### Unitary HVAC Condensing Furnace

###### Description

Condensing furnaces recover energy in combustion exhaust flue gasses that would otherwise simply be vented to the atmosphere, making them more efficient than non-condensing furnaces. This measure applies to a constant volume (CV) DOAS, MUAS, or any unitary HVAC system that is utilizing an indirect gas fired process to heat 100% OA to provide ventilation or make-up air to C&I building spaces. The unitary package must contain an indirect gas-fired, warm air furnace section, but the unitary package can be with or without an electric air conditioning section. The unitary package can be either a single package or split system that is applied indoors (non-weatherized) or outdoors (weatherized).

This measure excludes demand control ventilation, condensing unit heaters, and high efficiency (condensing) furnaces with annual fuel utilization efficiency (AFUE) ratings (for furnaces with less than 225,000 Btu/hr input capacity), which are covered by other measures for the C&I sector in the Technical Reference Manual (TRM)**[[1]](#footnote-1)**.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

###### Definition of Efficient Equipment

To qualify for this measure, the efficient unitary equipment must contain a condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 90% or higher, or alternatively, the unitary package must have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.90 or higher. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces[[2]](#footnote-2). The furnace must be vented and condensate disposed of in accordance with the equipment manufacturer installation instructions and applicable codes.

###### Definition of Baseline Equipment

The baseline equipment is expected to be unitary equipment that contains a non-condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 80%, or alternatively, the unitary package will have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.80. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces.

Note the current Department of Energy (DOE) federal minimum efficiency standard is 80% for 225,000 Btu/hr and higher input capacity furnaces per the Energy Conservation Standard for Commercial Warm Air Furnaces[[3]](#footnote-3). In the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings[[4]](#footnote-4) that minimum TE requirement is extended below 225,000 Btu/hr input capacity to require all commercial warm air furnaces and combination warm air furnace/air conditioning units to meet the minimum 80% TE.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years, which is consistent with the established TRM measure life for single-package and split system unitary air conditioners, since in colder climates these unitary packages typically contain a gas-fired, warm air furnace section, with an electric air conditioning section.

###### Deemed Measure Cost

The actual incremental equipment and installation costs should be used, if available. If not, the incremental cost of $5.42 per 1000 Btu/hr of output capacity should be used for the condensing furnace equipment (as part of a unitary package) and its installation (including the combustion condensate drainage and disposal system). This incremental cost is from the DOE Technical Support Document for the Notice of Proposed Rulemaking (NOPR) for the Commercial Warm Air Furnace Standard[[5]](#footnote-5). Per the DOE documentation, it is based on their representative 250,000 Btu/hr input capacity furnace at a 92% TE.

###### Loadshape

Loadshape C23 - Commercial Ventilation

###### Coincidence Factor

The coincidence factor is assumed to be 1.0 – that is, building ventilation will always be provided during peak periods.

**Algorithm**

###### Calculation of Savings

The following methodology provides formulas for estimating gas heating savings associated with condensing furnaces in unitary HVAC packages when applied as a constant volume dedicated outside air system (DOAS), make-up air system (MUAS), or any RTU that is indirectly heating 100% outside air (OA). These types of HVAC systems typically run continuously during the HVAC operating schedule to provide building ventilation and maintain indoor air quality or to compensate for exhaust and maintain neutral or slightly positive building pressurization. The algorithm estimates the gas use reduction resulting from utilizing condensing heating of 90% or higher thermal efficiency (TE) in place of the federal minimum TE of 80% (or other user defined baseline TE) for commercial warm air furnaces.

The methodology provides a representative group of operating schedules for the market sector applications highlighted earlier based on DOE commercial reference building models[[6]](#footnote-6). Heating loads during the operating schedule are determined based on hourly differences between a range of supply air (SA) heated to temperatures and the OA temperature using Typical Meteorological Year (TMY3)[[7]](#footnote-7) weather data. These hourly heating loads are generated for all hours when the OA temperature is below the base temperature of 55 oF for heating in C&I settings per the TRM. To accommodate the variability in heating base temperatures in C&I settings, these hourly heating loads are also generated for base temperatures of 45 oF and 65 oF for heating. The hourly heating loads are then summed for the entire year. The annual heating loads are calculated in this manner for the climate zone 2 weather station (Chicago O’Hare Airport), which is then normalized to its National Climatic Data Center (NCDC)[[8]](#footnote-8) 30 year (1981-2010) weather average by multiplying by the heating degree day (HDD) ratio of the NCDC/TRM HDD55 over the TMY3 HDD55 (HDD at base temperature of 55 oF), and likewise for the annual heating loads for HDD45 (HDD at base temperature of 45 oF) and HDD65 (HDD at base temperature of 65 oF), using the values in Table 1 and Table 2. Since detailed hourly weather data is not available for all 5 of the TRM climate zone weather stations, the annual heating loads for the other climate zones are determined by multiplying the climate zone 2 annual heating loads by the ratio of the other climate zone NCDC HDD over the climate zone 2 NCDC HDD, using the values in Table 1.

These annual heating loads on a per unit airflow basis are then used in conjunction with the actual airflow of the 100% OA system and its condensing efficiency to calculate the gas heating savings versus the baseline (non-condensing) heating efficiency. This measure results in additional electric use by the unitary HVAC package due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

Table 1. NCDC/TRM HDD Values for All Climate Zones

|  |  |  |  |
| --- | --- | --- | --- |
| Climate Zone -  Weather Station/City | NCDC 30 Year Average HDD458 | NCDC 30 Year Average HDD551,8 | NCDC 30 Year Average HDD658 |
| 1 - Rockford AP / Rockford | 2495 | 4272 | 6569 |
| 2 - Chicago O'Hare AP / Chicago | 2263 | 4029 | 6340 |
| 3 - Springfield #2 / Springfield | 1812 | 3406 | 5495 |
| 4 - Belleville SIU RSCH / Belleville | 1197 | 2515 | 4379 |
| 5 - Carbondale Southern IL AP / Marion | 1183 | 2546 | 4477 |

Table 2. TMY3 HDD Values for Climate Zone 2

|  |  |  |  |
| --- | --- | --- | --- |
| Climate Zone -  Weather Station/City | TMY3 HDD457 | TMY3 HDD557 | TMY3 HDD657 |
| 2 - Chicago O'Hare AP / Chicago | 2422 | 4188 | 6497 |

###### Electric Energy Savings

As noted previously, this measure results in additional SA fan electric use by the unitary HVAC system due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

∆kWh = - (tFAN \* cfm \* P) / (FAN/MOTOR \* 8520)

Where:

tFAN = annual fan runtime (hr), refer to Tables 1 through 4

cfm = airflow (cfm), use actual or rated system airflow

P = incremental pressure drop (inch W.G.), assume 0.15 if actual value not known

FAN/MOTOR = combined fan and motor efficiency, assume 0.60 if actual value not known

8520 = conversion factor (fan horsepower – HP – calculation constant of 6356 for standard air conditions adjusted by 1 HP = 0.746 kW, or 6356/ 0.746 = 8520 for this kW calculation)

**EXAMPLE:**

For a “big box” retail store operating 24 hours a day and 7 days a week (8760 hours per year) with a 5000 cfm DOAS that has an incremental pressure drop of 0.15 inch W.G. and a combined fan and motor efficiency of 0.6 has annual kWh savings of:

**∆kWh** = - (tFAN \* cfm \* P) / (FAN/MOTOR \* 8520)

= - (8760 \* 5000 \* 0.15) / (0.6 \* 8520)

= **- 1285 kWh**

###### Summer Coincident Peak Demand Savings

The additional SA fan electric use by the unitary HVAC system will typically result in a modest electric demand increase.

kW = (kWh / tFAN) \* CF

Where:

CF = 1.0

**EXAMPLE:**

Continuing the previous example:

**∆kW** = (kWh / tFAN) \* CF

= (- 1285 / 8760) \* 1.0

= **- 0.15 kW**

###### Natural Gas Energy Savings

∆Therms = [QOA \* cfm \* (1/TENC - 1/TEC)]/ 100,000

Where:

QOA = annual outside air (OA) heating load per cfm of OA (Btu/cfm)

First, select the most representative operating schedule for the application from among the four (4) scenarios listed below and its set of three (3) applicable tables. Second, select the table in that set with the most representative HDD base temperature – the base temperature for OA below which heating is required. If that base temperature is not readily determined, select the TRM default base temperature of 55 oF (HDD55) for heating in C&I settings. Third, select the climate zone within that table. Fourth, select an appropriate heated to supply air (SA) temperature within that table. Use the resulting QOA value, with linear interpolation allowed between SA temperatures.

The four (4) tables are indicative of the following building applications and operating schedules:

The four (4) scenarios available are indicative of the following building applications and operating schedules:

1. 24 hour a day and 7 day a week (24/7) operation, with HVAC operating schedule of 8760 hours per year, typical of large retail stores with DOAS, hotel/multifamily buildings with corridor MUAS, and healthcare facilities with DOAS. Use Table 3 through Table 5.
2. 6:00 AM to 1:00 AM every day operation, with HVAC operating schedule of 7300 hours per year, typical of full service and quick service restaurants with kitchen MUAS. Use Table 6 through Table 8.
3. 7:00 AM to 9:00 PM Monday-Friday, 7:00 AM to 10:00 PM Saturday, and 9:00 AM to 7:00 PM Sunday operations, with HVAC operating schedule of 5266 hours per year, typical of non-24/7 retail stores with DOAS. Use Table 9 through Table 11.
4. 7:00 AM to 9:00 PM Monday-Friday operation, with HVAC operating schedule of 3911 hours per year, typical of school buildings with DOAS. Use Table 12 through Table 14.

TENC = non-condensing thermal efficiency (TE), use federal minimum TE of 80% (0.80) or actual TE if known

TEC = condensing thermal efficiency (TE), use actual TE or if unknown assume 90% (0.90)

100,000 = conversion factor (1 therm = 100,000 Btu)

**EXAMPLE:**

Continuing the previous example, for a climate zone 2 (Chicago O'Hare AP / Chicago) application using a 90% TE condensing DOAS with a supply air temperature from the DOAS of 95 oF:

**∆Therms** = [QOA \* cfm \* (1/TENC - 1/TEC)]/ 100,000

= 303,268 \* 5,000 \* (1/0.80 – 1/0.90)/100,000

= **2,106 therms**

8760 Hour Annual Operation Scenario

Table 3. 8760 Hour Annual Operation Scenario for HDD45

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 8760 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 189,343 | 230,897 | 272,451 | 314,004 |
| 2 - Chicago O'Hare AP / Chicago | 171,737 | 209,427 | 247,116 | 284,806 |
| 3 - Springfield #2 / Springfield | 137,511 | 167,689 | 197,868 | 228,046 |
| 4 - Belleville SIU RSCH / Belleville | 90,839 | 110,775 | 130,711 | 150,647 |
| 5 - Carbondale Southern IL AP / Marion | 89,777 | 109,479 | 129,182 | 148,885 |

Table 4. 8760 Hour Annual Operation Scenario for HDD55

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 8760 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 216,145 | 268,852 | 321,559 | 374,266 |
| 2 - Chicago O'Hare AP / Chicago | 203,850 | 253,559 | 303,268 | 352,977 |
| 3 - Springfield #2 / Springfield | 172,329 | 214,351 | 256,374 | 298,397 |
| 4 - Belleville SIU RSCH / Belleville | 127,248 | 158,278 | 189,307 | 220,337 |
| 5 - Carbondale Southern IL AP / Marion | 128,817 | 160,229 | 191,641 | 223,053 |

Table 5. 8760 Hour Annual Operation Scenario for HDD65

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 8760 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 239,158 | 308,050 | 376,942 | 445,834 |
| 2 - Chicago O'Hare AP / Chicago | 230,820 | 297,311 | 363,802 | 430,292 |
| 3 - Springfield #2 / Springfield | 200,056 | 257,685 | 315,314 | 372,943 |
| 4 - Belleville SIU RSCH / Belleville | 159,426 | 205,351 | 251,276 | 297,200 |
| 5 - Carbondale Southern IL AP / Marion | 162,994 | 209,947 | 256,899 | 303,852 |

7300 Hour Annual Operation Scenario

Table 6. 7300 Hour Annual Operation Scenario for HDD45

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 7300 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 151,914 | 185,369 | 218,823 | 252,278 |
| 2 - Chicago O'Hare AP / Chicago | 137,788 | 168,132 | 198,476 | 228,819 |
| 3 - Springfield #2 / Springfield | 110,328 | 134,624 | 158,921 | 183,217 |
| 4 - Belleville SIU RSCH / Belleville | 72,882 | 88,932 | 104,982 | 121,033 |
| 5 - Carbondale Southern IL AP / Marion | 72,030 | 87,892 | 103,755 | 119,617 |

Table 7. 7300 Hour Annual Operation Scenario for HDD55

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 7300 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 173,511 | 215,950 | 258,389 | 300,828 |
| 2 - Chicago O'Hare AP / Chicago | 163,641 | 203,666 | 243,691 | 283,716 |
| 3 - Springfield #2 / Springfield | 138,338 | 172,174 | 206,010 | 239,846 |
| 4 - Belleville SIU RSCH / Belleville | 102,149 | 127,133 | 152,118 | 177,103 |
| 5 - Carbondale Southern IL AP / Marion | 103,408 | 128,701 | 153,993 | 179,286 |

Table 8. 7300 Hour Annual Operation Scenario for HDD65

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 7300 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 191,803 | 247,046 | 302,288 | 357,531 |
| 2 - Chicago O'Hare AP / Chicago | 185,117 | 238,434 | 291,750 | 345,067 |
| 3 - Springfield #2 / Springfield | 160,444 | 206,655 | 252,866 | 299,076 |
| 4 - Belleville SIU RSCH / Belleville | 127,859 | 164,685 | 201,510 | 238,336 |
| 5 - Carbondale Southern IL AP / Marion | 130,720 | 168,370 | 206,020 | 243,670 |

5266 Hour Annual Operation Scenario

Table 9. 5266 Hour Annual Operation Scenario for HDD45

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 5266 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 104,175 | 127,350 | 150,524 | 173,699 |
| 2 - Chicago O'Hare AP / Chicago | 94,488 | 115,508 | 136,527 | 157,547 |
| 3 - Springfield #2 / Springfield | 75,657 | 92,488 | 109,319 | 126,149 |
| 4 - Belleville SIU RSCH / Belleville | 49,979 | 61,097 | 72,215 | 83,334 |
| 5 - Carbondale Southern IL AP / Marion | 49,394 | 60,383 | 71,371 | 82,359 |

Table 10. 5266 Hour Annual Operation Scenario for HDD55

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 5266 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 118,320 | 147,406 | 176,492 | 205,578 |
| 2 - Chicago O'Hare AP / Chicago | 111,590 | 139,021 | 166,452 | 193,884 |
| 3 - Springfield #2 / Springfield | 94,335 | 117,524 | 140,714 | 163,904 |
| 4 - Belleville SIU RSCH / Belleville | 69,657 | 86,780 | 103,904 | 121,027 |
| 5 - Carbondale Southern IL AP / Marion | 70,516 | 87,850 | 105,184 | 122,519 |

Table 11. 5266 Hour Annual Operation Scenario for HDD65

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 5266 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 130,903 | 168,718 | 206,532 | 244,347 |
| 2 - Chicago O'Hare AP / Chicago | 126,339 | 162,836 | 199,333 | 235,829 |
| 3 - Springfield #2 / Springfield | 109,501 | 141,133 | 172,765 | 204,398 |
| 4 - Belleville SIU RSCH / Belleville | 87,262 | 112,470 | 137,678 | 162,886 |
| 5 - Carbondale Southern IL AP / Marion | 89,215 | 114,987 | 140,759 | 166,531 |

3911 Hour Annual Operation Scenario

Table 12. 3911 Hour Annual Operation Scenario for HDD45

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 3911 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 75,029 | 91,729 | 108,428 | 125,128 |
| 2 - Chicago O'Hare AP / Chicago | 68,053 | 83,199 | 98,346 | 113,492 |
| 3 - Springfield #2 / Springfield | 54,490 | 66,618 | 78,746 | 90,874 |
| 4 - Belleville SIU RSCH / Belleville | 35,996 | 44,008 | 52,019 | 60,031 |
| 5 - Carbondale Southern IL AP / Marion | 35,575 | 43,493 | 51,411 | 59,329 |

Table 13. 3911 Hour Annual Operation Scenario for HDD55

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 3911 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 85,672 | 106,825 | 127,979 | 149,132 |
| 2 - Chicago O'Hare AP / Chicago | 80,799 | 100,749 | 120,699 | 140,649 |
| 3 - Springfield #2 / Springfield | 68,305 | 85,170 | 102,035 | 118,901 |
| 4 - Belleville SIU RSCH / Belleville | 50,436 | 62,890 | 75,343 | 87,797 |
| 5 - Carbondale Southern IL AP / Marion | 51,058 | 63,665 | 76,272 | 88,879 |

Table 14. 3911 Hour Annual Operation Scenario for HDD65

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Air Fan Runtime = 3911 Hours | Qoa (Annual Btu/cfm)  At Supply Air Temperature Of | | | |
| Climate Zone -  Weather Station/City | 75oF | 85oF | 95oF | 105oF |
| 1 - Rockford AP / Rockford | 95,460 | 123,294 | 151,128 | 178,963 |
| 2 - Chicago O'Hare AP / Chicago | 92,132 | 118,996 | 145,860 | 172,724 |
| 3 - Springfield #2 / Springfield | 79,853 | 103,136 | 126,420 | 149,703 |
| 4 - Belleville SIU RSCH / Belleville | 63,635 | 82,190 | 100,745 | 119,299 |
| 5 - Carbondale Southern IL AP / Marion | 65,059 | 84,029 | 102,999 | 121,969 |

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-DSFN-V01-160601

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