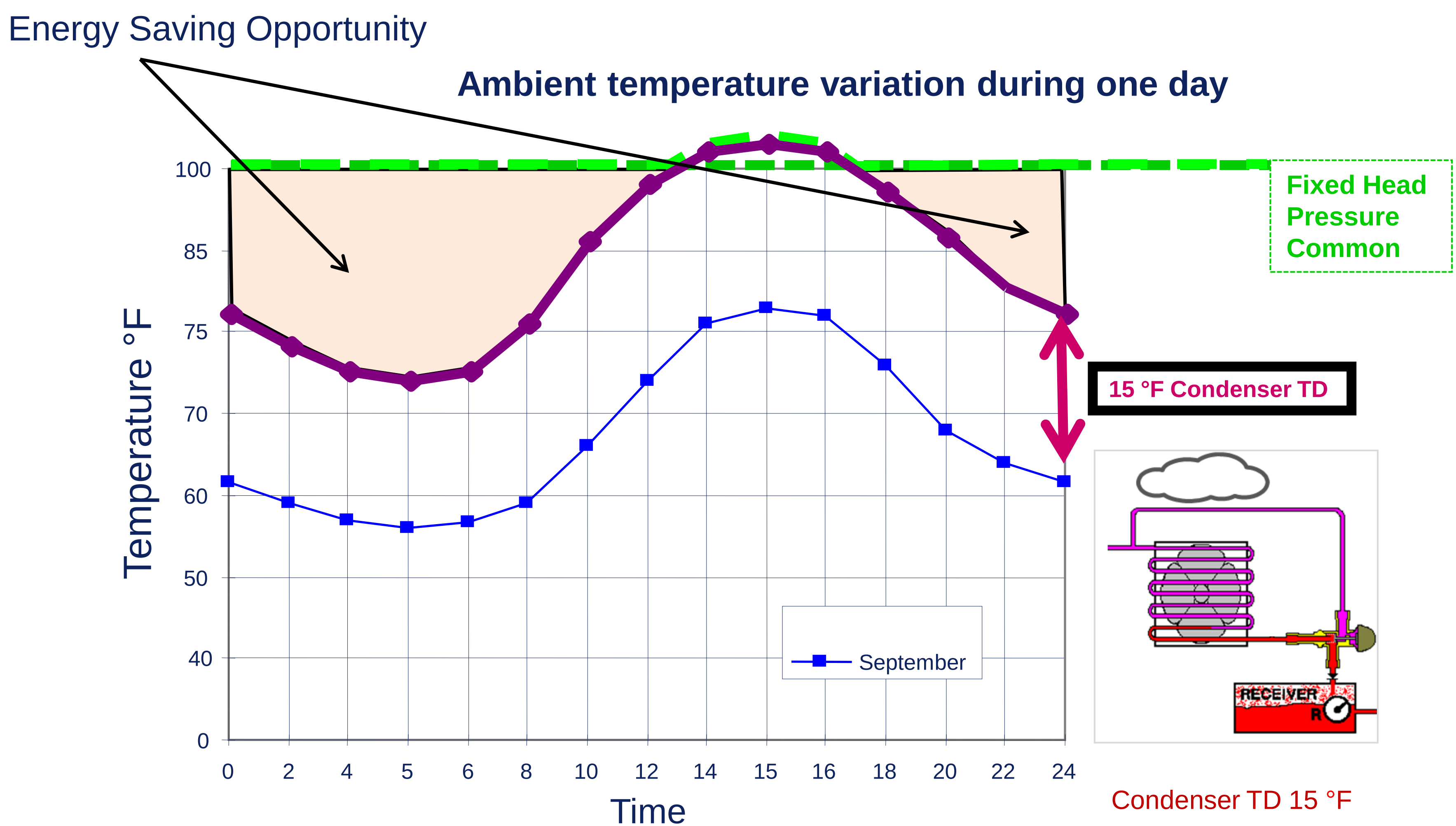
	Net Capacity and System Watts			Evap Fan Output		Defrost Output		
Ambient [F]	qss [btu/h]	Ess [W]	EER [btu/w.h]	EF_comp_on [W]	EF_comp_off [W]	W-h/defrost	DF [W]	Q_DF [btu/h]
95	16628	2531	6.57	226	45.2	0	0.0	0.0
59	22828	1741	13.11					
35	24428	1581	15.45					

Temp [F]	Bin Hour [hr]	qss [btu/h]	Ess [W]	BLH [btu/h]	BLL [btu/h]	LFH	LFL	WLH [btu/h]	WLL [btu/h]	q [btu]	E [W-hr]	BL[Btu's]
100.4	9	15698	2650	11715	1768	0.75	0.12	11753	1903	46383.91384	8102.629	45451
95	74	16628	2531	11640	1663	0.70	0.11	11686	1800	374630.073	59355.93	366685
89.6	257	17558	2413	11565	1558	0.66	0.10	11617	1697	1277542.47	183884.1	1249103
84.2	416	18488	2294	11490	1453	0.62	0.09	11548	1594	2029692.083	265717.6	1982425
78.8	630	19418	2176	11415	1349	0.59	0.08	11478	1491	3015728.611	359370.6	2942455
73.4	898	20348	2057	11340	1244	0.56	0.07	11408	1388	4215598.71	457449.3	4108963
68	737	21278	1939	11266	1139	0.53	0.06	11338	1284	3391510.883	335138.5	3302351
62.6	943	22208	1820	11191	1034	0.51	0.05	11267	1180	4251931.696	382491.1	4135924
57.2	628	22948	1729	11116	930	0.49	0.05	11195	1077	2773058.716	231900.3	2694774
51.8	590	23308	1693	11041	825	0.48	0.04	11122	973	2549919.818	206978.6	2475735
46.4	677	23668	1657	10966	720	0.47	0.04	11049	869	2862399.843	225575.7	2776567
41	576	24028	1621	10891	615	0.46	0.03	10975	765	2381299.398	182242.7	2307686
35.6	646	24388	1585	10817	510	0.45	0.03	10902	661	2610037.751	194032.3	2526841
30.2	534	24748	1549	10742	406	0.44	0.02	10829	557	2107368.721	152223.9	2038085
24.8	322	25108	1513	10667	301	0.43	0.02	10755	453	1240483.533	87092.58	1198406
19.4	305	25468	1477	10592	196	0.42	0.01	10682	348	1146329.428	78251.03	1106198
14	246	25828	1441	10517	91	0.41	0.01	10608	244	901456.1494	59850.84	868871
8.6	189	26188	1405	10443	-13	0.40	0.01	10535	140	674811.3852	43593.48	649615
3.2	78	26548	1369	10368	-118	0.39	0.00	10461	36	271157.8167	17051.37	260694
-2.2	5	26908	1333	10293	-223	0.39	0.00	10388	-68	16911.55891	1035.671	16237
									Total	38138252.56	3531338	37053069
											AWEF	10.49

Note: DOE minimum AWEF for this MT system is 7.60

1. Medium-Temp Outdoor R404A (Cooler)
   1. 2 HP Q = 17,400
   2. AWEF (outdoor MT +25 °F evap) = 10.49
   3. Min AWEF = 7.60 "PASS"

Floating Head Pressure vs. Fixed



Source: Emerson Climate Technologies

Taking Advantage of Low Ambient

Inputs

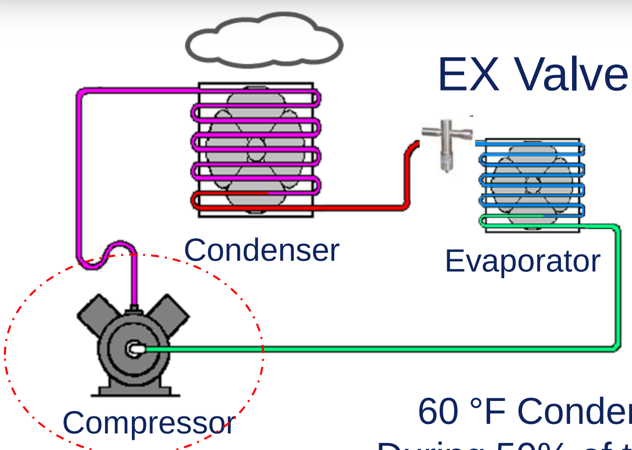
Evaporator Temperature (°F):	-20.0
Condensing Temperature (°F):	110.0
Return Gas Temperature (°F):	65.0
Evaporator Superheat (°F):	85.0
Compressor Superheat (°F):	85.0
Total Subcooling (F):	0.0

Results

Compressor Capacity (Btu/hr):	102,000
Net Refrigeration Effect (Btu/hr):	102,000
Power (W):	19,100
Compressor EER (Btu/Wh):	5.34
Evaporator EER (Btu/Wh):	5.34
Refrigerant Flow Rate (lb/hr):	1,900.0
Current (Amps):	25.2
Isentropic Efficiency (%):	71.2
Liquid Temp. (°F):	109.4
Discharge Temp. (°F):	230.0
Cond. Heat Rejection (Btu/hr)	167,188

62% More Capacity

Double the Energy Efficiency Ratio



60 °F Condensing During 50% of the Year

Inputs

Evaporator Temperature (°F):	-20.0
Condensing Temperature (°F):	60.0
Return Gas Temperature (°F):	65.0
Evaporator Superheat (°F):	85.0
Compressor Superheat (°F):	85.0
Total Subcooling (F):	0.0

Results

Compressor Capacity (Btu/hr):	166,000
Net Refrigeration Effect (Btu/hr):	166,000
Power (W):	15,500
Compressor EER (Btu/Wh):	10.71
Evaporator EER (Btu/Wh):	10.71
Refrigerant Flow Rate (lb/hr):	2,290.0
Current (Amps):	22.2
Isentropic Efficiency (%):	70.6
Liquid Temp. (°F):	59.2
Discharge Temp. (°F):	176.0
Cond. Heat Rejection (Btu/hr)	218,902

Floating Head System

Outdoor AWEF Example
Condensing Unit Improvements

- **1.0 HP low-temp R404A outdoor freezer unit**
  - Great compressor
  - Oversized coil
  - Floating head
  - ECM fan motor — all the bells and whistles!
- **2970 Btu/H, so minimum AWEF = 0.00023 (2970) + 2.73 = 3.42**
- **BIN analysis shows that this great unit only has AWEF of 3.06**
- **12% improvement needed**
- **Any suggestions?**

Source: Emerson Climate Technologies

Polling Question #3

Has our webinar been helpful to you today?

a. Very

b. Somewhat

c. Not very

Thank You!

What Questions Do You Have?