seventhwave

What you need to know about residential furnaces, air conditioners and heat pumps if you're NOT an HVAC professional

Scott Pigg

February 2017, Duluth MN

In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

"This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1.5 hours** of credit toward **Building Officials and Residential Contractors** continuing education requirements."

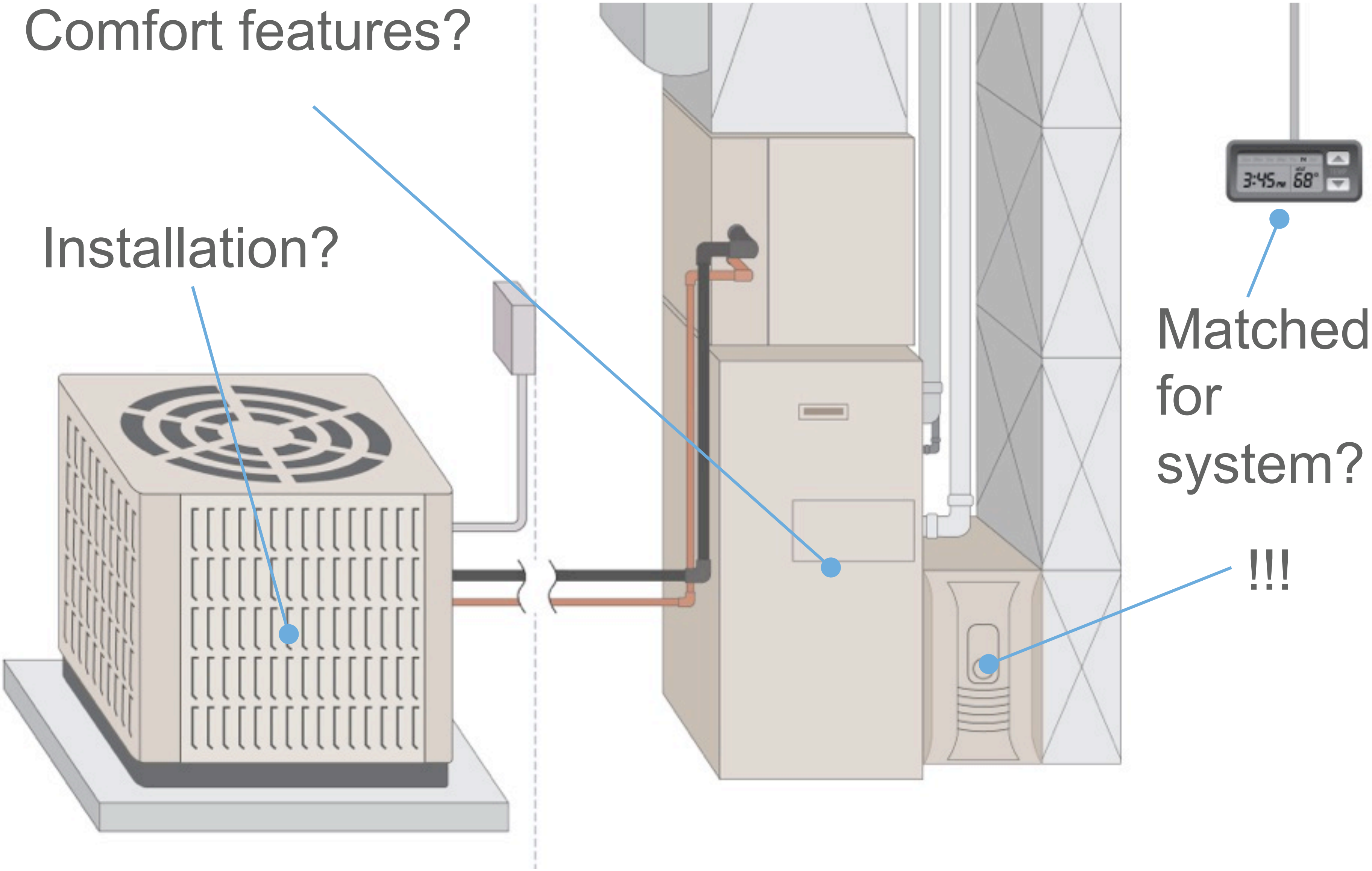
For additional continuing education approvals, please see your credit tracking card.

Test your knowledge!

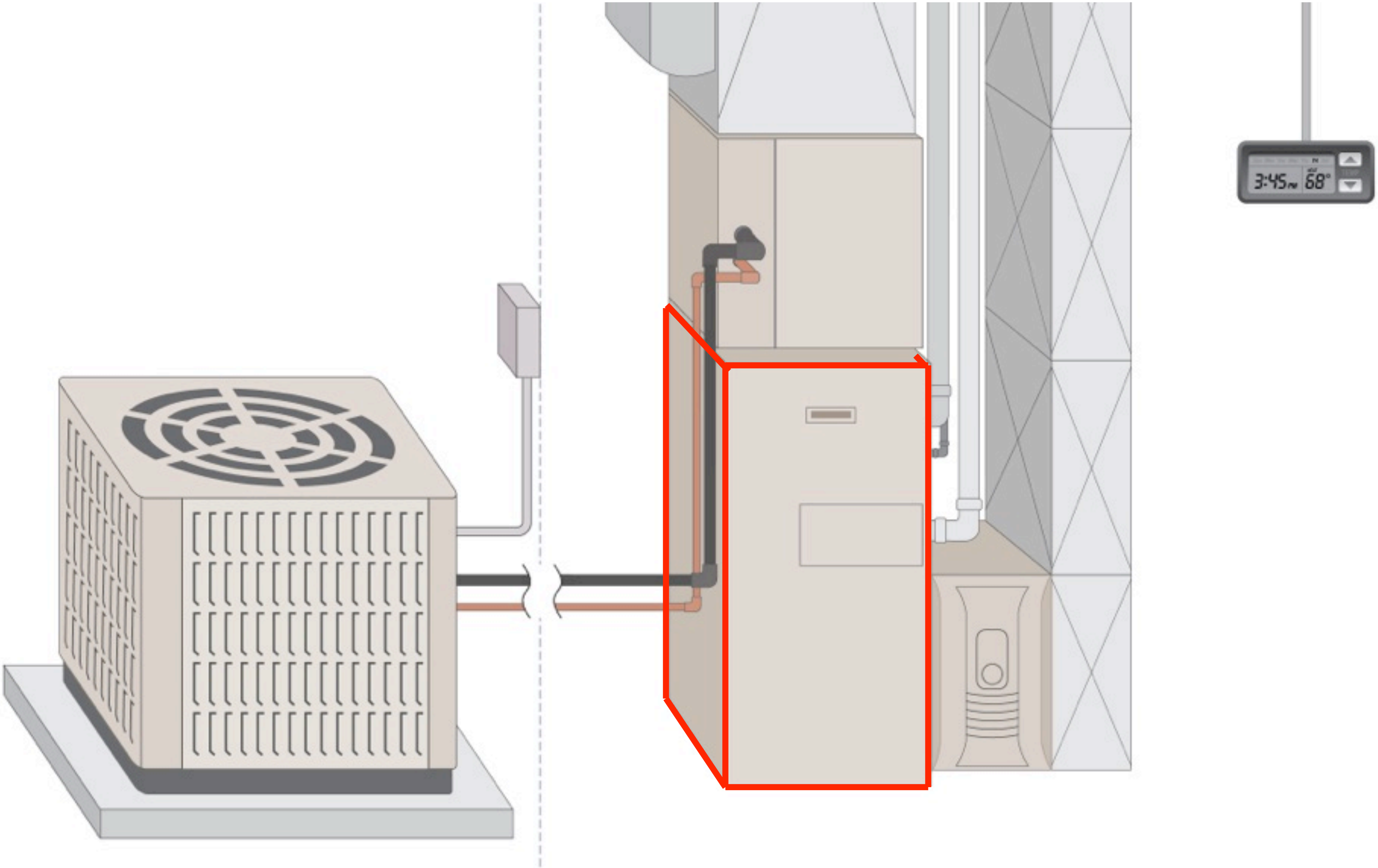
1. Go to: **c3ping.com**
2. Enter Ping ID: **6160**
3. Enter a name
4. "Waiting for the next question…"

Who's here?

A. Builder / remodeler
B. Home Performance Consultant
C. Weatherization provider
D. HVAC contractor / distributor
E. Other

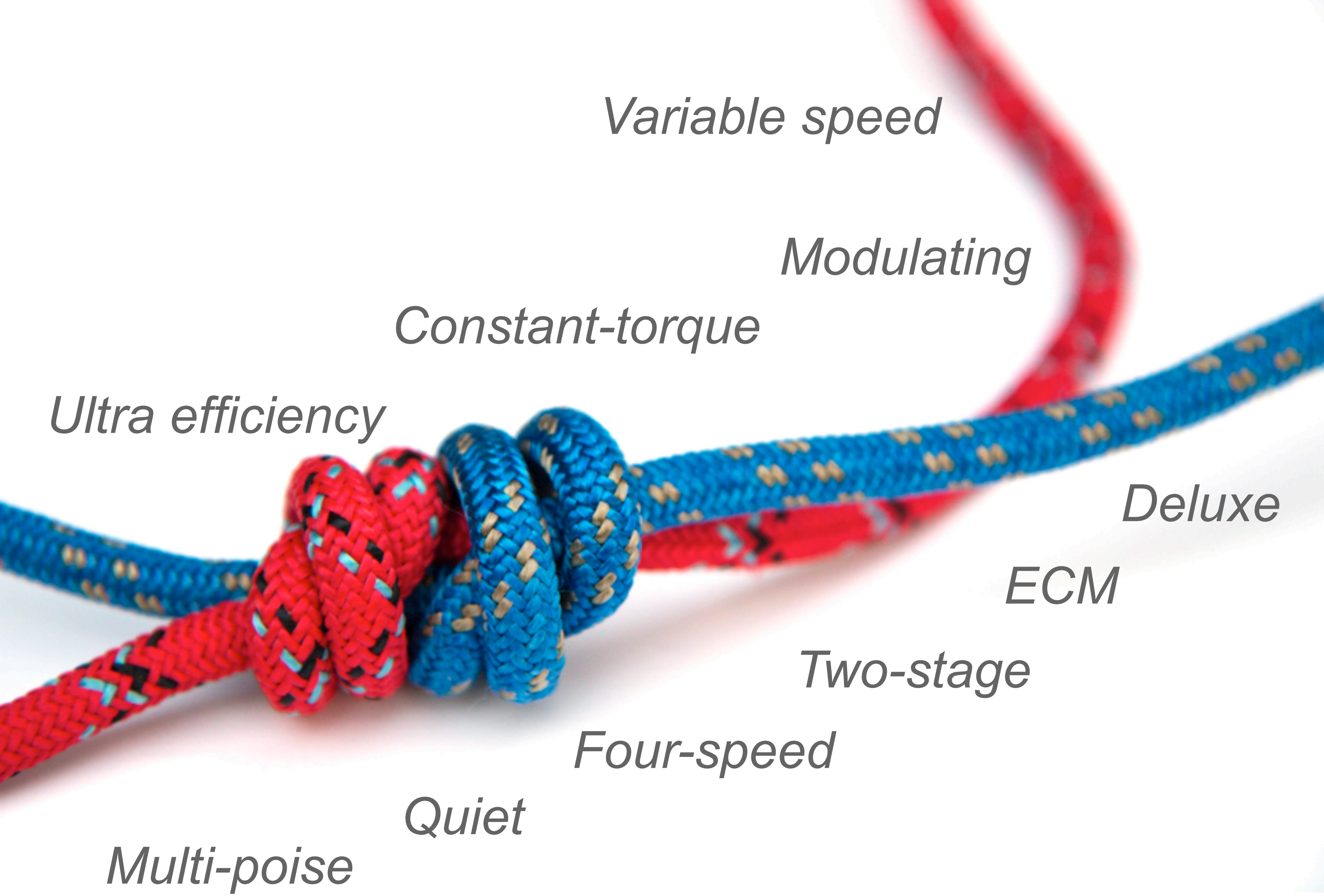

Comfort features?
Installation?
3:45
68°
Matched for system?
!!!

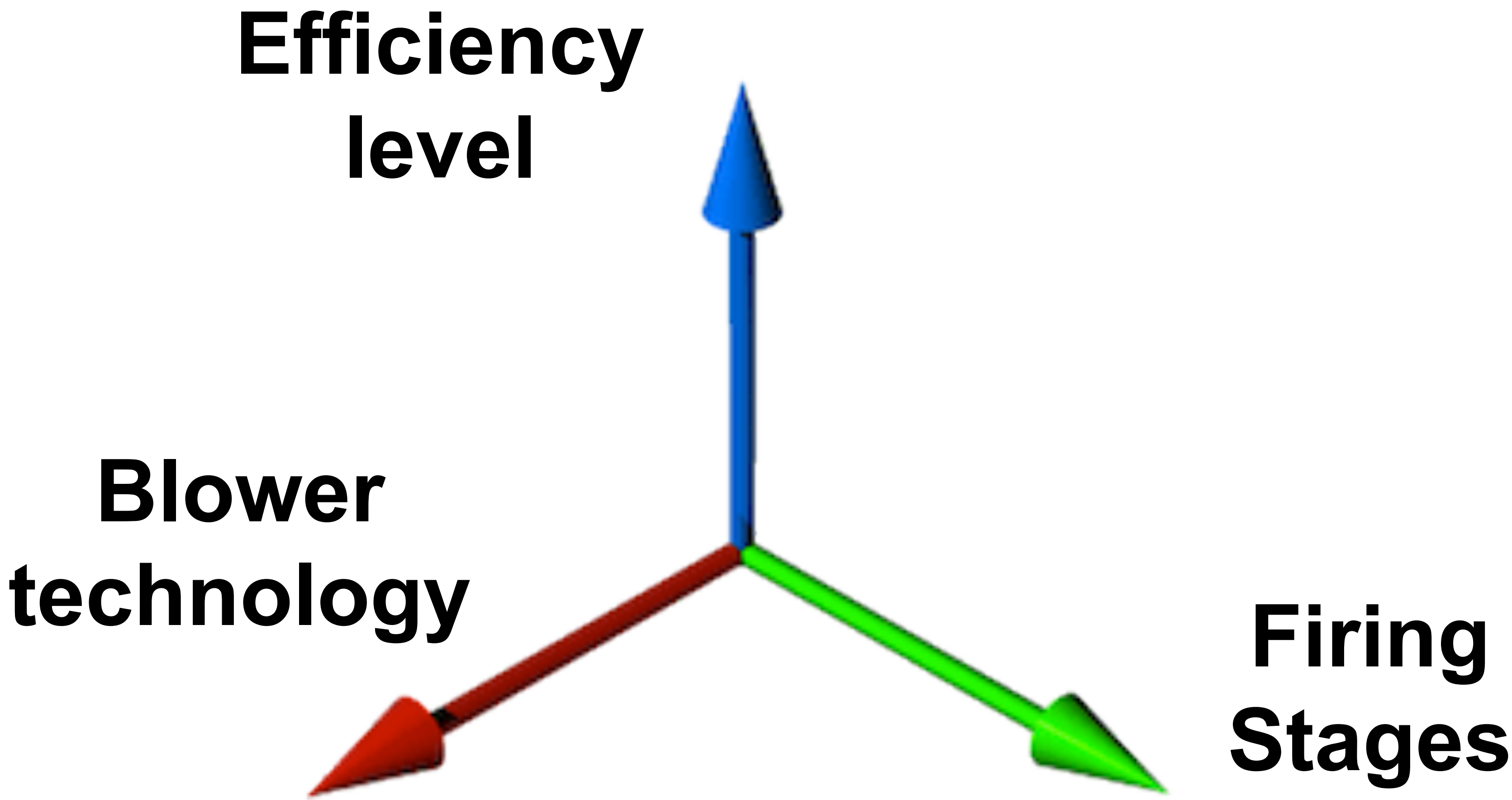
Furnace



The heating system in MY home is…

A. … a natural gas or propane furnace
B. … an oil furnace
C. … a hot-water or steam boiler
D. … something else

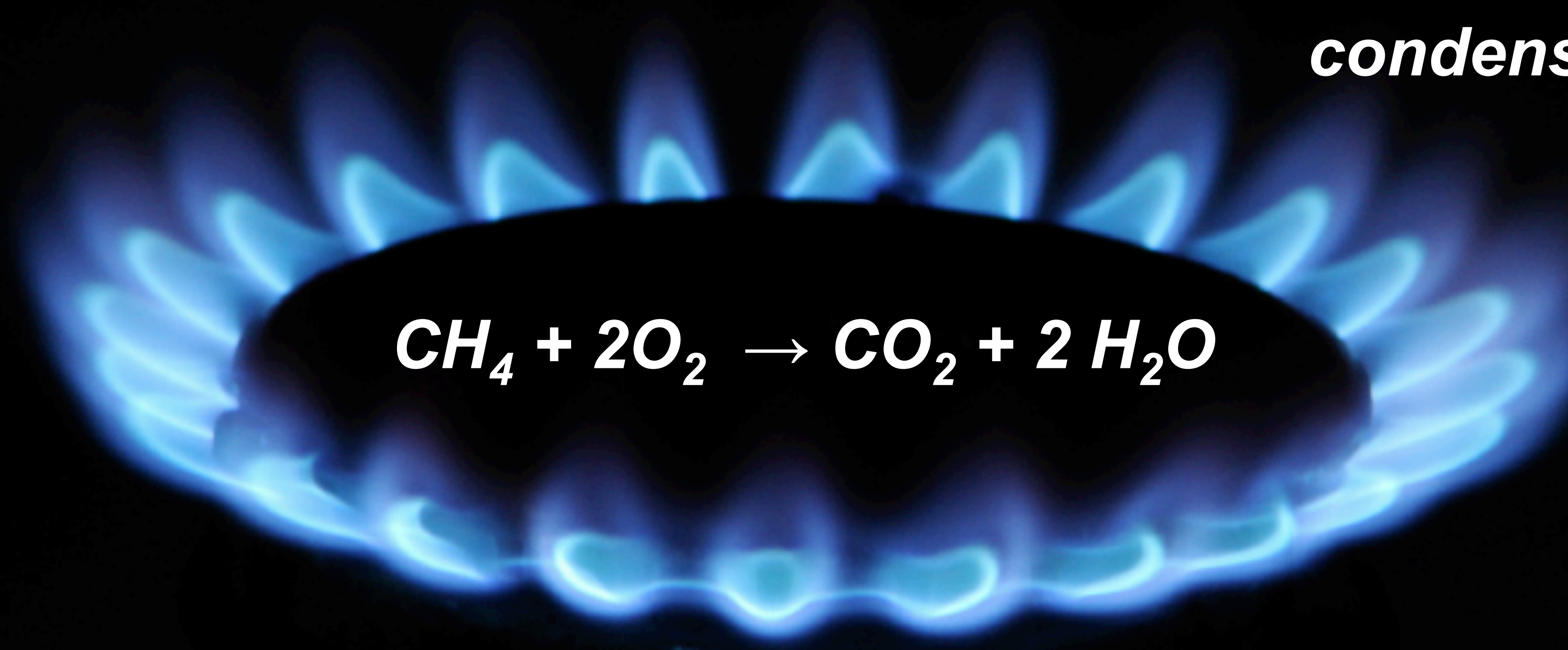

Variable speed
Modulating
Constant-torque
Ultra efficiency
Deluxe
ECM
Two-stage
Four-speed
Quiet
Multi-poise


Efficiency
level
Blower
technology
Firing
Stages

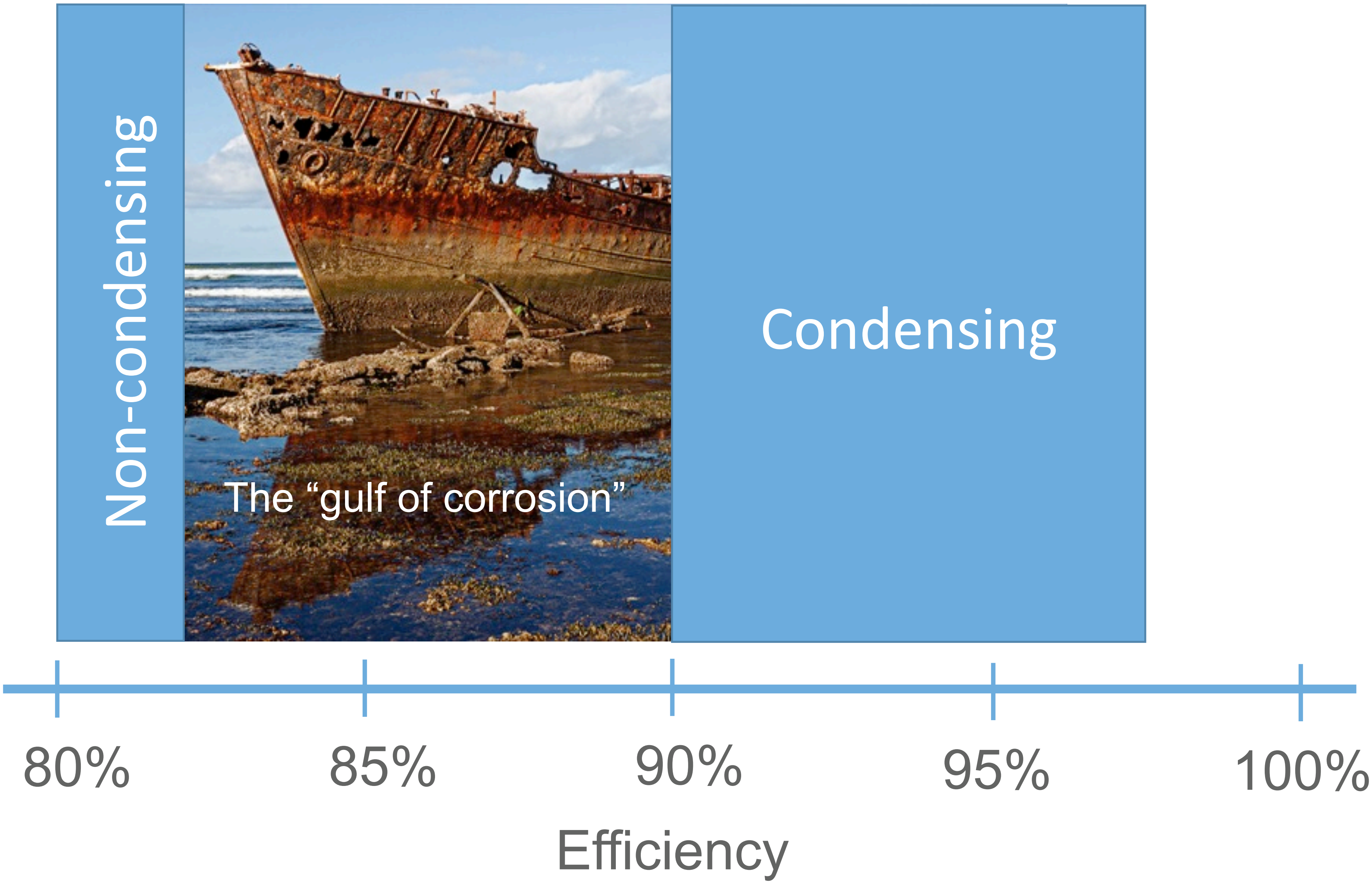
Efficiency level

To condense...

...or not to condense?



$$CH_4 + 2O_2 \rightarrow CO_2 + 2\,H_2O$$



Non-condensing
The "gulf of corrosion"
Condensing
80%
85%
90%
95%
100%
Efficiency

MY furnace is…

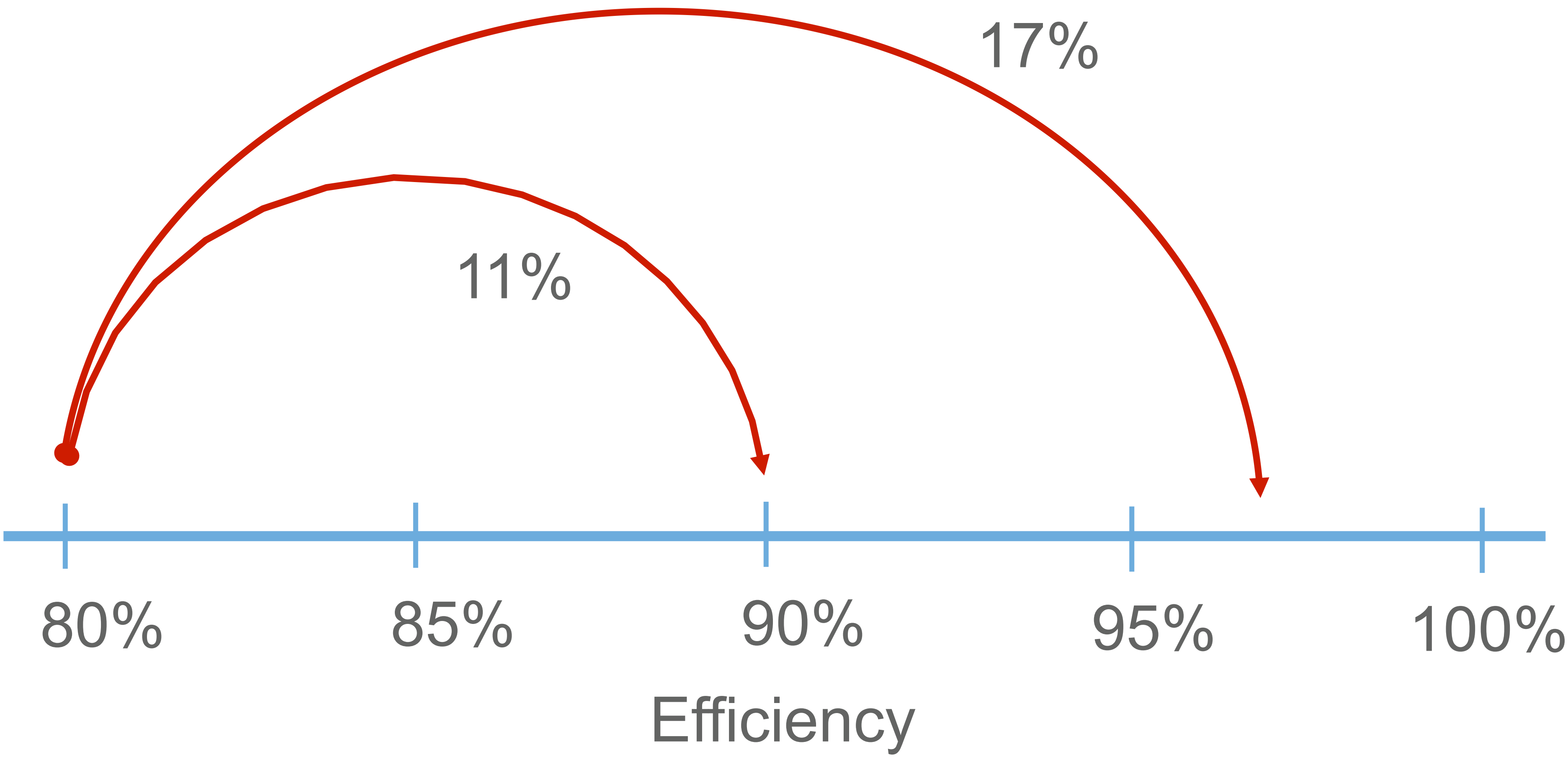
A. …Non-condensing
B. …Condensing
C. (I'm not sure)

The savings from upgrading from non-condensing to condensing are…

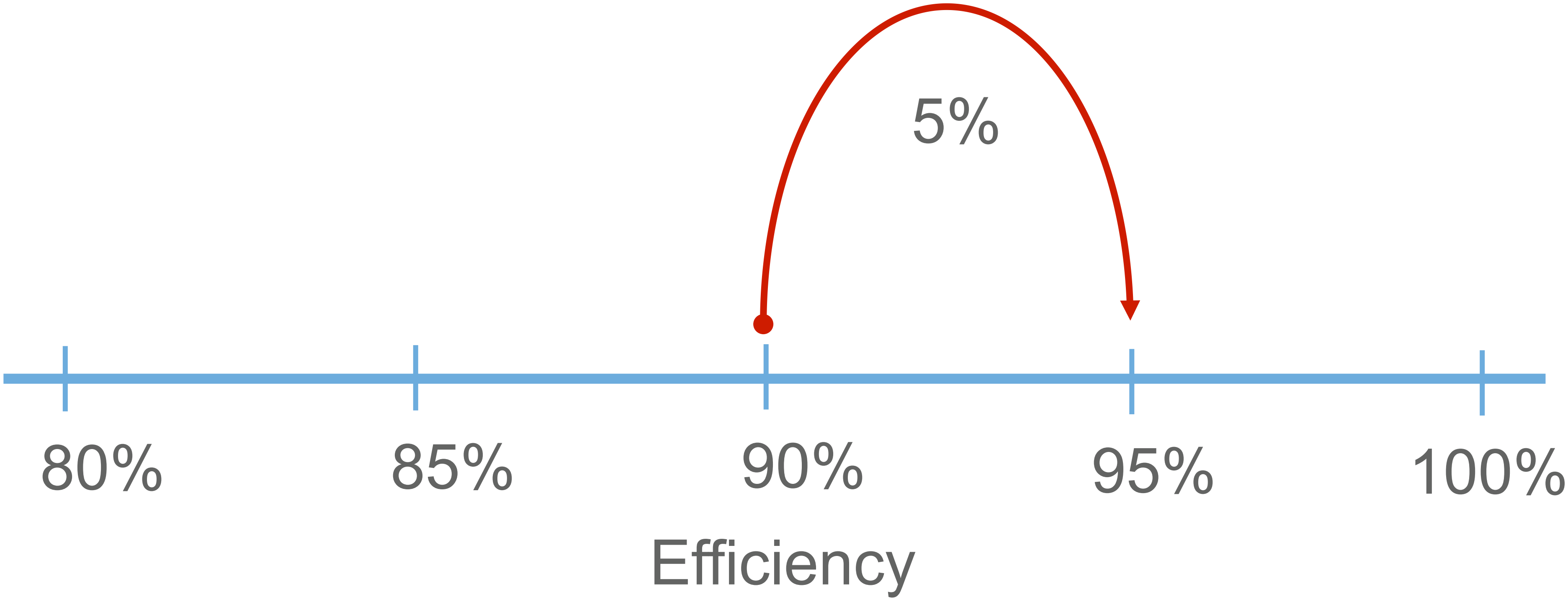
A. 5%
B. 10%
C. 15%
D. 20%
E. 25%

The savings from upgrading from non-condensing to condensing are…

A. 5%
B. 10%
C. 15%
D. 20%
E. 25%


17%
11%
80%
85%
90%
95%
100%
Efficiency

Upgrade to <u>higher</u> efficiency condensing?



Annual Fuel Utilization Efficiency

AFUE

.5 min,
.0 min,
nfinity;

.75 min,
2.5 min,
5 min.

, use $T_{F,OFF}(t_4) = T_{F,OFF}(t_5) + 0.1$.
, use $T_{F,OFF}(t_3) = T_{F,OFF}(t_5) + 0.2$.
, use $T_{F,OFF}(t_3) = T_{F,OFF}(t_4) + 0.1$.

ers employing post purge with post-
.1.1 and 9.5.1.2), the times t_3, t_4,
lows.

$_P$ + 1.5) min,
$_P$ + 9.0) min,
nfinity.

$_P$ + 3.75) min,
$_P$ + 22.5) min,
5 min,

defined in 9.5.1.1 (furnaces) and
2 (boilers);
s temperature measured at time (t_3)
hutdown from steady-state opera-
the system burner, determined in
ance with 9.5, in °F;
s temperature measured at time (t_4)
hutdown from steady-state opera-
the system burner, determined in
ance with 9.5, in °F;
m flue gas temperature for furnac-
he 45-minute reading for boilers,
ned in accordance with 9.5, in °F.

ective Flue Gas Temperature
Calculate the effective flue gas
shutdown of the system burner,
and defined as

$(t_3) - T_{F,OFF}(t_5)] e^{t_3/\tau_{OFF}}$

defined in 11.2.9.6,
defined in 11.2.9.6,
defined in 11.2.9.6,
defined in 11.2.9.6.

mum Flue Gas Temperature
Temperature Calculate the
erature difference above room
essed in °F and defined as

$T_{F,OFF}(t_5) - T_{RA}$

where

$T_{F,OFF}(t_5)$ = value as defined in 11.2.9.6, and
T_{RA} = value as defined in 11.2.5.

11.2.9.9 Minimum Stack Gas Temperature Difference above Room Temperature Calculate the minimum stack gas temperature difference above room temperature, $\Psi_{S,\infty,X}$, expressed in °F and defined as follows.

For systems numbered 1-4 and systems 5-8 if $(S/F)(D_s^\circ) > D_F$,

$$\Psi_{S,\infty,X} = \frac{(D_F)(\Psi_{F,\infty,X})}{(S/F)(D_s^\circ)}.$$

For systems numbered 5-8 for which $(S/F)(D_S^\circ) \le D_F$,

$$\Psi_{S,\infty,X} = \Psi_{F,\infty,X}$$

where

D_F = off-cycle flue gas draft factor, which is equal to:

- 1.0 for units with atmospheric burners, systems 1, 5, 9 (except direct vent and atmospheric burners with either electro-mechanical inlet dampers or flue dampers);
- 0.4 or D_P for units with power burners, systems 2, 3, 4, 6, 8, 10;
- 1.0 or D_P for direct vent units with atmospheric burners, system 9 (direct vent only);
- 1.0 or D_P for atmospheric burners with either electro-mechanical inlet dampers or flue dampers (system 1) and with units employing isolated combustion (system 9);
- 0.05 for units complying with 8.8.3.

D_S° = off-cycle stack gas draft factor, without stack damper, which is equal to:

- 1 for systems 1, 2, 5, and 6;
- 0.4 for system 3;
- 0.85 or $[(0.79 + D_P)/1.4]$ for systems 4 and 8,

where

D_P = the power burner draft factor as determined by the optional procedure defined in 9.7,
S/F = value as defined in 11.2.4,
$\Psi_{F,\infty,X}$ = value as defined in 11.2.9.8.

11.2.9.10 Effective Stack Gas Temperature Difference at Shutdown Calculate the effective stack gas temperature difference at shutdown, $\Psi_{S,O,X}$, expressed in °F and defined as follows.

For systems numbered 1-4 and 5-8 if $(S/F)(D_S^\circ) > D_F$,

$$\Psi_{S,O,X} = \frac{(D_F)(\Psi_{F,O,X})}{(S/F)(D_S^\circ)}.$$

For systems 5-8 for which $(S/F)(D_S^\circ) \le D_F$,

$$\Psi_{S,O,X} = \Psi_{F,O,X}$$

where

D_F = value as defined in 11.2.9.9,
$\Psi_{F,O,X}$ = value as defined in 11.2.9.7,
S/F = value as defined in 11.2.4,
D_S° = value as defined in 11.2.9.9.

11.2.9.11 Ratio of Average Burner On-Time Per Cycle to On-Cycle Time Constant Calculate the ratio of average burner on-time per cycle to on-cycle time constant, R_{ON}, defined as

$$R_{ON} = t_{ON}/\tau_{ON}$$

where

for furnaces, t_{ON} = 3.87 min, the average burner on-time per cycle, and
τ_{ON} = value as defined in 11.2.9.4;

for boilers, t_{ON} = 9.68 min, the average burner on-time per cycle, and
τ_{ON} = value as defined in 11.2.9.4.

11.2.9.12 Ratio of Average Burner Off-Time Per Cycle to Off-Cycle Time Constant Calculate the ratio of average burner off-time per cycle to off-cycle time constant, R_{OFF}, defined as

$$R_{OFF} = t_{OFF}/\tau_{OFF}$$

where

for furnaces, t_{OFF} = 13.3 min, the average burner off-time per cycle, and
τ_{OFF} = value as defined in 11.2.9.6;

for boilers, t_{OFF} = 33.26 min, the average burner off-time per cycle, and
τ_{OFF} = value as defined in 11.2.9.6.

11.2.9.13 Start-up Burner Cycling Effect Correction Factor Calculate the burner start-up cycling effect factor ($C_{T,ON}$) defined as

$$C_{T,ON} = \frac{1 - \dfrac{(\Psi_{F,O,X})(e^{-R_{OFF}})}{(T_{F,SS} - T_{F,OFF}(t_5))}}{1 - \dfrac{(\theta_{F,O,X})(\Psi_{F,O,X})(e^{-(R_{ON}+R_{OFF})})}{(T_{F,SS} - T_{F,OFF}(t_5))^2}}$$

where

$\theta_{F,O,X}$ = value as defined in 11.2.9.5,
$\Psi_{F,O,X}$ = value as defined in 11.2.9.7,
R_{OFF} = value as defined in 11.2.9.12,
R_{ON} = value as defined in 11.2.9.11,
$T_{F,SS}$ = value as defined in 11.2.5,
$T_{F,OFF}(t_5)$ = value as defined in 11.2.9.6.

11.2.9.14 Shutdown Burner Cycling Effect Correction Factor Calculate the burner shutdown cycling effect factor ($C_{T,OFF}$) defined as

$$C_{T,OFF} = \frac{C_{IID}\left[1 - \dfrac{(\theta_{F,O,X})(e^{-R_{ON}})}{(T_{F,SS} - T_{F,OFF}(t_5))}\right]}{1 - \dfrac{(\theta_{F,O,X})(\Psi_{F,O,X})(e^{-(R_{ON}+R_{OFF})})}{(T_{F,SS} - T_{F,OFF}(t_5))^2}}$$

where

$\Psi_{F,O,X}$ = value as defined in 11.2.9.7,
$\theta_{F,O,X}$ = value as defined in 11.2.9.5,
R_{OFF} = value as defined in 11.2.9.12,
R_{ON} = value as defined in 11.2.9.11,
$T_{F,SS}$ = value as defined in 11.2.5,
$T_{F,OFF}(t_5)$ = value as defined in 11.2.9.6,
C_{IID} = 1, for units with continuously burning pilot lights; 0.90 for units with intermittent or interrupted ignition devices.

11.2.9.15 Effective Flue Gas Temperature Difference at Burner Shutdown, Corrected for Burner Cycling Effect Calculate the effective flue gas temperature difference at burner shutdown, corrected for burner cycling effect, $\Psi_{F,O}$.

For systems numbered 1-8,

$$\Psi_{F,O} = (\Psi_{F,O,X})(C_{T,OFF}).$$

For systems 9-10,

$$\Psi_{F,O} = (C_{T,OFF})(C_S^J)(\Psi_{F,O,X})$$

where

$\Psi_{F,O,X}$ = value as defined in 11.2.9.7,
$C_{T,OFF}$ = value as defined in 11.2.9.14.

The correction factor, which corrects the effect of outdoor air passing through the heat exchanger during the off-period, C_S^J, is defined as

$$C_S^J = 1.22.$$

11.2.9.16 Effective Minimum Flue Gas Temperature Difference above Room Temperature, Corrected for Burner Cycling Effect Calculate the difference above room temperature, $\Psi_{F,\infty}$, corrected for burner cycling effect, expressed in °F and defined as follows.

For systems numbered 1-8,

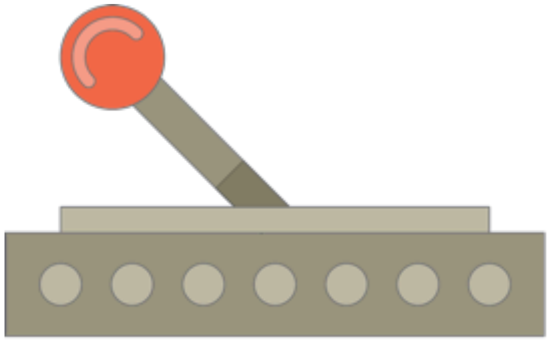
$$\Psi_{F,\infty} = \Psi_{F,\infty,X}.$$

For systems numbered 9-10,

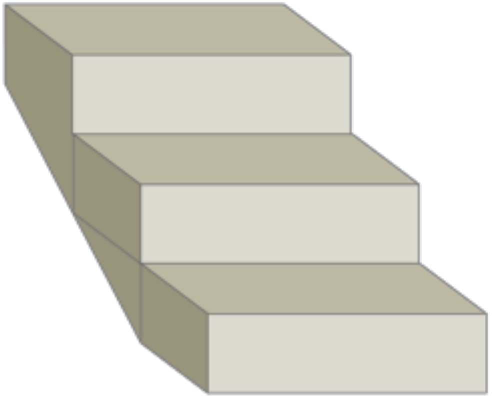
$$\Psi_{F,\infty} = (C_S^J)(\Psi_{F,\infty,X})$$

Firing stages

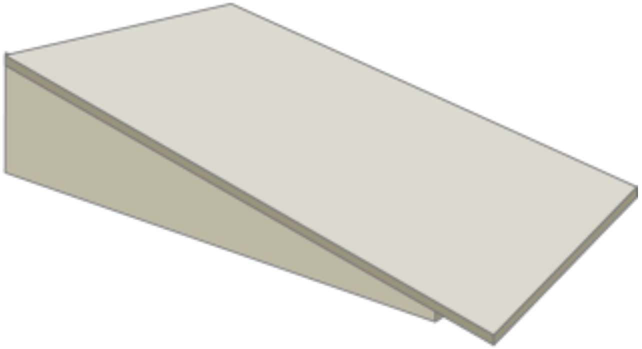
Single-stage



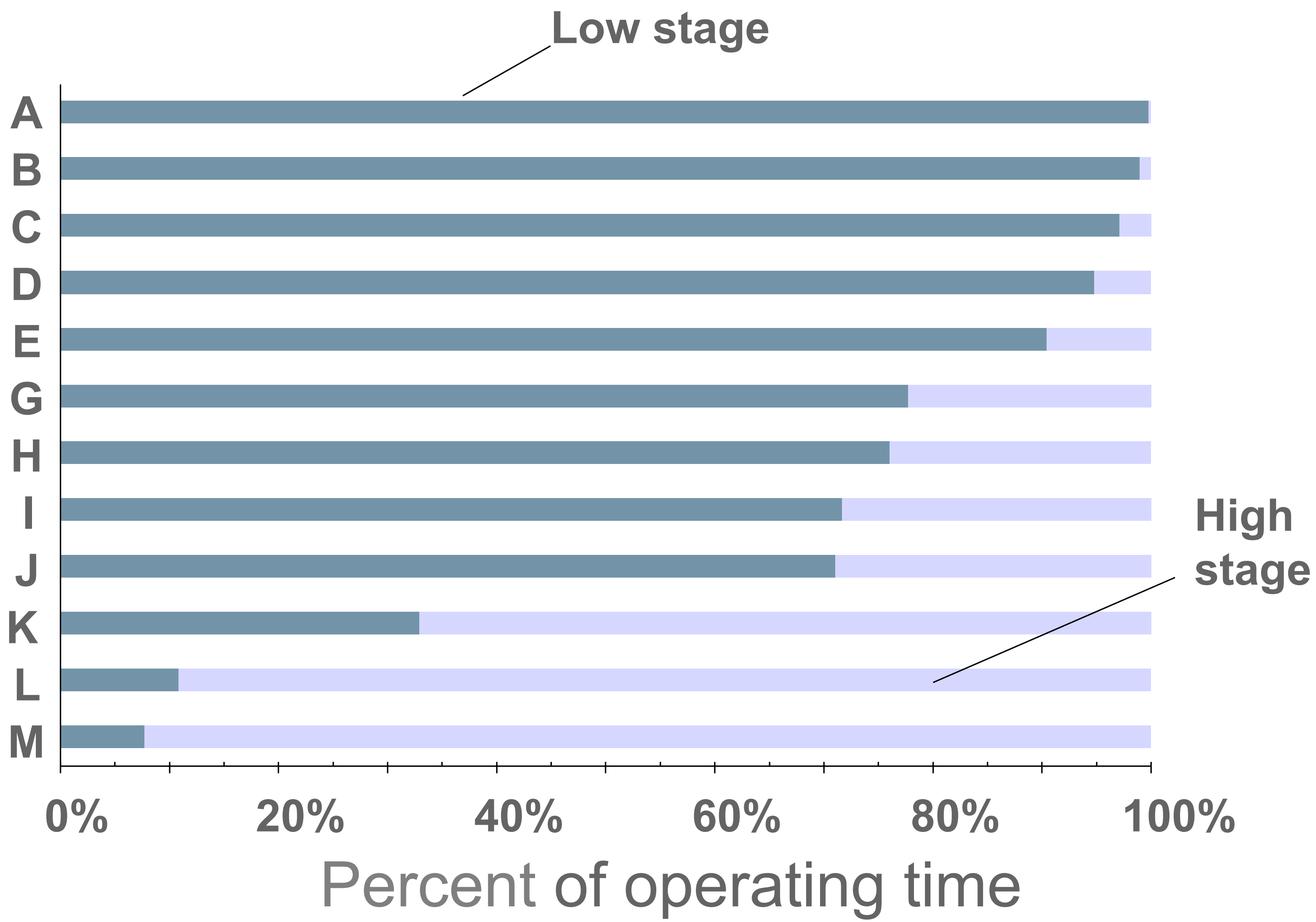
Multi-stage



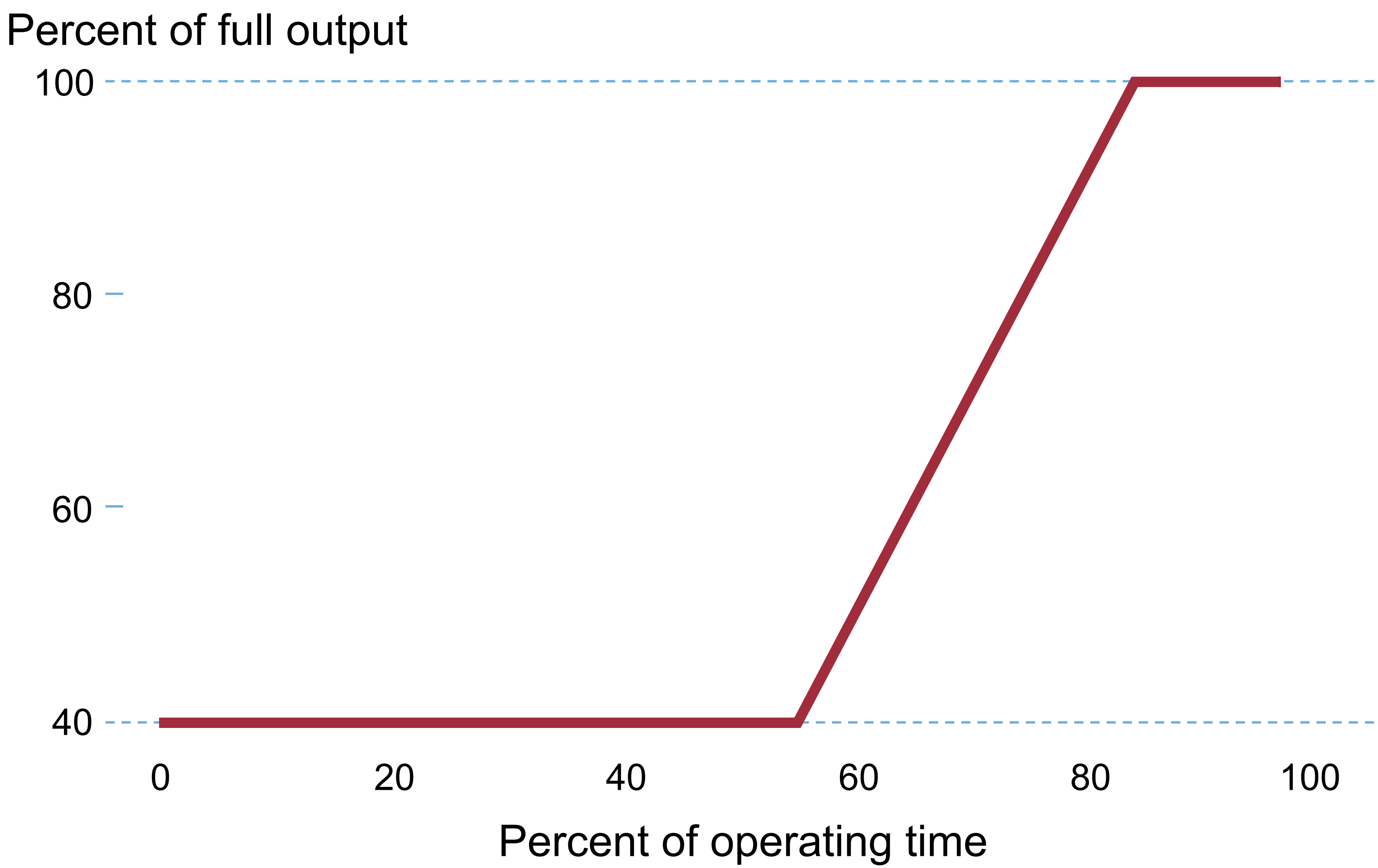
Modulating



Two-stage operation
(12 monitored furnaces)



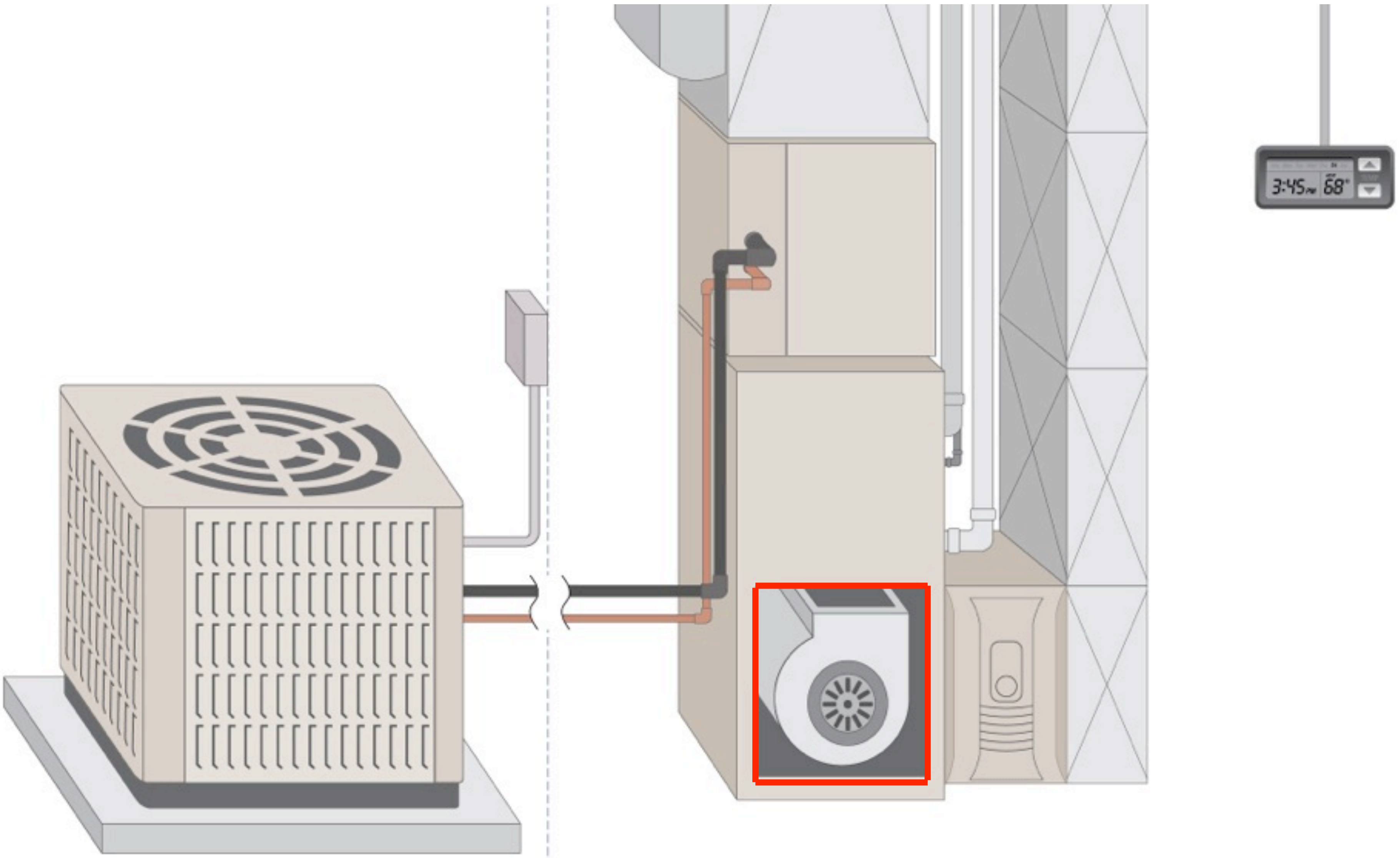
Typical modulating furnace



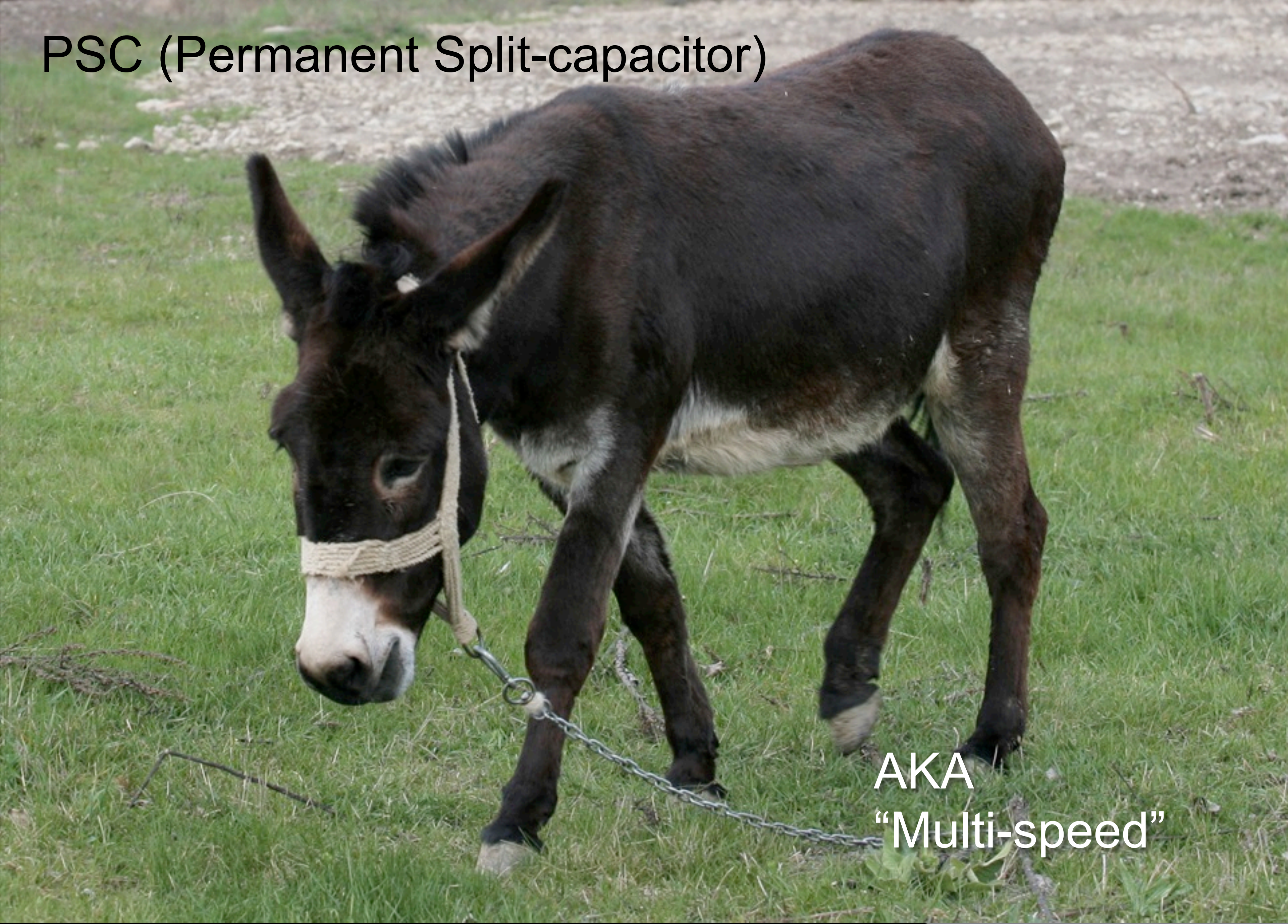
MY furnace is…

A. …Single-stage
B. …Multi-stage
C. …Modulating
D. (I'm not sure)

Blower technology



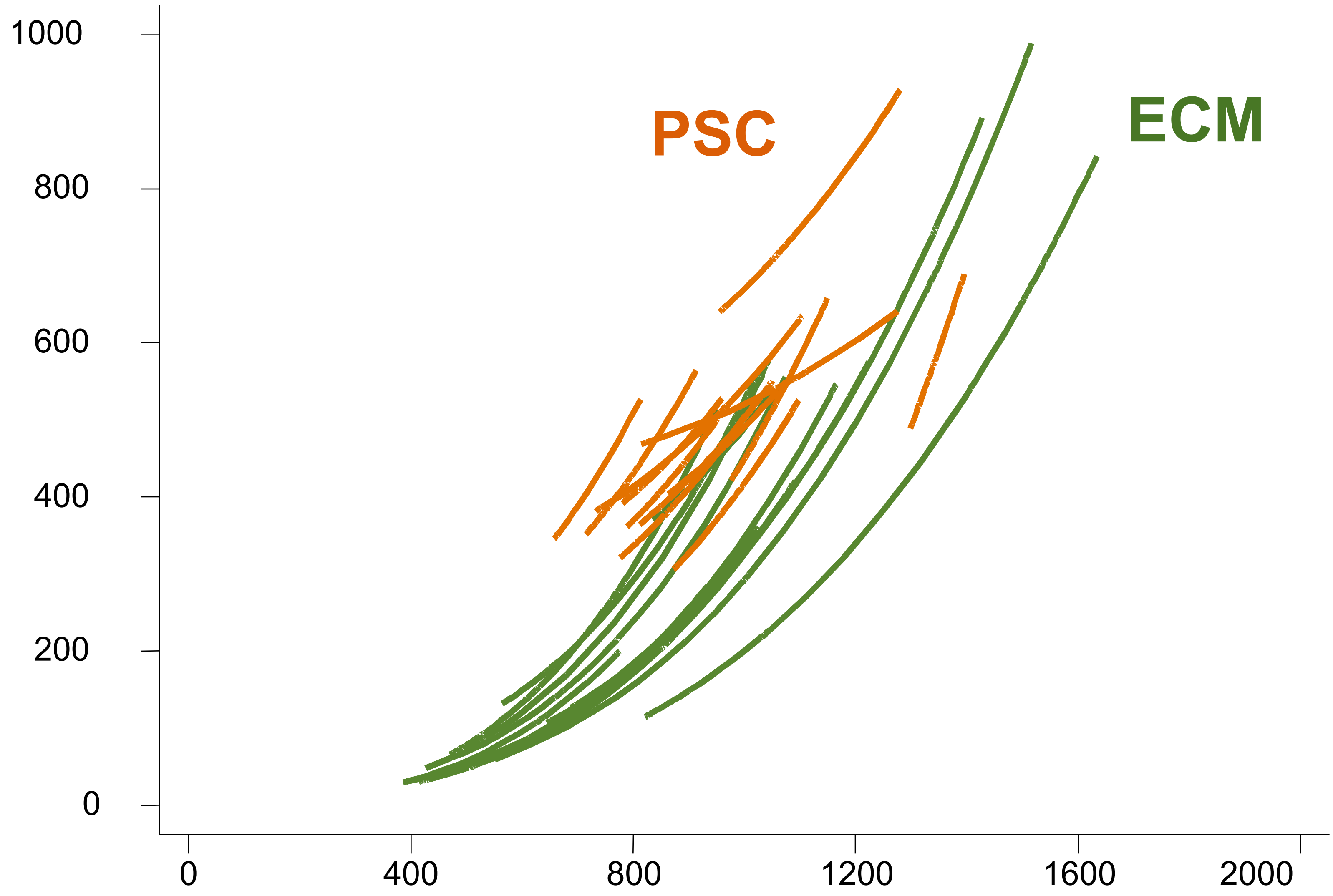
PSC (Permanent Split-capacitor)



ECM (Electronically commutated motor)

AKA
“variable speed”

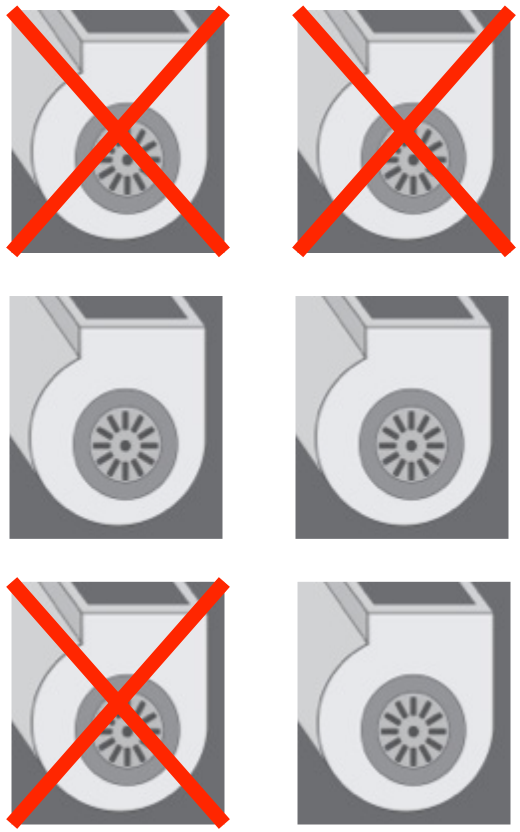
Electricity consumption (watts)



Yearly ECM electricity savings

Fan "ON" use

before after



= $60

= $450

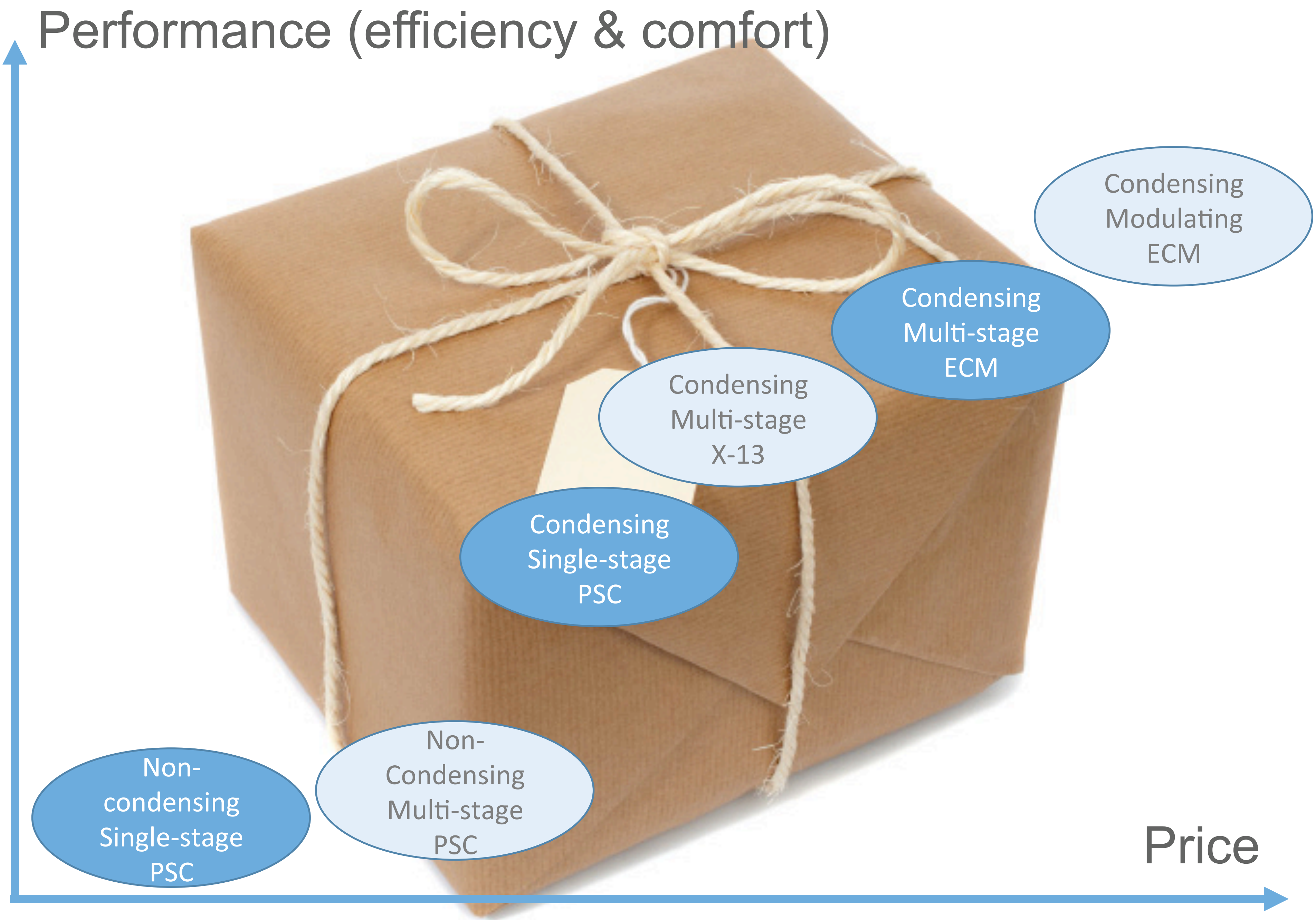
= $0

(@ 13 cents/kWh)

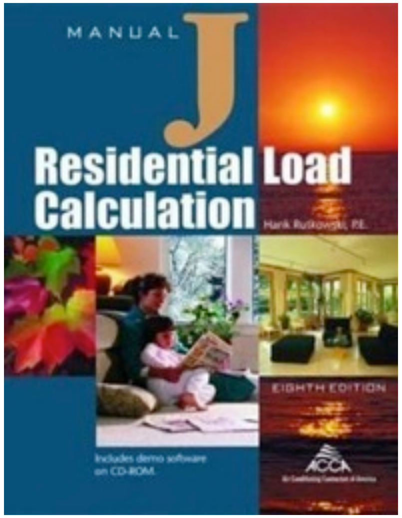

X-13 (trade name)
AKA
“constant torque”

MY furnace has…

A. …a PSC blower
B. …an ECM blower
C. …an X-13 blower
D. (I'm not sure)


Performance (efficiency & comfort)
Price
Non-condensing Single-stage PSC
Non-Condensing Multi-stage PSC
Condensing Single-stage PSC
Condensing Multi-stage X-13
Condensing Multi-stage ECM
Condensing Modulating ECM

Furnace sizing



40,000 Btuh

60,000 Btuh

80,000 Btuh

100,000 Btuh

Minnesota energy code:

“Oversizing of heating equipment shall not exceed ____ percent of the calculated load requirement”

A. …5
B. …10
C. …20
D. …40

Minnesota energy code:

"Oversizing of heating equipment shall not exceed ____ percent of the calculated load requirement"

A. …5
B. …10
C. …20
D. …40

What percent of Minnesota furnaces exceed the code limit for oversizing?

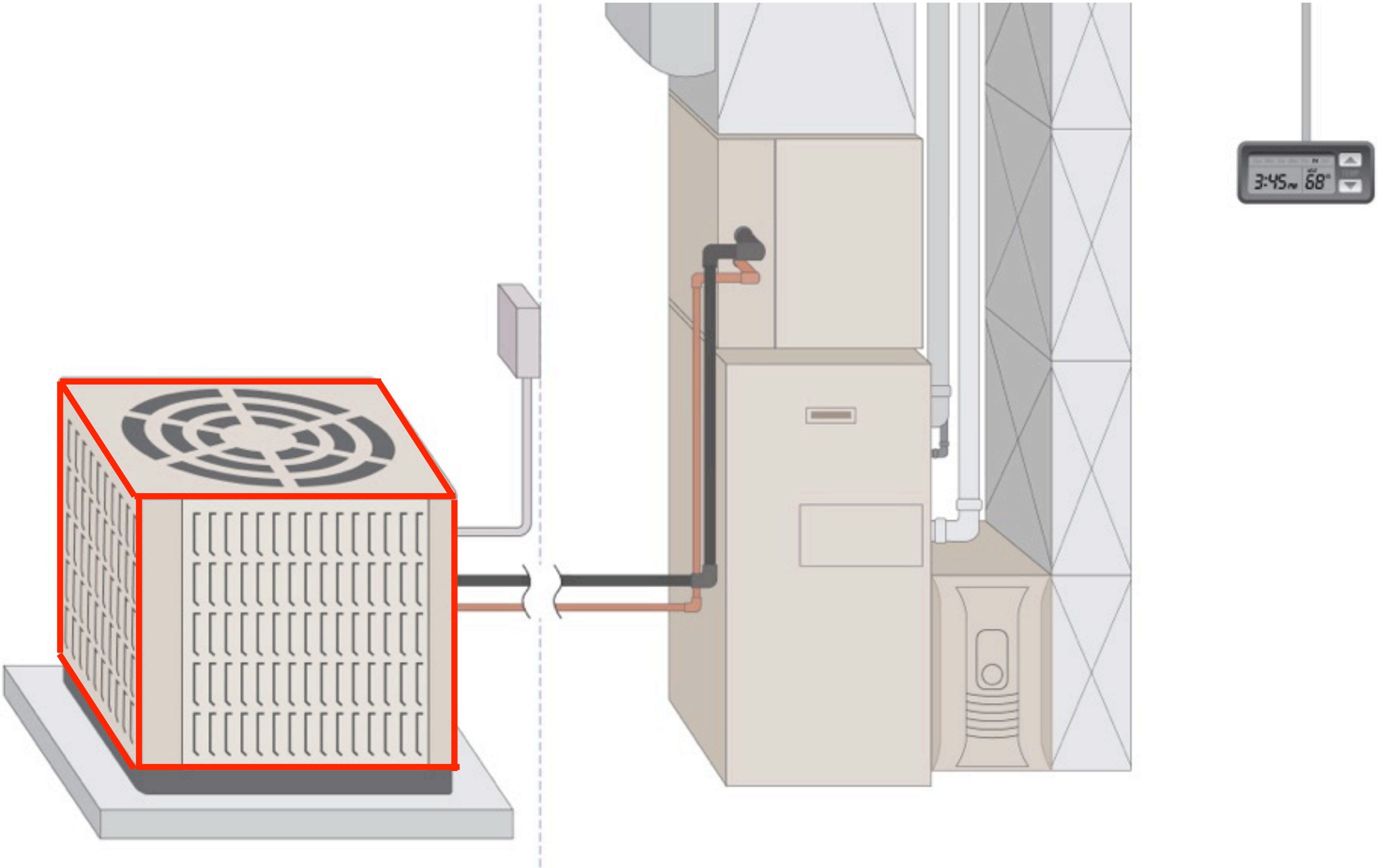
A. 15%
B. 30%
C. 60%
D. 95%

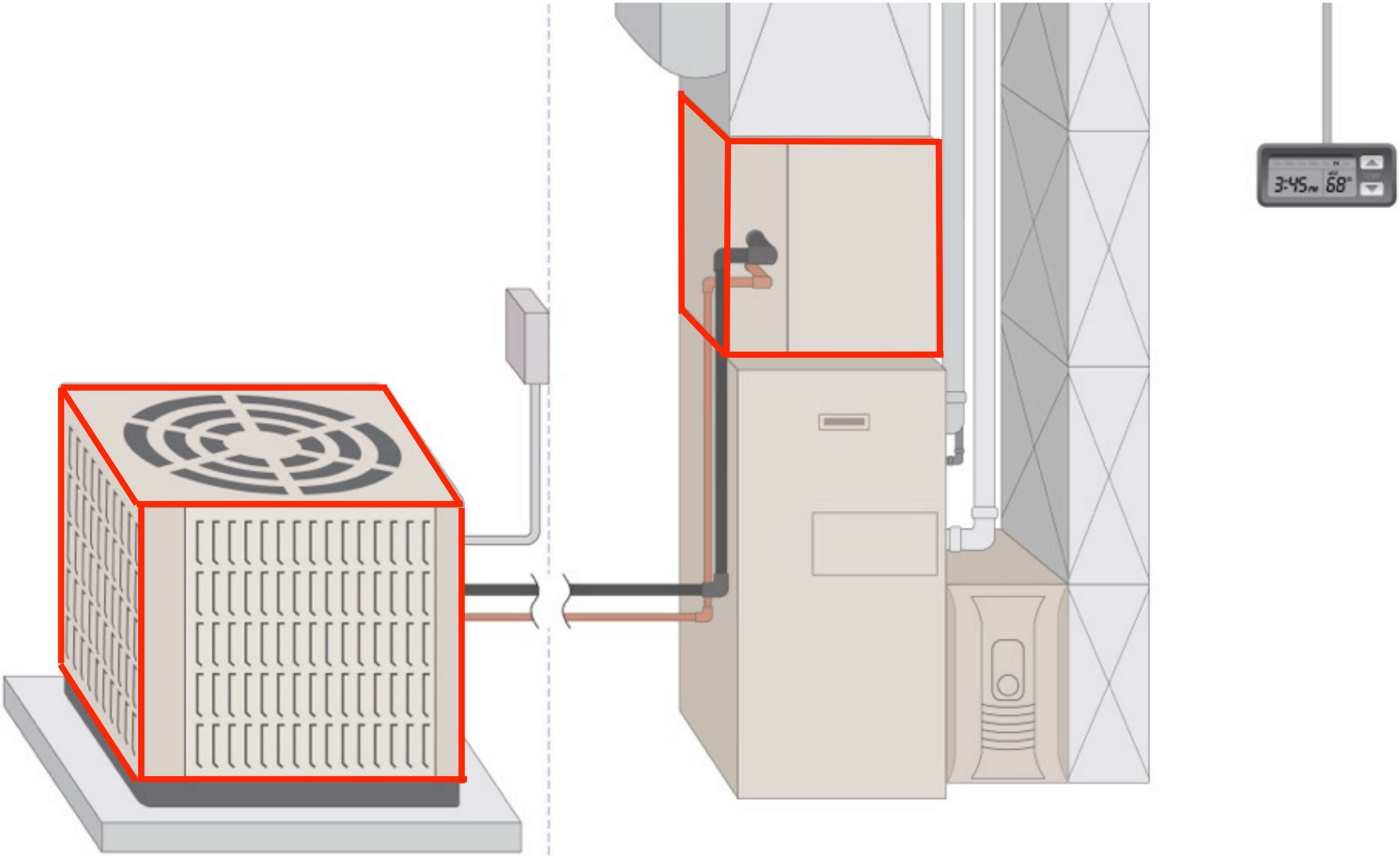
What percent of Minnesota furnaces exceed the code limit for oversizing?

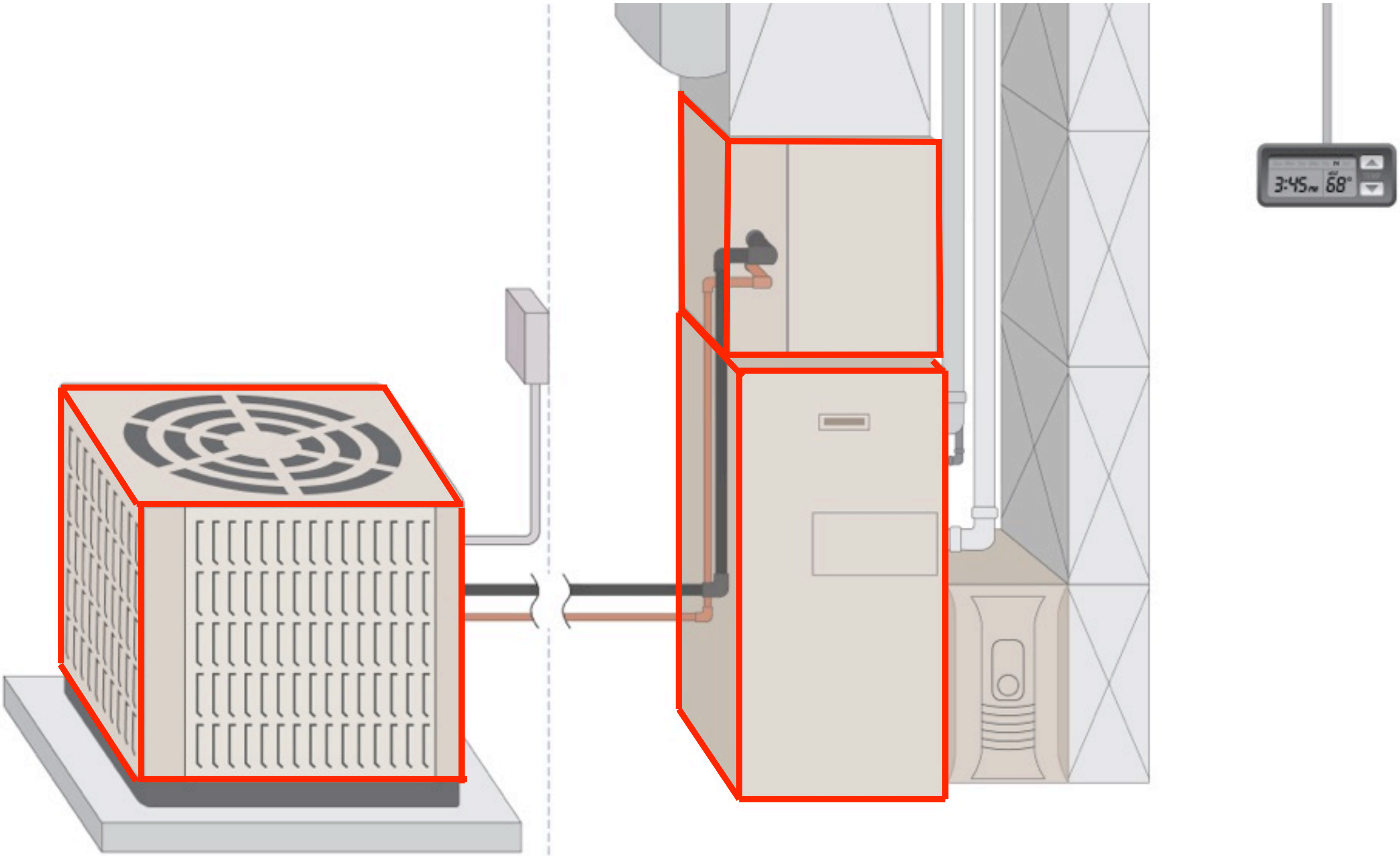
A. 15%
B. 30%
C. 60%
D. 95%

Questions about furnaces?

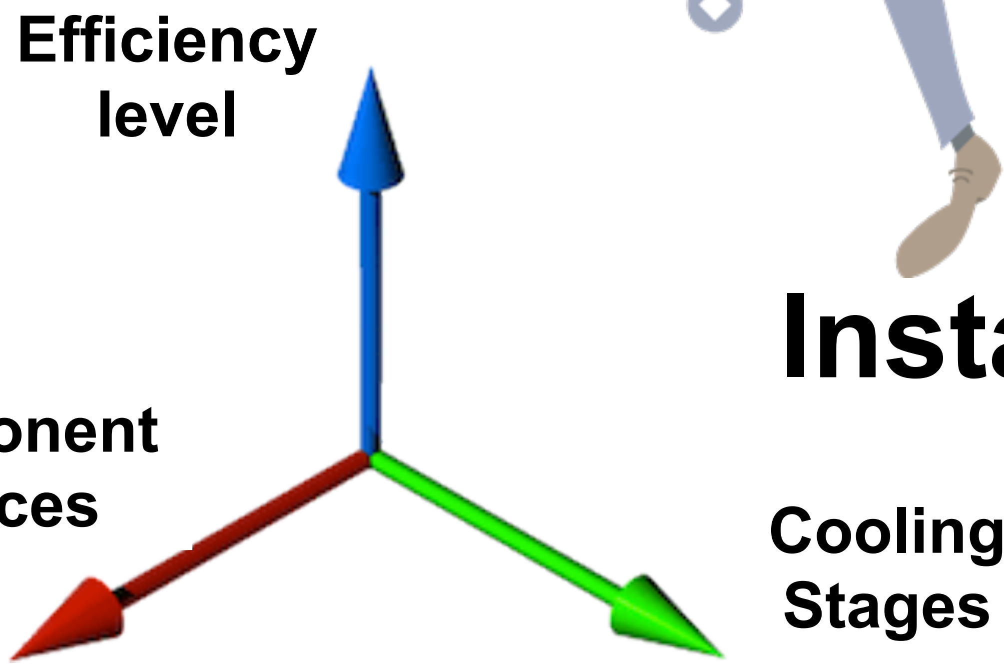
Air conditioner




3:45
68°


3:45
68°

Installation?



Seasonal Energy Efficiency Ratio

SEER

How many hours per year does the average central air conditioner in Minneapolis run?

A. …120 hours
B. …240 hours
C. …325 hours
D. …450 hours
E. …630 hours

How many hours per year does the average central air conditioner in Minneapolis run?

A. …120 hours
B. …240 hours
C. …325 hours
D. …450 hours
E. …630 hours

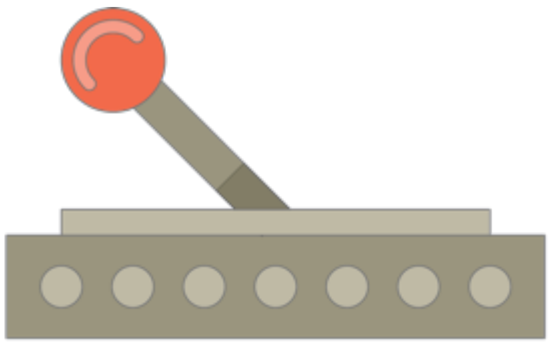
SEER upgrade savings

SEER	Savings (vs SEER 13)
13	$0
14	$20
15	$35
16	$50
17	$65
18	$75

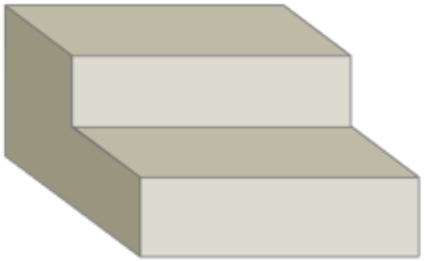
(2.25 tons capacity, 325 annual hours, 13 cents/kWh)

Cooling stages

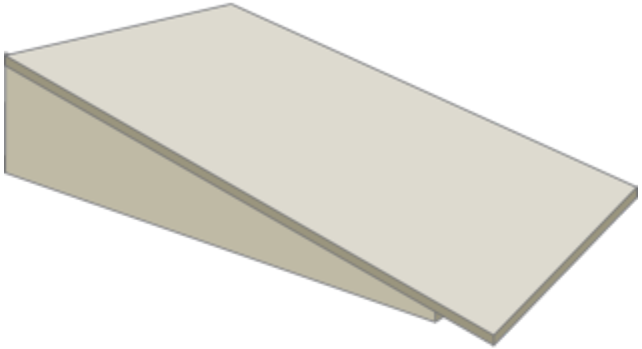
Single-stage



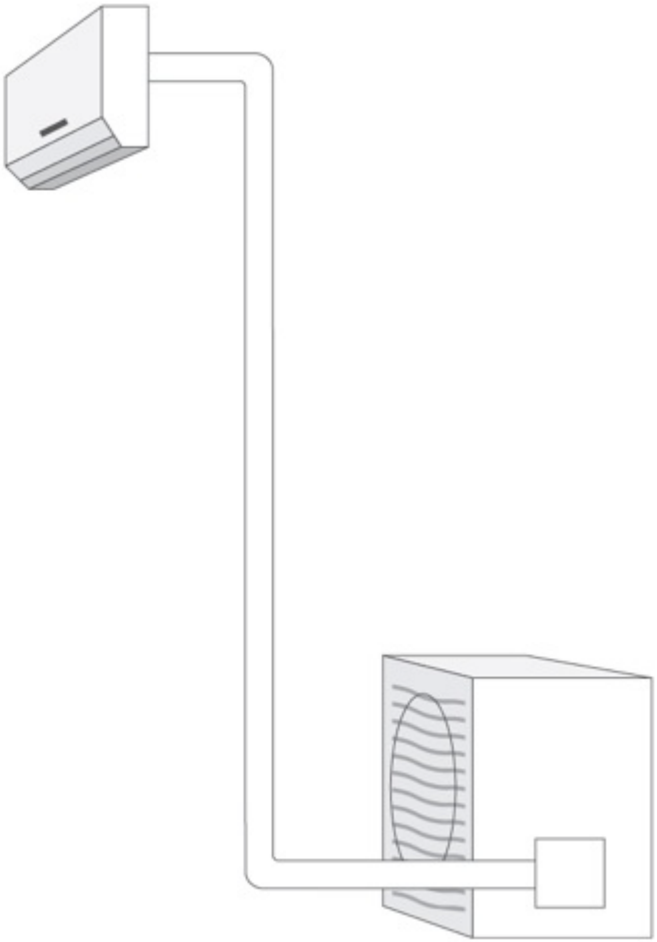
Two-stage



Modulating



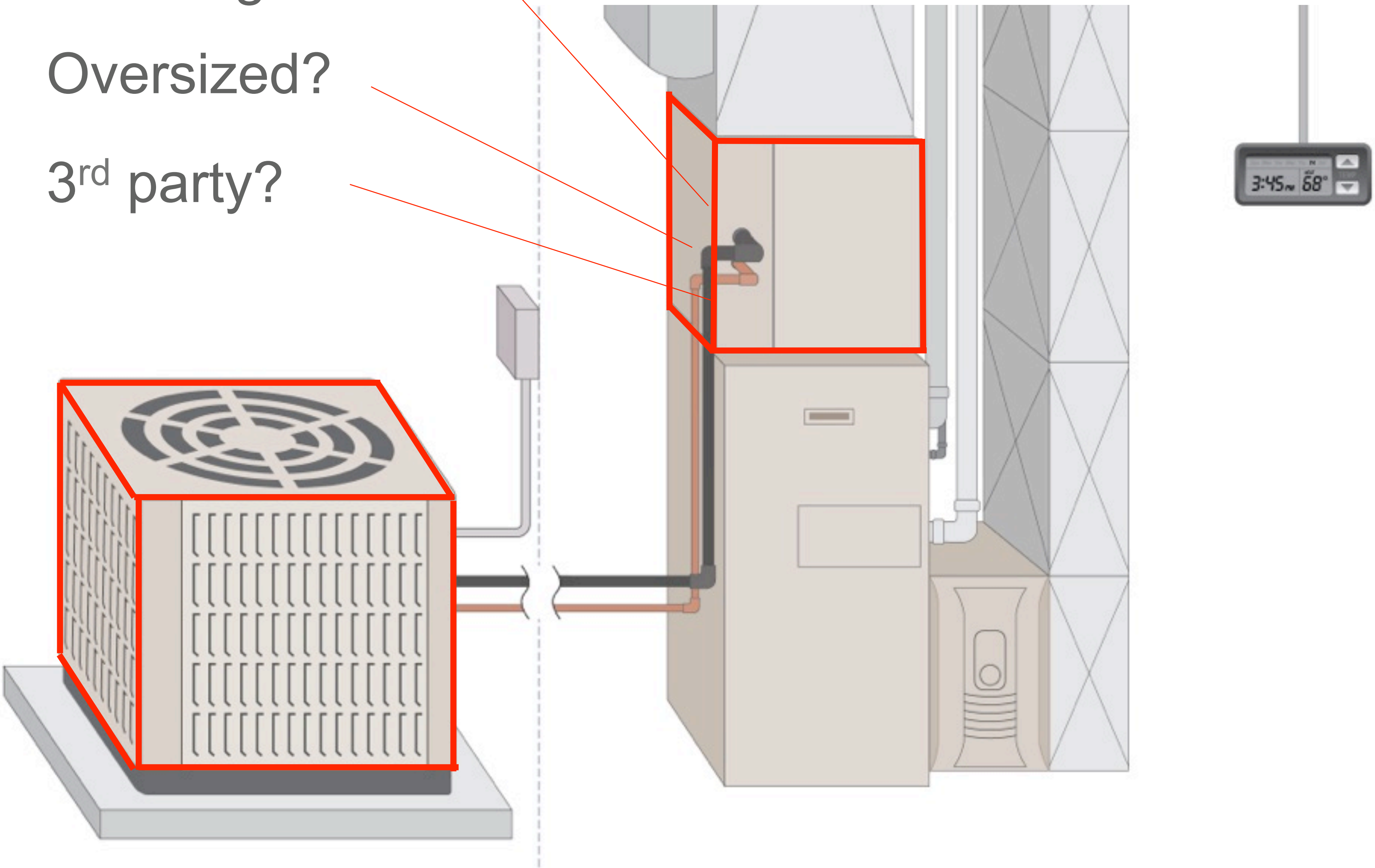
Mini Split



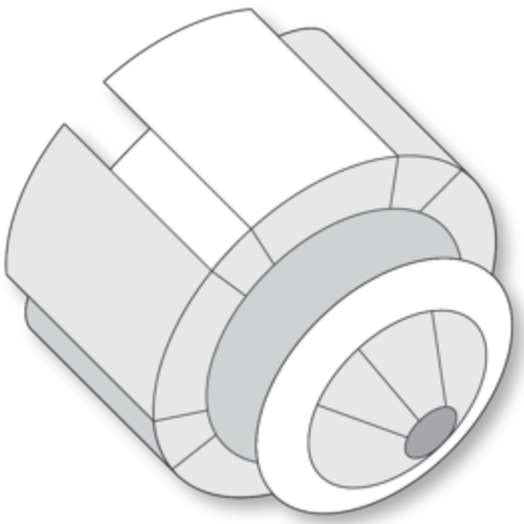
Metering device?

Oversized?

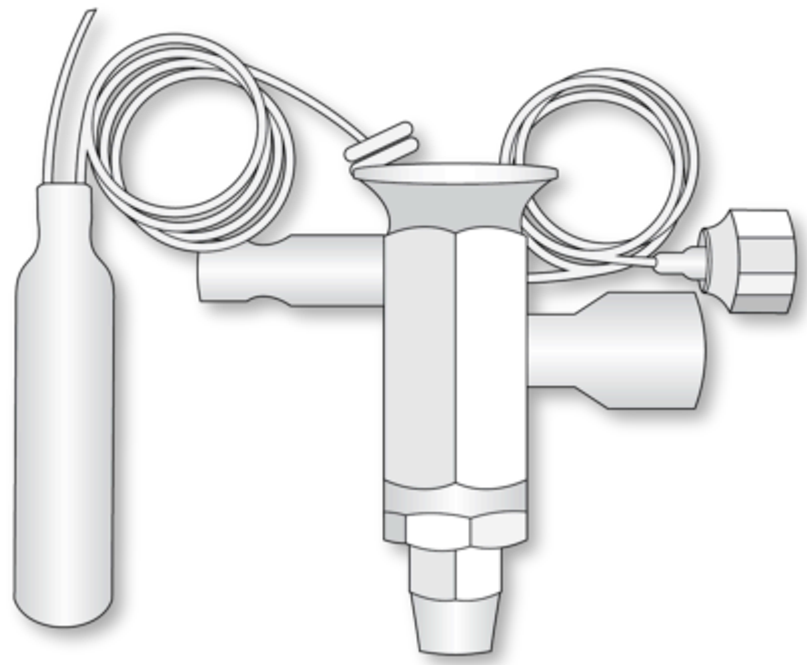
3rd party?



Metering device



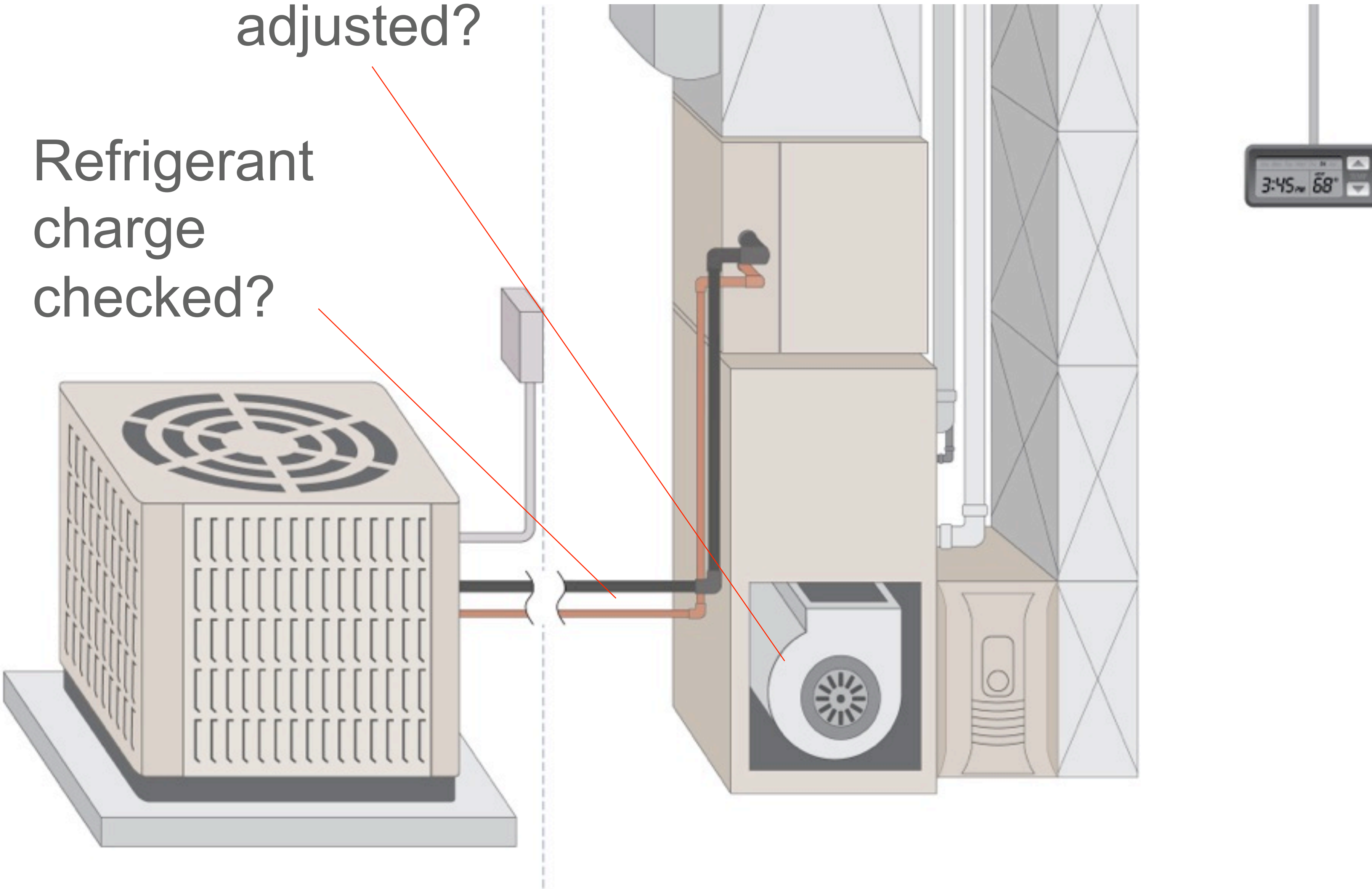
Fixed orifice



Thermostatic expansion valve (TXV)

Airflow adjusted?

Refrigerant charge checked?



What percent of MN A/C systems have improper refrigerant charge or airflow?

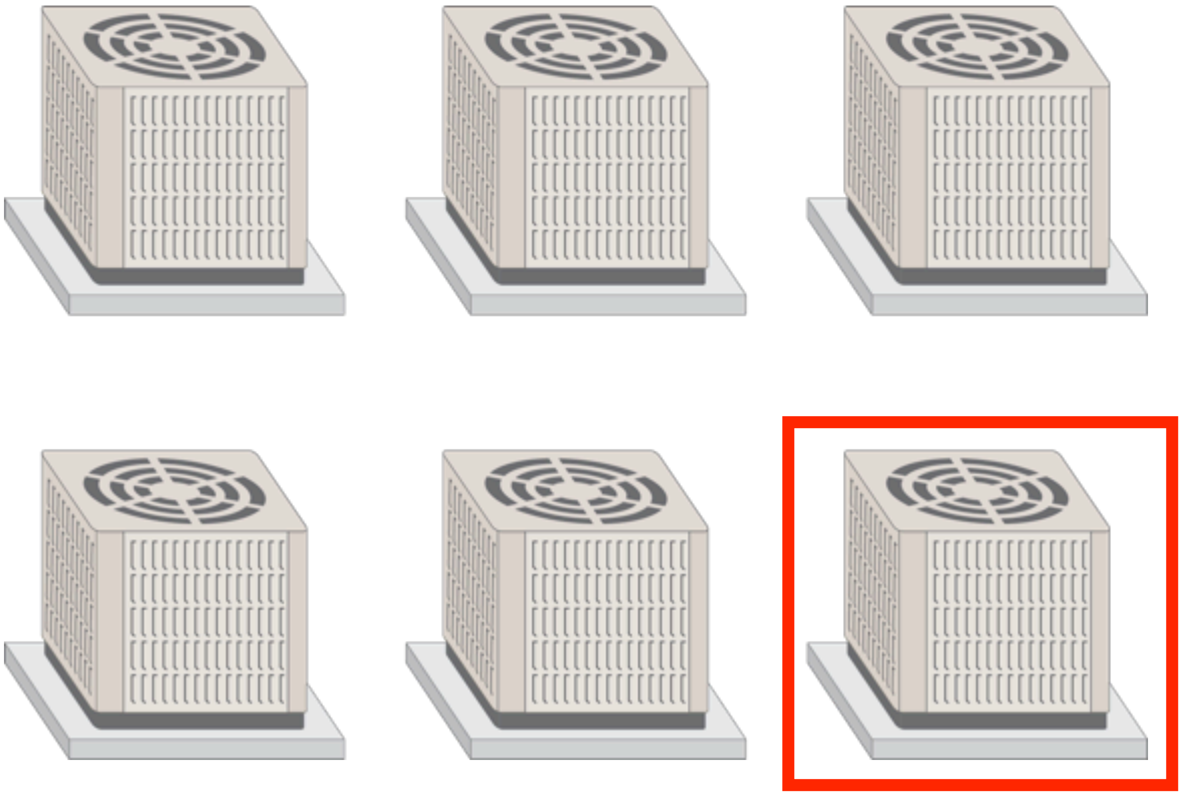
A. …10%
B. …20%
C. …40%
D. …60%
E. …85%

What percent of MN A/C systems have improper refrigerant charge or airflow?

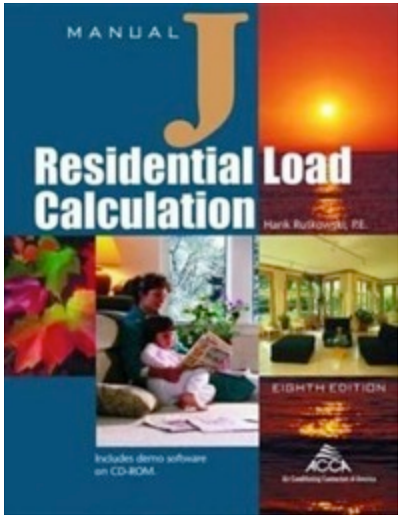
A. …10%
B. …20%
C. …40%
D. …60%
E. …85%

Typical savings: 10%

One in six can save 25%+



A/C sizing



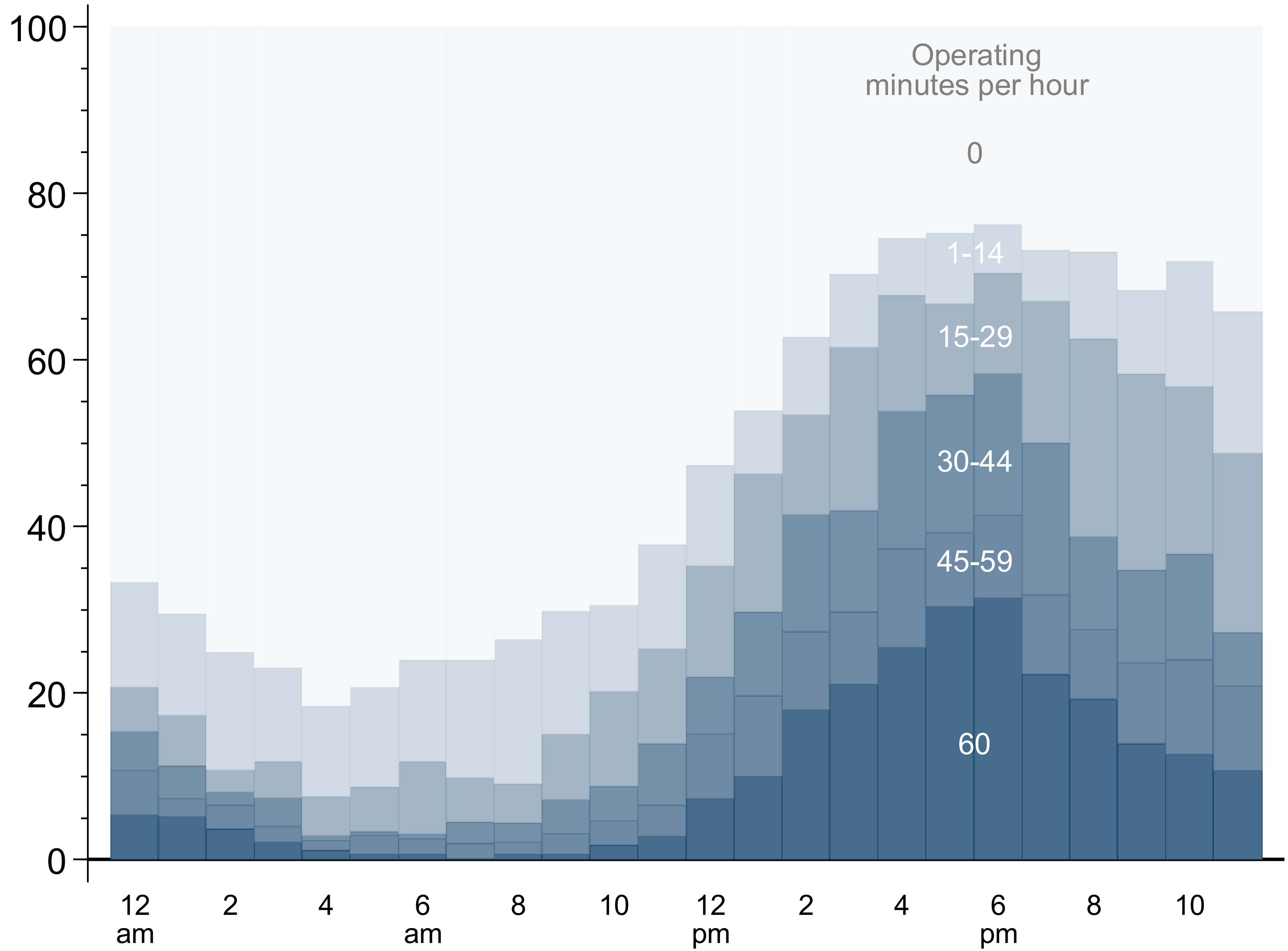
2 tons

2.5 tons

3 tons

What is a “ton” of cooling?

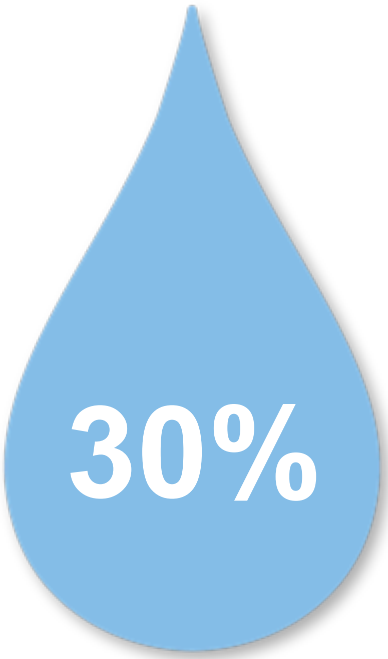
12,000 Btuh



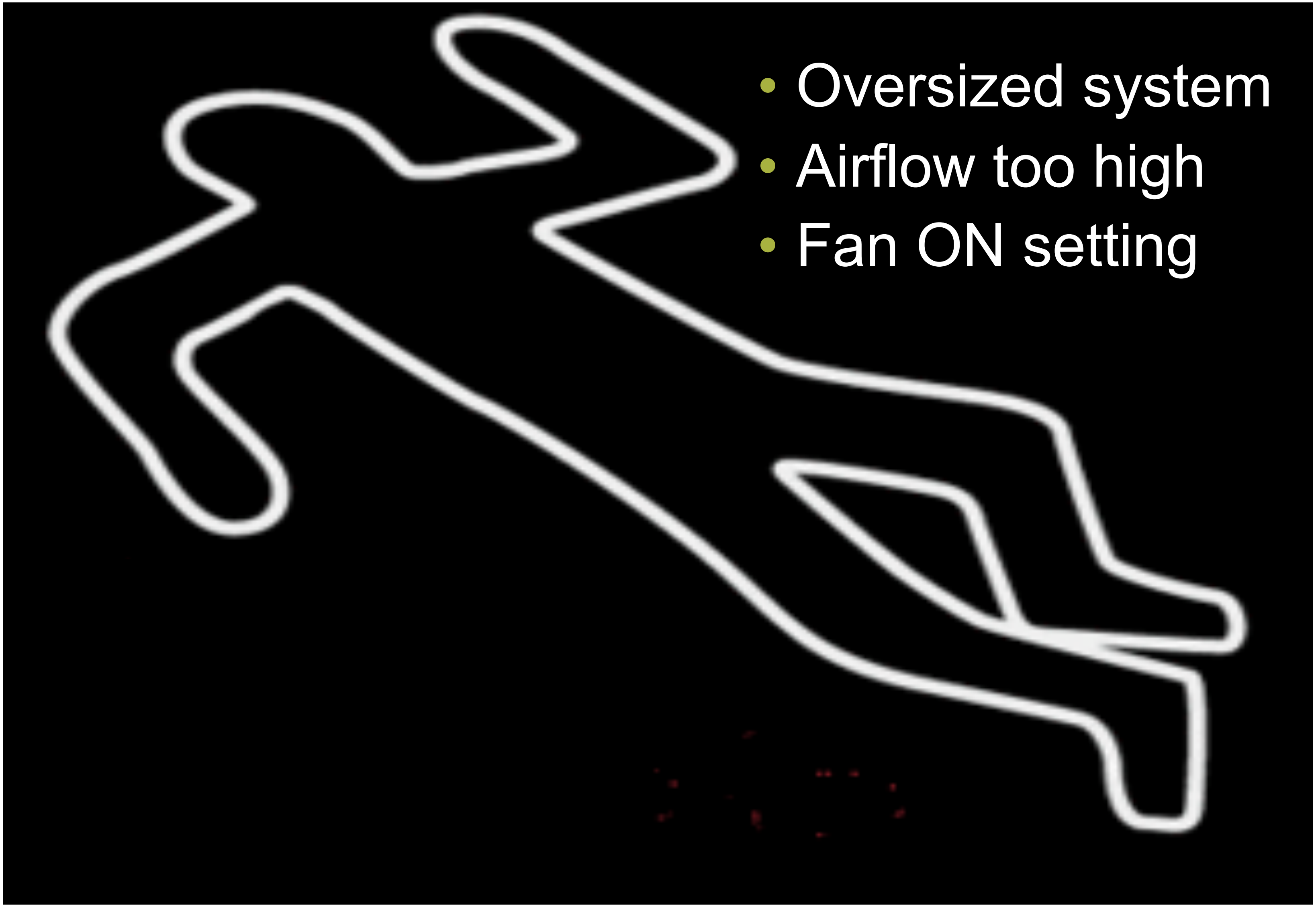
100
80
60
40
20
0
Operating
minutes per hour
0
1-14
15-29
30-44
45-59
60
12
am
2
4
6
am
8
10
12
pm
2
4
6
pm
8
10

The two jobs of an air conditioner

70%

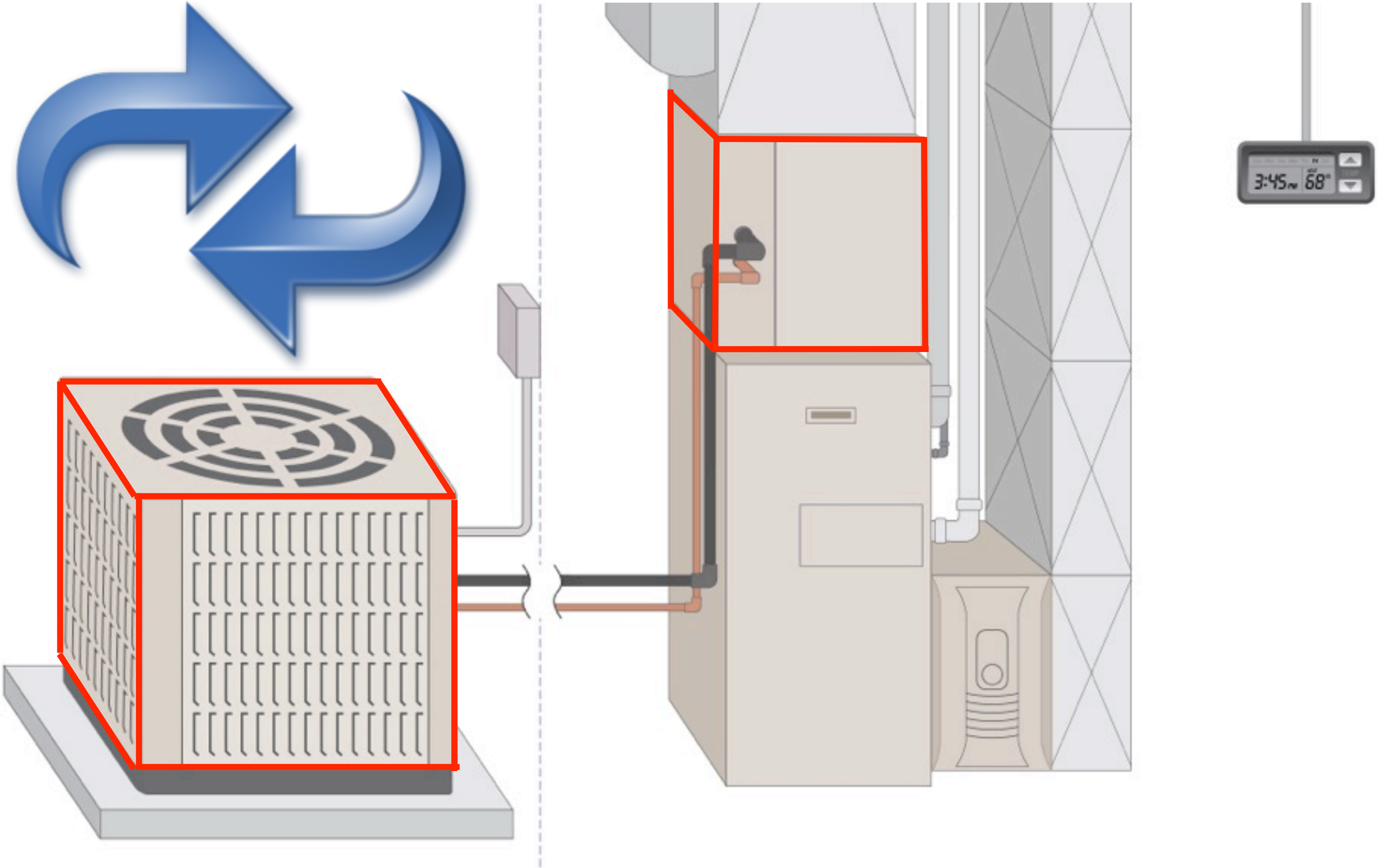


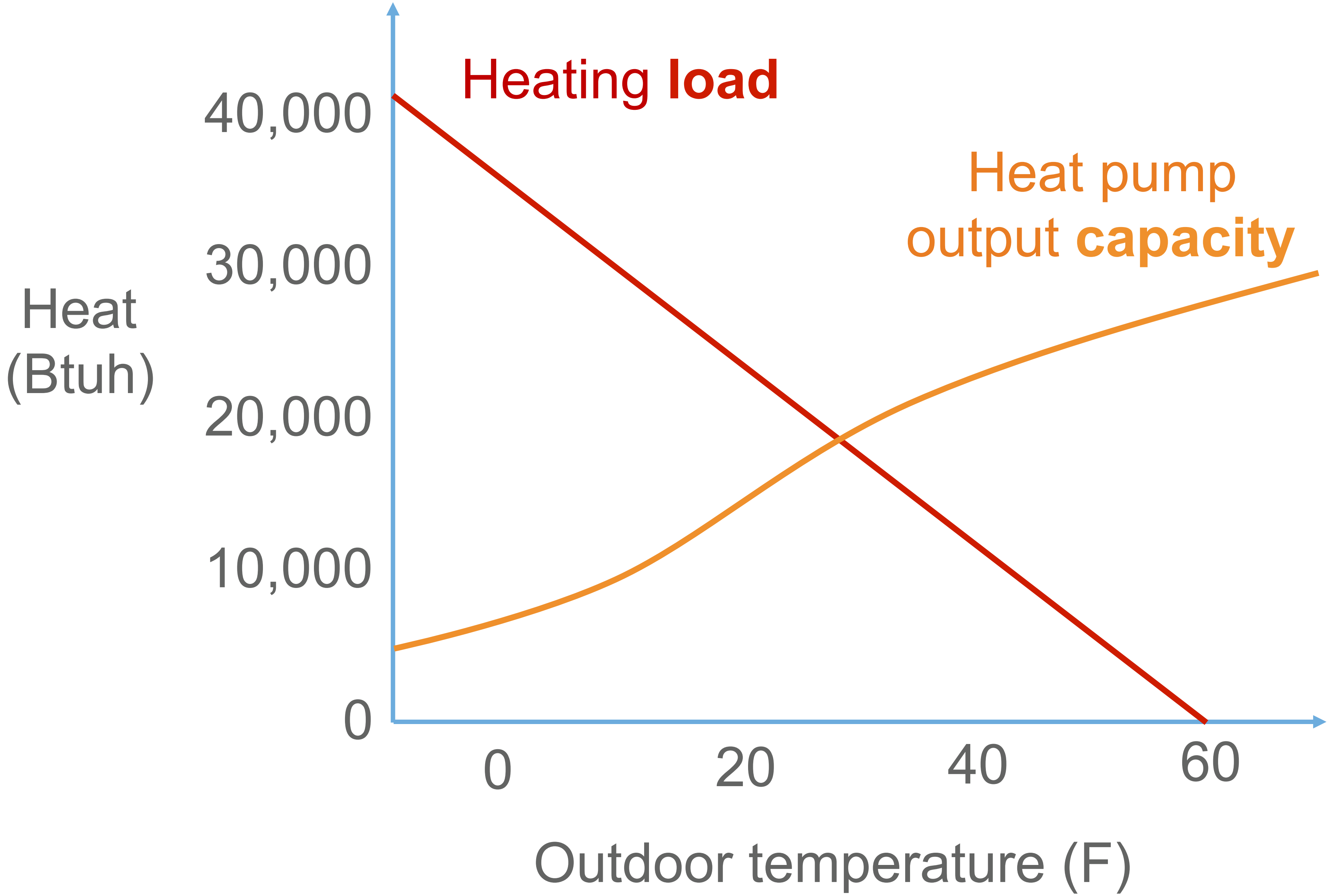
The three dehumidification killers



Questions about air conditioners?

What about heat pumps?




Heating **load**
Heat pump output **capacity**
40,000
30,000
20,000
10,000
0
Heat (Btuh)
0
20
40
60
Outdoor temperature (F)

Heating system		Cost
Natural gas furnace (condensing)		$1.00
Propane furnace (condensing)		$1.80
Baseboard electric		$4.20
Heat pump	@50F	$1.20
	@40F	$1.40
	@30F	$1.60

For:

natural gas at 75 cents per therm
propane at $1.50 per gallon
electricity at 13 cents per kWh

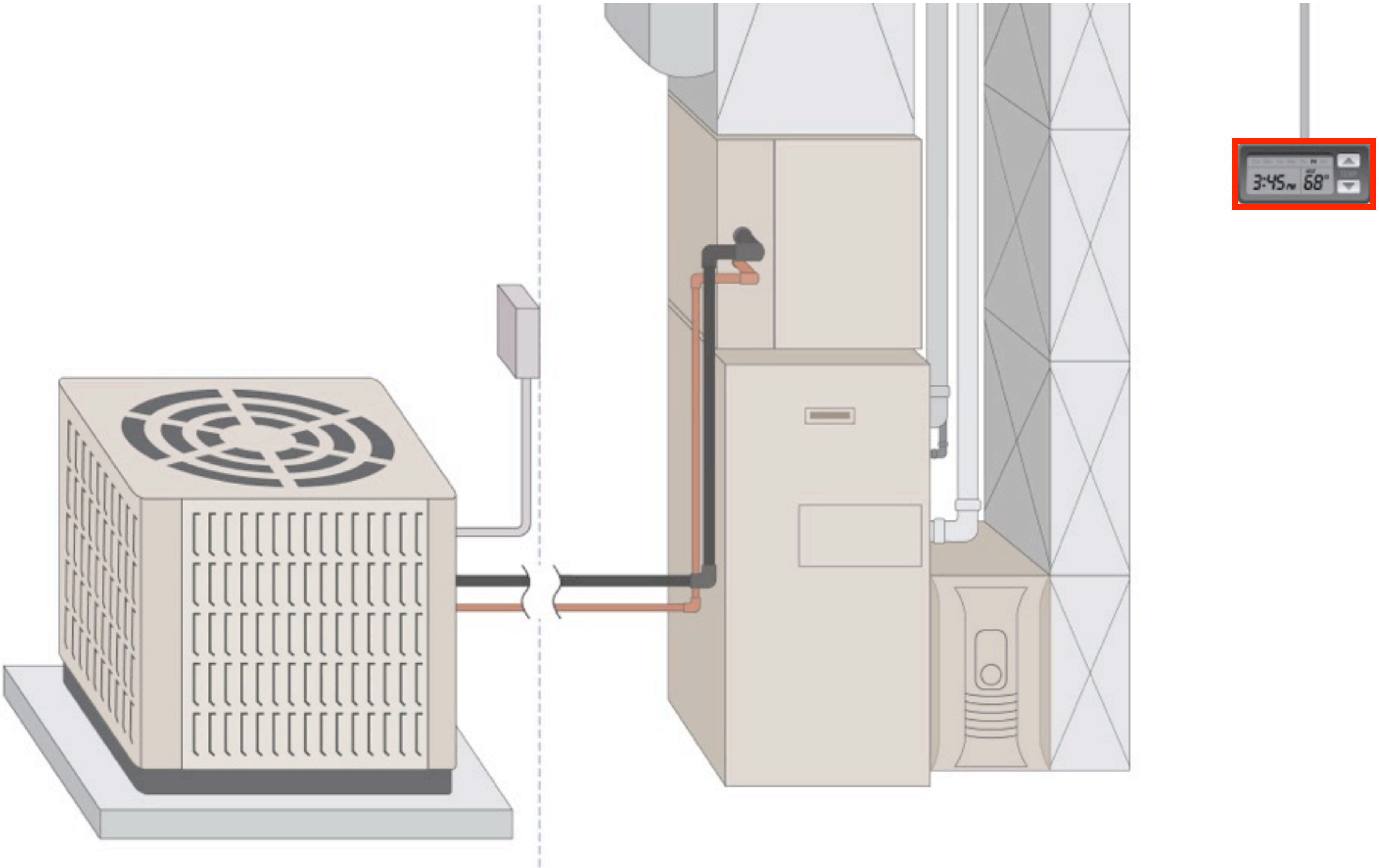
Heating system		Cost
Natural gas furnace (condensing)		$1.00
Propane furnace (condensing)		$1.80
Baseboard electric		$4.20
Heat pump	@50F	~~$1.20~~ **$0.55**
	@40F	~~$1.40~~ **$0.65**
	@30F	~~$1.60~~ **$0.75**

For:

natural gas at 75 cents per therm
propane at $1.50 per gallon
electricity at ~~13~~ **6** cents per kWh

Questions about heat pumps?

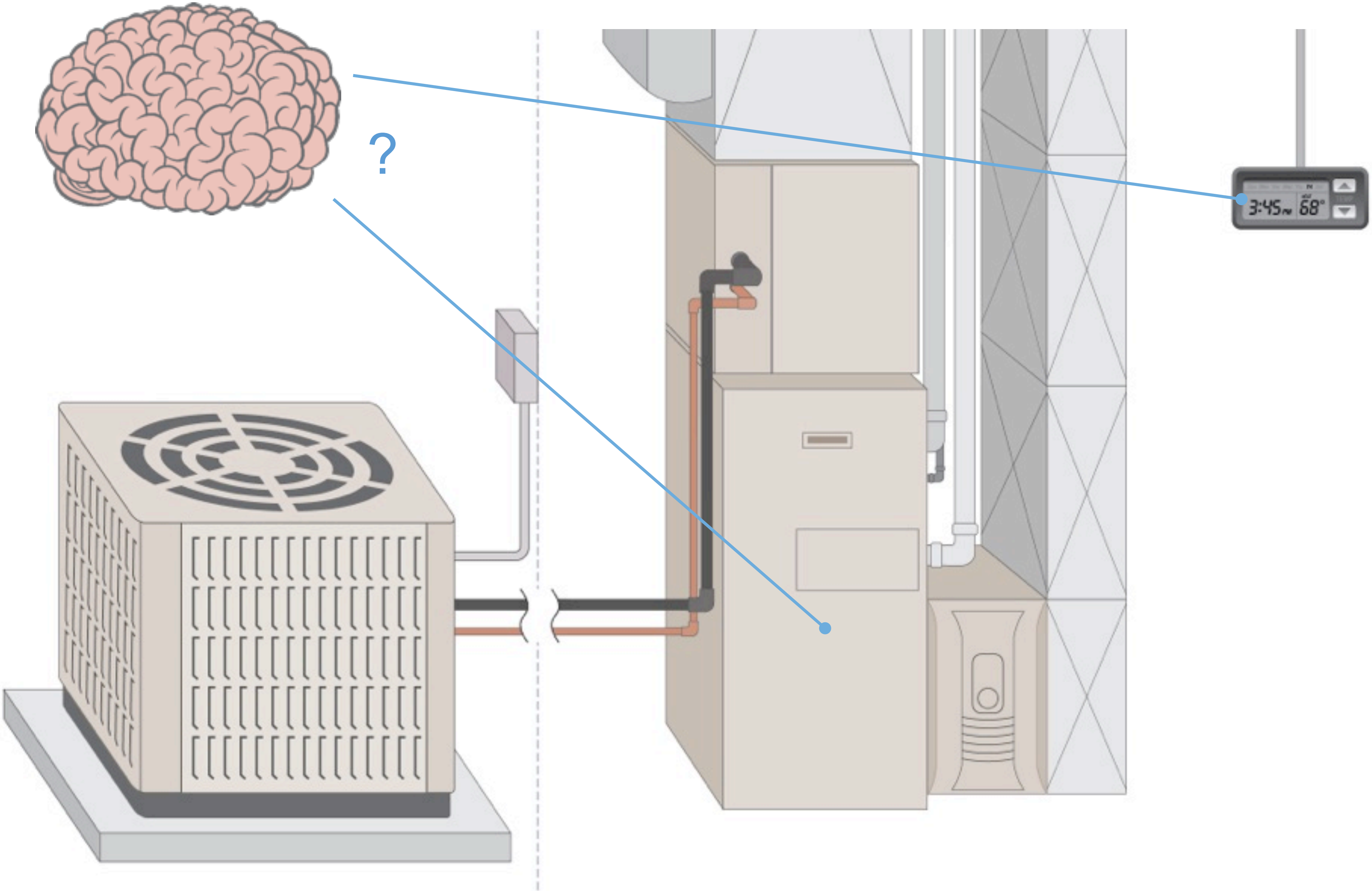
Thermostat



Lots of options

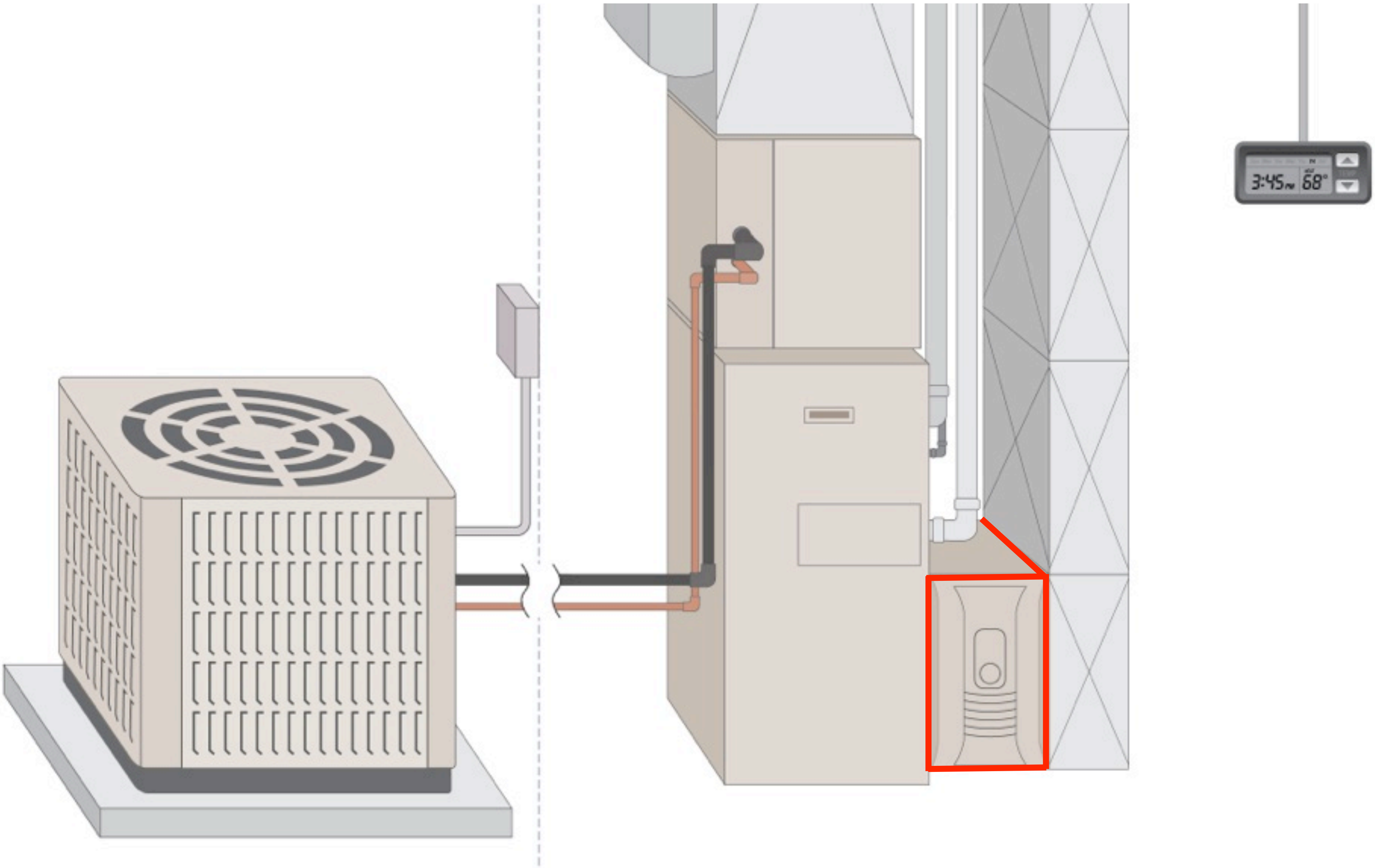
- Programmable?
- Connected?
- "Smart"?
- Proprietary?

Where's the brain?



Questions about thermostats?

Filter



Options

- 1” disposable
- 4” disposable
- Electrostatic

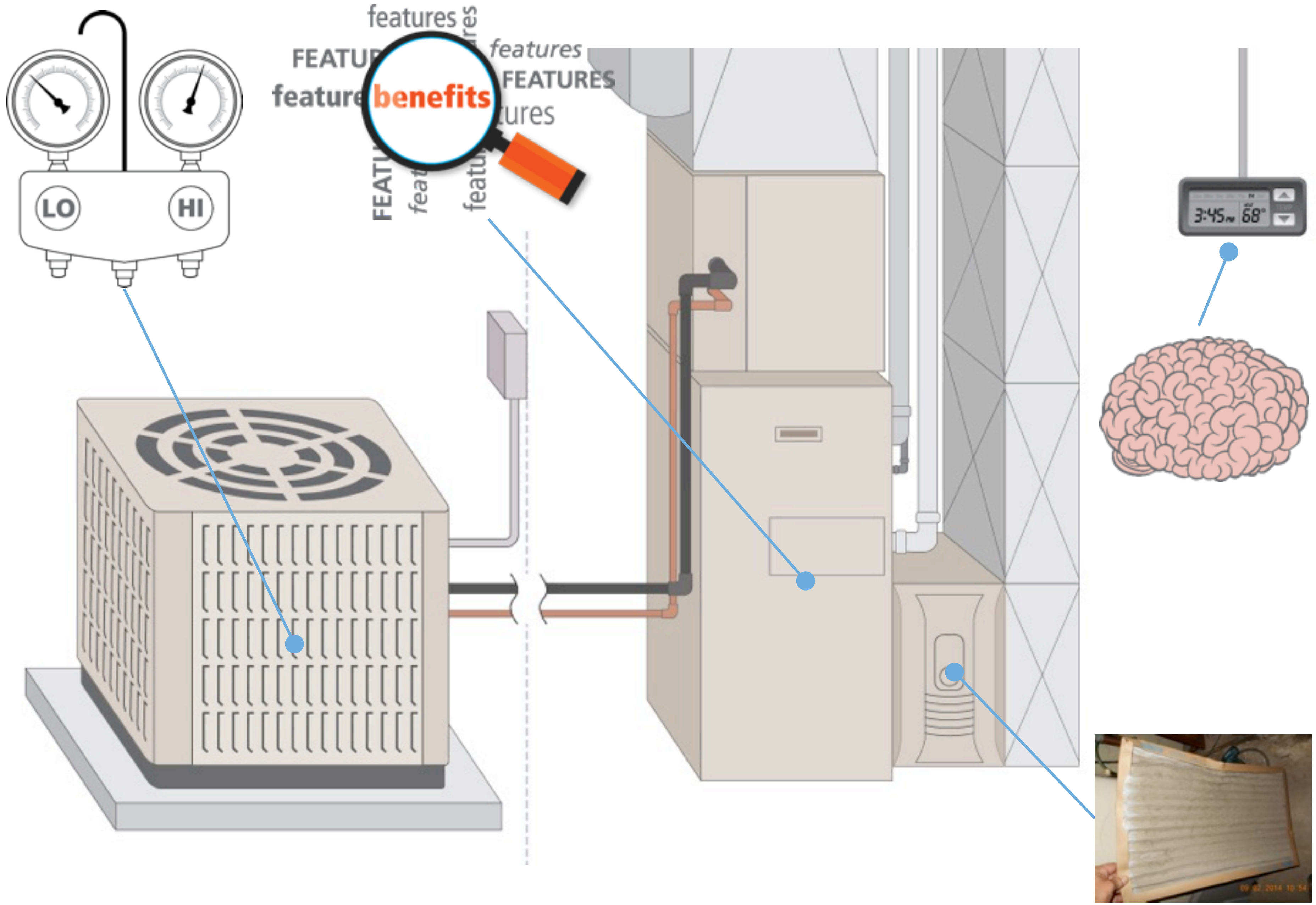
- Filtering efficiency

Minimum Efficiency Reporting Value

MERV

Recipe for disaster

Questions about filters?


LO
HI
features
FEATURES
benefits
3:45
68°

Thank you!

spigg@seventhwave.org