Multifamily Performance Program

Simulation Guidelines

For Multifamily Building Service Providers

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1 Scope and Objectives

This document contains methodologies for energy simulation and model calibration for buildings in NYSERDA's Existing Buildings Multifamily Performance Program (Program). NYSERDA Multifamily Building Solution Network (Provider) must use this guidance to evaluate energy reduction measures and to calculate the projected savings and cost effectiveness of recommendations included in the Savings Verification and Information Tool (SAV-IT). This document may be shared with the developer or property owner if requested.

This document is a resource for Providers, the Program Implementer, and NYSERDA to ensure that:

- Savings projections are realistic;
- The number of model revisions is minimized because more guidance is provided from the beginning;
- Productivity is improved because Providers do not need to individually research the assumptions for various modeled parameters or develop external calculations;
- Consistent simulation methodology is used from Provider to Provider and from building to building based on peer-reviewed protocols;
- The best energy simulation and model calibration practices are followed; and
- Modeling assumptions are within reasonable ranges.

This document will be periodically updated to cover additional topics. The sources for new material will include information from Multifamily Performance Program Technical Topics (Tech Tips).

2 General Approach

Savings from energy reduction measures shall be estimated using the *Whole Building Calibrated Simulation Approach,* as described in ASHRAE Guideline 14[1]. This approach involves modeling the existing building (creating a pre-retrofit simulation) with an approved whole building simulation software tool. The parameters for the pre-retrofit simulation are adjusted so that the projected annual energy consumption of each fuel is within the allowable margin from the annual utility bills, as described in the Model Calibration section of this document. Energy reduction measures are evaluated by making changes to the appropriate parameters of calibrated pre-retrofit simulation.

Pre-retrofit simulation inputs shall be based on results of field inspections, measurements, and as-built drawings. Where assumptions are made regarding building operating conditions, such as lighting runtime hours, interior temperature, hot water demand, etc., the assumed values shall be within the ranges provided in this document. If the provider believes that there are special conditions that dictate the use of different assumptions or approaches for a particular project, these special conditions and appropriate references shall be documented in the SAV-IT and are subject to program review.

Inputs of pre- and post-retrofit simulations must be the same unless the related component is specifically addressed by proposed measures. *All* differences between the pre- and post-retrofit model inputs must be documented in the SAV-IT, including key assumptions built into the simulation tool. For example, if U-values of the proposed windows or post-construction ACH are automatically set by the software, such as in EA QUIP, these defaults must be explicitly listed in the SAV-IT.

The same operating condition assumptions shall be used in the energy reduction measure as in the existing building, unless a change in operating conditions is specifically included as part of the measure or unless directed otherwise in this document. For example, the lighting hours of operation must be the same in pre- and post-retrofit models unless one of the proposed measures includes installation of devices that affect fixture runtime, such as occupancy sensors, timers, or photocells.

Measures that are expected to increase energy consumption must be included in the post-retrofit model (i.e. higher proposed ventilation rates). The increase in energy usage must be offset by other measures to demonstrate achievement of the program energy target.

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[1] *From ASHRAE Guideline 14*: The whole building calibrated simulation approach involves the use of a computer simulation tool to create a model of energy use and demand of the facility. This model, which is typically of pre-retrofit conditions, is calibrated or checked against actual measured energy use and demand data and possibly other operating data. The calibrated model is then used to predict energy use and demand of the post-retrofit conditions. Savings are derived by comparison of the modeled results under the two sets of conditions or by comparison of modeled and actual metered results.

3 Model Calibration

3.1 General Approach

Projects may include several buildings that are individually metered for some or all fuels or have a common set of utility bills. Each building may have a single whole-building set of bills for each fuel or may include multiple sets of bills (i.e. electricity consumption in apartments is metered separately from the common space). This section provides guidelines for aggregating model results and utility bills for the purpose of model calibration.

- When a single building has multiple sets of bills for a given fuel — for example, if electricity consumption in apartments is directly metered, or if there is a separate set of electric bills for the common space — all individual sets must be combined so that there is one set of bills representing the total whole building consumption of each fuel. Comparing the individual sets of bills to the modeled consumption of corresponding spaces — for example, comparing electricity usage of common spaces predicted by the model to the billing data for common spaces — may provide valuable additional insight into building operation, but it is not required.
- When a project includes multiple buildings, the model calibration approach depends on the metering configurations and whether the buildings have similar envelope and mechanical systems.

Buildings are considered to have *similar envelopes* if *all* of the following conditions are met:

- Building geometries are similar:
    - Total conditioned building area differs by no more than 20%
    - Percentage of area taken by common spaces differs by no more than 20 percentage points
    - Spaces in buildings are of a similar occupancy type
    - Areas of surfaces of each type (exterior and below grade walls, windows, roof, slab) differ by no more than 20%
- Thermal properties of envelope components are similar
- Infiltration rates are similar

Example: There are two 60,000 SF, 6-story buildings in the project. One building has 12,000 SF of corridors and common spaces (20% of total building area). The other building has the same corridor area, plus a community room, rental office and laundry on the first floor, with the total area of common spaces equal to 20,000 SF (33% of total building area). The percentage of common spaces in each of these buildings differ by 13 percentage points (33%-20%), and the buildings have spaces of different occupancy types; because of the different occupancy types, they may not be considered as having similar geometry.

Buildings are considered to have *similar mechanical systems* if *all* of the following conditions are met:

- HVAC or domestic hot water equipment in buildings is of similar type
- Overall plant efficiency varies by no more than 5 percentage points
- Mechanical ventilation rates are similar (within 10% based on air changes per hour (ACH)

Buildings are considered to have similar usage if the annual fuel usage per square foot of conditioned floor area differs by no more than 10%.

Calibration approaches for several typical configurations are described in Table 3-1. Other approaches may be allowed and are subject to program review.

Table 3-1. Calibration Approaches for Several Typical Configurations

	Similarity of Buildings and Systems	Type and Similarity of Heating Bills	Modeling Approach
Case A	Non-similar envelope or mechanical	Billing for heating fuel is either per apartment or per building.	Buildings must be explicitly modeled and individually calibrated to the corresponding set of utility bills.
Case B	Similar envelope and mechanical	Billing for heating fuel is either per apartment or per building; usage is similar between buildings.	Create single model representing *one* building; calibrate to area-weighted average annual usage.
Case C	Similar envelope and mechanical	The meter or billing data for heating fuel applies to multiple buildings.	Create single model representing *all* buildings that are served by a single heating-fuel meter; calibrate to the total annual usage shown for all fuels used at those buildings.
Case D	Non-similar mechanical systems	The meter or billing data for heating fuel applies to multiple buildings.	If simulation tool supports explicit modeling of non-identical HVAC systems in a single model file, the same approach as for Case C may be used. For tools that do not have this capability (such as TREAT), separate models must be created representing each building, and the total heating usage of these models must be calibrated to utility bills.

3.2 Calibration Requirements

If the simulation tool supports weather-normalized model-to-billing comparison by fuel and end use, such as in TREAT, the difference between the annual modeled use and the actual consumption for heating, cooling, and base load must differ by no more than -10% to 0%. The model should not show more energy consumption than the bills. Where variation exceeds -10% to 0%, review the billing data and model inputs for anomalies, data entry errors, misinterpretation of performance features, etc.

Users of approved modeling software tools that do not include billing analysis functionality are required to use the *Model Calibration Tool* spreadsheet that will be made available to them upon request.

4 Simulation Program – For High Performance Component Only

Currently approved simulation software for use in the MPP High Performance Component includes:

- EA-Quip
- eQUEST
- Hourly Analysis Program (HAP)
- Trane Trace
- TREAT (multifamily edition)

New analytical tools may apply to the program by submitting an application describing tool capabilities and demonstrating compliance with the listed program requirements. Based on program review, the tool may be accepted for use on one or several pre-approved pilot projects. Deliverables for projects that are not identified as pilot projects prior to preparing the comprehensive energy assessment and that utilize software not approved for use in the program will not be accepted. Only analytical tools that satisfy the requirements outlined below may be used.

- Compliance with ASHRAE 90.1 Appendix G simulation and documentation requirements; OR
- Approval for EPAct Federal Tax Deductions; OR
- DOE approval for use in Weatherization Assistance Program for multifamily buildings.
- Support of systems and configurations that are typical for multifamily buildings in the northeastern United States.
- Support of Multifamily Performance Program business process and reporting requirements.
- Availability of technical support, training, and/or user manual and documentation.
- NYSERDA Multifamily Performance Program staff will not provide assistance with software-related questions or model troubleshooting.
- Built-in troubleshooting tools and errors/warnings reports.
- Integrated support for evaluation of design alternatives (improvements).

The energy consumption of systems, equipment, and controls that are not directly supported by the software used for the project should be calculated outside of the simulation tool. External calculations may not be used to replace functions that are supported by the software tool. The results of external calculations may be used to inform modeling inputs or to adjust modeling results. The external calculation methodology must be documented and is subject to program review. Original spreadsheets must be included in the submittals where applicable.

> Example 1: The proposed scope of work includes replacement of incandescent fixtures with fluorescent fixtures. Since any approved simulation tool will calculate savings from reduced lighting wattage, including interaction with space heating/cooling, the energy savings from this measure must be modeled in the simulation tool.
>
> Example 2: The proposed scope of work includes installation of daylighting controls. If the simulation tool used for the project does not support daylighting modeling, then the provider may use external custom calculations or software tools to estimate the related energy savings or reduction in fixture runtime.

5 Thermal Zones

The thermal zones defined in the model impact the simulation accuracy. The following rules must be followed:

Each space or group of spaces that is served by non-identical HVAC systems, or that will be served by non-identical HVAC systems due to a proposed retrofit, must be modeled as a separate thermal zone served by an HVAC system of appropriate type and efficiency. For simulation tools such as TREAT that do not allow modeling multiple HVAC systems in one project, efficiency of the modeled HVAC system that represents the various actual systems found in the building must be based on the efficiencies of actual systems weighted by the heating load of thermal zones that they serve.

> Example 1: Site condition: Each apartment has a dedicated gas-fired furnace and a split system air conditioner. All in-unit systems are the same.
>
> Modeling approach: Since all in-unit systems are identical, apartments may be combined into one thermal zone, provided that other conditions outlined in this section are met.
>
> Example 2: Site condition: Apartments in a building have hydronic baseboards and are served by a central boiler. Stairwells and utility areas have electric unit heaters.
>
> Modeling approach: Stairwells and utility areas may be combined into one thermal zone because they are served by the same type of heating system (electric heaters). Apartments should be modeled as a separate zone served by central boiler. For TREAT projects, usage of electric unit heaters may be estimated using the heating load of the zone that includes stairwells and utility areas and modeled as a secondary heating system using fixed percentage of monthly energy or similar approach.
>
> Example 3: Site condition: All utility spaces in the building are served by electric heaters. The SAV-IT includes a recommendation to replace electric heaters in some of these spaces with gas unit heaters.
>
> Modeling approach: Utility spaces for which the new heating system is proposed may only be combined with other utility spaces that would undergo the same improvement to correctly estimate the post-retrofit reduction in heating electric load and the increase in gas heating load.
>
> Example 4: Site condition: All apartments in the building are served by a central heating system. Some of the apartments also have room air conditioners.
>
> Modeling approach: In order to correctly account for cooling energy usage, apartments may be modeled as two thermal zones — one combining all rooms that are cooled and another combining all rooms with no cooling.

If a space or group of spaces is determined to be overheated, and the overheating is being addressed in the SAV-IT, overheated spaces *may* be modeled as a separate zone. Space temperature measurements or other means that were used to determine temperature and size of overheated zones must be included in the SAV-IT. If overheated zones are not modeled explicitly, then the procedure used to calculate modeled pre- and post-retrofit temperature of aggregated zones must be documented in the SAV-IT. An example calculation is included in Section 8.1.

Each space or group of spaces that have unique internal or solar heat gains or envelope loads *may* be modeled as separate thermal zones to improve the accuracy of the simulation. Combining apartments with different exposures or apartments adjacent to different surface types (roof, slab-on-grade, etc.) into one thermal zone may underestimate the cooling and heating loads.

Example 5: Site condition: On a sunny day in April, south-facing apartments may get overheated due to solar gains, while north-facing apartments may need heat to maintain the thermostat setpoint.

Modeling approach: If all apartments are modeled as a single thermal zone, then solar gains through south-facing windows will offset heating load of north-facing apartments, which is not an accurate representation of site conditions. This will decrease the modeled heating usage and impact model-to-billing calibration. Modeling south-facing and north-facing apartments as two separate zones will improve the accuracy of simulation.

6 Heating and Cooling Systems

6.1 Heating Equipment

General

Several efficiency descriptors may be available for the existing heating equipment and the equipment considered as the retrofit.

> Combustion Efficiency (E_c) accounts for stack losses and may be measured in the field by performing a combustion efficiency test.
>
> Thermal Efficiency (E_t) accounts for the heat loss through the boiler jacket during boiler firing in addition to the stack losses; therefore, E_t is lower than E_c for the given equipment. It may be calculated as the ratio of the nameplate boiler output to the nameplate boiler input.
>
> Annual Fuel Utilization Efficiency (AFUE) accounts for stack and jacket loss, as well as for equipment performance during the part load conditions in a "typical" installation. AFUE also accounts for the energy that is wasted when the boiler is "idling" to maintain internal temperature while the building is not calling for heat. AFUE cannot be measured in the field or calculated based on the parameters shown on the nameplate. It is determined through testing performed by the manufacturer. AFUE is also called "seasonal efficiency" and is typically only provided for equipment under 300,000 Btu/hr. The AFUE represents the part-load efficiency at the average outdoor temperature and load for a typical boiler installed in the United States. Although this value is useful for comparing different boiler models, it is not meant to represent actual efficiency of a specific installation [49]. With the exception of condensing boilers, part-load efficiency metrics are usually not provided for larger boilers.

A more complete explanation of each efficiency descriptor is available in the MPP's April 17, 2008 *Tech Tip – Boiler Efficiency* (see Appendix E).

Energy consumption of fans and pumps associated with the heating system must be captured in both the pre- and post-retrofit models.

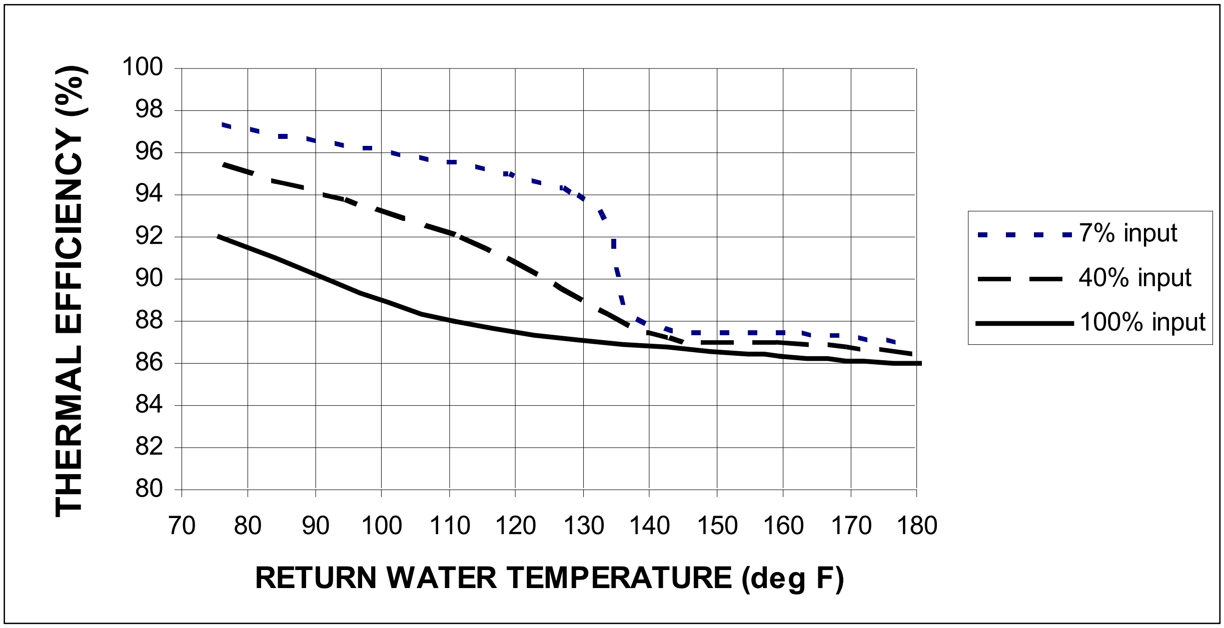
> Example 1: Site Conditions: Electric baseboards in apartments are replaced by a central hot water boiler.
>
> Modeling Approach: Electricity consumption of pumps serving the new system must be included in the post-retrofit model to fully capture the tradeoffs between electric and hydronic heating. Ignoring the heating-related electricity consumption of the post-retrofit system will lead to overestimated electricity savings.

Performance of heating equipment may vary significantly depending on the overall HVAC system design and field conditions. The model inputs must be based on the performance of the existing and proposed heating systems for the conditions that exist at the given site. The relevant system design parameters must be described in the SAV-IT for both existing and proposed conditions.

> Example 2: *Site Conditions*: The scope of work includes replacement of the existing boiler with a new condensing boiler. Marketing literature for the condensing boiler reports that the boiler has a thermal efficiency up to 98%.

Modeling Approach: The performance of condensing boilers depends strongly on the return water temperature and the variations in load, as shown in Figure 1, which is based on manufacture's literature for an example boiler. The operating conditions that are required to achieve the modeled efficiency must be documented in the SAV-IT. The existing piping arrangement and a sample of radiators must be evaluated to ensure that the conditions required to achieve the modeled efficiency are feasible.

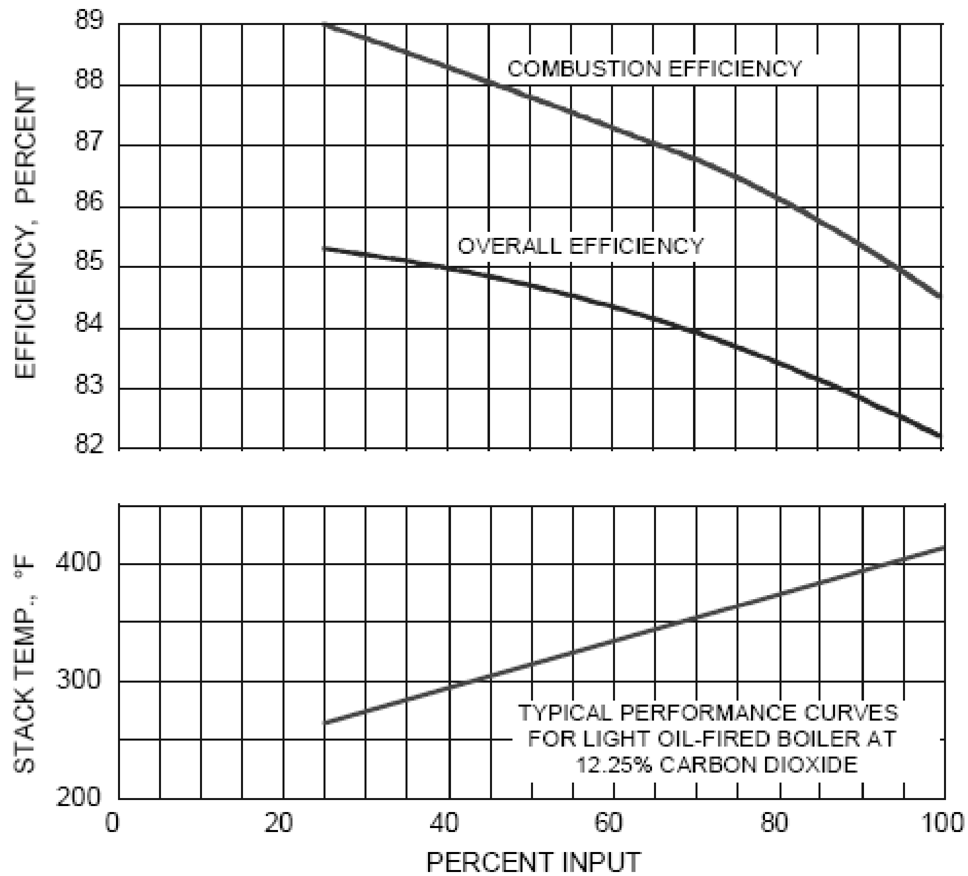
Figure 1. Example Condensing Boiler Thermal Efficiency



Example 3: Site Conditions: The work scope includes replacement of the existing boiler with a boiler that is equipped with a burner that can fire at reduced inputs while modulating both fuel and air.

Modeling Approach: Projected savings should capture increased efficiency of modulating boiler at part load conditions. The performance curves entered in eQUEST or efficiency adjustment calculations for TREAT should be based on boiler part-load performance from manufacture, or typical performance of modulating boilers from ASHRAE Systems and Equipment Handbook.

Figure 2. Boiler Efficiency as Function of Fuel and Air Input



Example 4: Site Conditions: Energy modeling indicates that the existing boiler is significantly oversized. The scope of work proposes to replace the existing boiler with a new higher efficiency unit of the appropriate size.

Modeling approach: In space heating applications, low part-loading for a boiler occurs over much of the heating season because of equipment oversizing and the fact that space heating boilers must be sized to meet the maximum load even though this load only occurs rarely. For example, one study found that multifamily boilers with on/off burners are typically only 21% loaded on a heating season average basis" [50].

Run fraction at a given load condition may be estimated in the field by observing the burner operation. For example, if a boiler fires for 5 minutes, then remains off for 20 minutes before restarting, the run fraction is equal to 5 minutes / (5 minutes + 20 minutes) = 0.2 or 20% [52].

In eQUEST, the boiler part-load performance penalty may be captured by specifying the size of the equipment in the Boiler Properties window of the Basic Specifications tab. In addition, specify the appropriate performance curves in f (part load ratio) input box of Performance Curves tab. The eQUEST library has default curves for atmospheric, forced draft, and condensing boilers. Alternatively, custom curves may be created using manufacture-specified or measured efficiency at part load conditions. eQUEST will combine part load equipment characteristics with hourly heating loads and use the appropriate efficiency for each hour of the year in the simulation.

In TREAT, part-load efficiency is handled as described in the User Manual: "The part-load adjustment is calculated for each month depending on equipment type and part-load ratio during the month and varies between 0.75 and 1. If part-load ratio for boilers is less than 0.1, then monthly usage is adjusted by 0.75 + 2.5 * PartLoadRatio. For forced air heating and cooling systems, the monthly usage is adjusted by 0.75 + 0.25 * PartLoadRatio."

Existing Conditions

For equipment with a heating capacity of 300,000 Btu/hr or less, if the listed AFUE is available from the equipment manufacturer for the existing equipment, $AFUE_{actual}$ shall be used in the pre-retrofit model. For equipment with a heating capacity of 300,000 Btu/hr or less with unknown listed AFUE, and for equipment with heating capacity greater than 300,000 Btu/hr, $E_{t,actual}$ shall be used. $AFUE_{actual}$ and $E_{t,actual}$ shall be calculated as described below.

Exception: If a heating retrofit is considered and AFUE is available for the existing equipment but is not available for the proposed equipment, Et, actual shall be used for the existing equipment.

AFUE actual and Et,actual for the existing equipment shall be calculated assuming that deterioration in annual or thermal efficiency is proportional to the deterioration in combustion efficiency as follows:

AFUEactual=AFUElisted*Ec,actual/Ec,listed

Et,actual=Et,listed*Ec,actual/Ec,listed

Where

AFUEactual = actual AFUE of existing equipment

AFUElisted = AFUE of existing equipment listed on the nameplate or in the manufacturer's literature.

Ec,actual = actual combustion efficiency of existing equipment measured during the audit.

Ec,listed = combustion efficiency of existing equipment listed on the nameplate or in manufacturer's literature.

Et,actual = actual thermal efficiency of existing equipment.

Et,listed = thermal efficiency of existing heating equipment listed on equipment nameplate or in manufacturer's literature.

If either $E_{c,listed}$ or $E_{t,listed}$ is not available for the existing equipment, then Table 6-1 shall be used to estimate $E_{t,actual}$ based on the measured combustion efficiency $E_{c,actual}$. To compute $E_{t,actual}$, subtract the numbers in the table from the measured (actual) combustion efficiency percentage.

Table 6-1. Average Percentage Point Differences Between E_t & E_c [17]

Fluid	Heat Exchanger	300,000-2,500,000 Btu/hr		2,500,000 - 10,000,000 Btu/hr	
		Natural Gas	Oil #2	Natural Gas	Oil #2
Steam	Cast Iron	2.1	2.4	1.5	1.6
Water	Cast Iron	1.6	2.4	1.4	1.6
	Steel	2.2	3.4	NA	NA

For equipment below 300,000 Btu/hr, if $AFUE_{actual}$ cannot be calculated as described in the section above, and for air-source heat pumps, then Table 6-2 must be used to estimate efficiency based on the equipment age.

Table 6-2.Minimum Age-Based Efficiency

Mechanical Systems	Units	pre-1991	1992 to present
Gas Furnace	AFUE	0.76	0.78
Gas Boiler	AFUE	0.77	0.8
Oil Furnace or Boiler	AFUE	0.8	0.8
Air-Source Heat Pump	HSPF	6.8	6.8
Ground-Water Geothermal Heat Pump	COP	3.2	3.5
Ground-Coupled Geothermal Heat Pump	COP	2.7	3

The simulation model may account for lower summer efficiencies for the space heating boiler, in the case where this boiler heats domestic hot water. The assumptions and references must be documented in the SAV-IT.

Improvements

System Replacement

AFUE shall be used to model the performance of equipment proposed as retrofit when the listed AFUE is available from the equipment manufacturer for both existing and proposed equipment. In all other cases, thermal efficiency (E_t) shall be used to model both pre- and post-retrofit equipment. Alternative methods may be used with appropriate references and documentation.

> The maximum AFUE and/or thermal efficiency for new condensing boilers must be modeled at 92% or less. Higher boiler efficiencies may be achievable with an aggressive outdoor reset schedule. However, distribution systems designed for higher-temperature return water may not be able to provide sufficient heat with the low return water temperatures required for condensing. In addition, near boiler piping may not be designed to allow for low-return water temperatures. If a higher efficiency is modeled, the following documentation must be provided: 1) the outdoor reset schedule; 2) a detailed description of the near-boiler piping and distribution system showing that sufficient heat can be provided to the building at low return water temperatures OR the proposed plan for updating the near-boiler piping and distribution system to accommodate lower return water temperatures.
>
> Rated efficiency of proposed HVAC equipment must be included in the SAV-IT and must be based on the test procedure appropriate for the specified equipment type, as listed in Tables C403.2.3 of the 2015 Energy Conservation Construction Code of New York State. Equipment that does not have the standard

rating, such as ARI rating, may be allowed as a measure, but is subject to program review.

Boiler Tune-up

The estimated useful life of boiler tune ups shall not exceed one year. The efficiency increase due to boiler tune-up depends on the boiler condition prior to the tune-up and the scope of work being performed. The longevity of such savings is difficult to determine, as factors such as water quality, fuel, and proper maintenance are all influential. For example, commercial boilers that use gas and light oil may only need to be cleaned once a year in comparison to boilers using heavy oil, which require several cleanings each year [43].

Cooling Equipment

Efficiency of Existing Equipment

If the efficiency of existing system cannot be determined based on the equipment nameplate, the following values must be used in the pre-retrofit model:

- central air conditioners: SEER 10 / EER 9,2 [53, p.41],
- heat pumps: SEER 10 / HSPF 6.8 [53, p.44].
- room air conditioners [53, p.73]
  - <20,000 Btu.hr: SEER 9.7
  - >=20,000 Btu/hr: SEER 8.5

Refrigerant charge correction

Refrigerant charge correction may be modeled as 10% improvement in pre-retrofit EER [53, p. 58].

6.2 Distribution System

Variable Frequency Drives (VFD)

Savings from the installation of variable speed drives shall be determined based on the fan/pump affinity laws using an exponent of 2.2 (to account for system effect) and no more than a 30% reduction in average flow. Savings can be attributed to water or air distribution.

Example 1: Site condition: A central chiller plant in a high-rise multifamily building, using a primary/secondary pumping scheme feeds 300 gallons per minute (gpm) of water throughout the building to fan coil units. The pump is driven with a 10 hp motor with an operating bhp of 8.5. A VFD will be installed with an estimated average flow reduction of 20%. Existing motor revolutions per minute (RPM) is 1,800 (RPM is to be taken from design documents where available or from field gathered data).

Flow is directly proportional to rotational speed:

$$Q1/Q2 = N1/N2,\ 300/240 = 1800/N2,\ N2 = 1{,}440$$

Where:

Q = chilled water flow before and after VFD installation.

N = motor RPM before and after VFD installation.

Once the new RPM is found the reduction in kW can be determined as follows.

$$kW1/kW2 = (N1/N2)^{2.2},\ kW2 = kW1/(N1/N2)^{2.2}$$

Where:

$kW1 = 8.5(bhp) * 0.746/0.88$ (motor efficiency) $= 6.34$ kW

$kW2 = 7.2/(1800/1440)^{2.2}$

$kW2 = 7.2 / 1.75 = 4.11$

Pre- and post-kW should then be multiplied to the typical run hours for the unit based on location where applicable and the difference in kWh determined. The improvement can now be modeled as an appliance using the difference in kWh as the yearly consumption and removed as part of the improvement.

Steam Trap Replacements

Steam trap replacement savings shall be determined using Grashof's equation. Trap failure rate shall be estimated based on manufacturer's data when available or 10% / yr up to 40%. In no case shall the savings be more than 25% of the annual heating fuel consumption. The equation states:

Lbs/hr (loss) $= C \times G \times 3{,}600 \times A \times p^{0.97}$

Where:

C = Coefficient of discharge for hole, use 0.7

G = Grashof's constant = 0.0165

3,600 = # of seconds in (1) hour

A = Area of discharge of equivalent orifice diameter in square inches (use 75% of area to account for partially blocked openings)

P = pressure in steam line prior to trap, use 2.5 psia

Savings can then be calculated as:

MMBtu/yr = ((lb/hr loss(total) * 1,000 (Btu/lb steam) * hours of operation) / 1,000,000) / Boiler efficiency.

Example 1: Site condition: A steam system feeding 100 radiators has not been maintained for 5 years. The equivalent trap orifice diameter is ¼". The heating system operates for 2,000 hours per year with a boiler efficiency of 78%.

Lbs/hr (loss) $= C \times G \times 3{,}600 \times A \times p^{0.97}$

C = 0.7

G = 0.0165

$A = (3.14 \times (0.25/2)^2)/2 = 0.098$sqin

P = 2.5

Lb/hr/trap = 9.91, # of failed traps = 100 x 0.4(max) = 40 traps

Total lbs/hr of steam lost = 9.91 x 40 396.4 lbs/hr

MMBtu / yr = (396.4 lbs/hr x 1,000 Btu/lb x 5,000) / 1,000,000 = 1,982/ .78 = 2,541

MMBtu/yr

After determining MMBtu savings, use standard fuel conversions to determine amount of fuel savings. Fuel savings can be modeled as an appliance with the same consumption and then removed for appropriate savings.

7 Heating/Cooling Temperature Schedule

7.1 Existing Conditions

Actual indoor temperatures during heating and cooling seasons must be modeled as thermostat setpoints. Heating and cooling setpoints used in the model must be documented in the SAV-IT.

If the total area-weighted building temperature of all modeled zones combined is outside a range of 69°F – 76°F for at least some of the time during the heating season, then the inputs must be supported by a record of indoor temperatures measured in multiple locations. See the MPP Technical Topic, *Indoor Temperature,* for more information. [24, 25, 28].

Example 1:

Site Conditions: It is determined that 20% of apartments are overheated and that the average temperature for these apartments is 82°F. The average space temperature in the remaining apartments is 72°F.

Modeling Approach: Overheated spaces may be modeled as a separate zone or aggregated with other apartments. If modeled as a separate zone, then the space temperature of the zone representing overheated apartments will be modeled as 82 °F, and the space temperature of the zone representing the rest of the apartments will be modeled as 72°F.

If overheated areas are aggregated with other apartments into single zone, then the modeled temperature of this zone is calculated as 82°F * 20% + 72°F * 80% = 74°F.

With either approach, the weighted average temperature in the model is 74°F, which falls within the range allowed by this Section 8.1(b).

7.2 Improvements

Table 7-1. Temperature Reduction at Apartment Level

TEMPERATURE REDUCTION AT APARTMENT LEVEL		
Existing	**Proposed**	**Modeling Protocol**
Non-programmable thermostats; corresponding heating or cooling bills NOT paid by residents	Programmable thermostats in apartments or TRVs with no upper limit set	Not allowed in scope of work as an energy efficiency measure [25] – unlikely to generate energy savings
Non-programmable thermostats; corresponding heating or cooling bills paid by residents	Night setback via programmable thermostats in apartments	Heating: maximum 3°F setback for 8 hours per day [53, p. 55] Cooling: maximum 2°F increase for 6 hours per day [18]
Any resident-controlled thermostat, TRV, or other temperature control	Range-limited thermostats, TRVs, or other controls with a specific upper limit on indoor temperature	Must use interior space temperature no less than specified upper limit [24, 25]. Maximum 2°F temperature reduction.

Note that if modeled energy savings are based on the reduction of space temperature in apartments where occupants have unlimited apartment-level control over the heating setpoint, the post retrofit temperature during occupied periods should not be less than 74°F in buildings with owner-paid corresponding utilities, or 72°F in buildings with resident-paid corresponding utilities [25].

Table 7-2. Temperature Control at Building Level – Steam Systems

TEMPERATURE CONTROL AT BUILDING LEVEL – STEAM SYSTEMS		
Existing	**Proposed**	**Modeling Protocol - Steam**
On/off control only; no outdoor reset Note that outdoor reset for steam systems is defined as a control that adjusts the length of the steam cycle as the outdoor temperature changes.	Outdoor reset	Model as a temperature reduction. Do not model as "outdoor reset" as this option only applies to hot water system or vacuum steam systems. Must provide details of existing controls and evidence that outdoor reset is not currently being utilized. 1°F maximum temperature reduction
Outdoor reset; heating imbalances observed	EMS with indoor temperature sensors	Distribution imbalances *not* addressed: 2°F maximum temperature reduction Distribution imbalances addressed: 3°F maximum temperature reduction
Outdoor reset; no heating imbalances	EMS with indoor temperature sensors	3°F maximum temperature reduction

The temperature reductions in the table above are weighted average reductions, inclusive of night setback.

Table 7-3. Temperature Control at Building Level – Hot Water Systems

TEMPERATURE CONTROL AT BUILDING LEVEL – HOT WATER SYSTEMS		
Existing	**Proposed**	**Modeling Protocol – Hot Water**
On/off control only, no outdoor reset	Outdoor reset	Model as outdoor reset control on hot water loop. Must provide details of existing controls and evidence that outdoor reset is not currently being utilized. System must be able to operate with outdoor reset (condensing boilers and/or boilers separated from heating loop).
	Outdoor reset and EMS with indoor temperature sensors	Model as above for outdoor reset portion of savings. Additionally, model a temperature reduction of 1°F maximum if the outdoor reset curve (i.e. the hot water loop set point) will be adjusted based on feedback from apartment sensors.
Outdoor reset	EMS with indoor temperature sensors	Model as a temperature reduction if outdoor reset curve (hot water loop set point) will be adjusted based on feedback from apartment sensors. 1°F maximum temperature reduction

Steam boilers that supply a hot water loop are to be considered a hot water system. The temperature reductions in the table above are weighted average reductions, inclusive of night setback. For more information, see Appendix F.

8 Air Infiltration and Mechanical Ventilation

8.1 Mechanical Ventilation

Mechanical ventilation shall be modeled according to data collected by the provider during the site visit, including the fan runtime hours and flow rates. Fan flow rates may be measured, obtained from as-built drawings and specifications, estimated based on manufacturer's data for the installed model and ductwork characteristics, or estimated based on the rated fan motor horsepower listed on the nameplate.

The electricity consumption of fan motors shall be included in the model based on the rated power consumption and the annual fan run time, as determined in the field. The following equations may be used to estimate fan motor energy:

$$kW_{fan} = CFM\left(\frac{FanStatic\ Pressure}{8520 \cdot FanEfficiency}\right) \qquad [20]$$

$$kW_{fan} = bhp\left(\frac{0.746}{FanEfficiency}\right) \qquad [15]$$

where:

CFM = design flow rate

FanStaticPressure = pressure drop in ductwork, inch H_2O

FanEfficiency = fan motor efficiency fraction

8520 = conversion factor, $\left(\frac{ft3 * inches}{minutes * kW}\right)$

bhp = break horsepower of fan motor

If the proposed improvements include a change in mechanical ventilation rates, then the projected savings should reflect the impact of the change on heating and cooling loads and fan motor energy consumption.

8.2 Pre-retrofit Infiltration

Average air changes per hour (ACH) in the conditioned space caused by natural infiltration of outdoor air during the heating season must be below 1.0 ACH, or below 0.21 CFM per square foot[2] of gross vertical exterior wall area [2,4,6,7,8,9].[3] However, infiltration rates may be much lower than these maximum values in most

2 This value of CFM/sq. ft. represents infiltration through all components of the building envelope, including the roof, normalized to CFM per square foot of gross vertical wall area above ground.

3 These are approximations based on a review of reports by Gulay, et al., (1993); Palmiter, et al., (1995); Shaw et al., (1980, 1990, and 1991); and Sherman et al., (2004). Information on measured infiltration rates in multifamily buildings

multifamily buildings, and 0.6 ACH should be considered typical. Average heating season air changes that are higher than 1.0 ACH might occur when there are many intentional openings, such as a high occurrence of open windows. If present, these conditions must be documented in the SAV-IT.

Blower door measurements may be converted to estimated annual infiltration rates using the equations below [21]:

$ACH=ACH_{50}/K$

$ACH_{50}=CFM_{50}*L/\text{Building Volume [CF]}$

Coefficients K and L may vary depending on the building and test conditions. In the absence of project-specific references, K=20 and L=60 should be used.

Non-apartment spaces with low area of exterior surfaces, such as corridors or basements, have much lower infiltration rates. For example, 0.2 ACH is considered typical for a basement. A notable exception to this rule are mechanical rooms, which often have much higher infiltration rates due to intentional combustion air openings.

is extremely limited. Most of the available information cannot be directly correlated to New York State's building stock and climate conditions.

8.3 Interaction between Infiltration and Mechanical Ventilation

Outdoor air flow rates in pre- and post-retrofit models shall reflect the combined effect of natural and mechanical ventilation. If the simulation tool does not automatically account for the interaction between infiltration and ventilation, which is the case for most tools, including TREAT and eQUEST, then the combined flow rate must be calculated using equation (51) in Chapter 16 of the 2017 *ASHRAE Handbook–Fundamentals*, as quoted below:

$$Q_{comb} = Q_{bal} + \sqrt{Q_{unbal}^2 + Q_{infiltration}^2}$$

(Equation 8.1)

Q_{comb} [CFM] = combined rate of natural and mechanical ventilation.

Q_{bal} [CFM] = balanced mechanical ventilation in a space or group of connected spaces that have both exhaust and supply fans. This represents the portion of mechanical ventilation where the exhaust flow is equal to the supply flow. Q_{bal} = minimum ($Q_{exhaust}$, Q_{supply})

Q_{unbal} [CFM] = unbalanced mechanical ventilation flow in a space of group of connected spaces. This is the portion of mechanical ventilation where either the exhaust or supply flow is greater than the other.

Q_{unbal} = maximum ($Q_{exhaust}$, Q_{supply})- Q_{bal}. If the space has only supply or exhaust, all the flow is unbalanced.

$Q_{infiltration}$ [CFM] = natural (non-mechanical) infiltration rate.

Equivalent combined rate Q_{comb} may be modeled as either all-mechanical or all-natural ventilation, or as a combination of the two as appropriate for the simulation tool being used. See Modeling Approach section for calculation procedure.

8.4 Infiltration Reduction Improvements

Air sealing and infiltration reduction improvements should be conservatively estimated as not to overstate energy savings. When calculating the proposed infiltration reduction, it is recommended that you use known leakage rates of specific building components, for both pre- and post-retrofit conditions. Included in Appendix C is a table from the 2001 ASHRAE Fundamentals Handbook listing the Effective Leakage Area through common building components.

Once the combined reduction in Effective Leakage Area has been calculated, the following formula can be used to calculate the natural ACH reduction achieved:

$$A_n = 6.944\left(\frac{A_L}{A_f}\right)\left(\frac{H}{H_o}\right)^{0.3}$$

A_n = Normalized leakage area, equivalent to natural ACH reduction achieved [56]

A_l = Effective Leakage Area (in^2)

A_f = Gross floor area (ft^2)

H = Building height (ft)

H_0 = reference height of one-story building, 8 ft

Field research has shown that extensive air sealing measures can reduce a building's total infiltration rate by 18% to 38% [2, 9]. Consistent with that, the maximum percentage reduction in infiltration from all improvements combined should be capped at 38%. This does not include the portion of infiltration that is attributable to occupant behavior, such as opened windows due to poor heating control.

If an infiltration reduction measure is included in the scope of work, it is important to update the interaction between the infiltration and mechanical ventilation for post-retrofit conditions using Equation 8.1 above. More details are included in the Modeling Approach section below.

8.5 Modeling Approach

As mentioned in the section above, it is important to consider the interactions between infiltration and mechanical ventilation when calculating savings associated with either of these types of measures. The combined natural and mechanical ventilation should be calculated using Equation 8.1 above for both pre- and post-retrofit conditions and entered correctly into the energy modeling software.

When entering mechanical ventilation, adjust rates to reflect runtimes. Whole building natural infiltration higher than 0.6 ACH usually indicates above average air leakage, which should be evident from the site visit, with the locations of leakage documented in the SAV-IT.

9 Lighting

9.1 General

The modeled wattage of fixtures that have ballasts or transformers must include the consumption of all components and not just the nominal lamp wattage. Every effort should be made to look up the specifications for the particular ballast model number. Appendix A lists total wattages for the typical lamp/ballast combinations that may be used in the model if the fixture-specific information is not available.

If the hourly lighting load distribution must be entered into the modeling tool, then the software default schedules, or the schedules developed by NREL and made available at the Building America website at http://www1.eere.energy.gov/buildings/building_america/perf_analysis.html (End-Use Profiles), may be used, provided that the load distribution does not exceed the total hours of operation required in this document.

Exterior lighting that is on the site utility meters (e.g., pole fixtures for walkways and parking, exterior lighting attached to the building, etc.) must be included in the energy simulation and considered for retrofit. Improvements to exterior lighting may involve replacement of existing fixtures with new fixtures having better efficacy, reducing the number of fixtures to eliminate overlighting, and installing lighting controls such as timers, occupancy sensors and photosensors.

The same hours of operation must be used for pre- and post-retrofit fixtures unless the measure includes the installation of device(s) that affect the fixture runtime.

9.2 Existing Conditions

The modeled wattage of existing incandescent fixtures must be equal to the wattage of the installed bulbs, but no greater than the maximum rated fixture wattage (see Appendix A).

Lighting inside apartment units for which no retrofit is proposed should be modeled as having an installed wattage of 2.0 W/SF [10] and operating 2.34 hr/day [23], or 2.0 * 2.34 = 4.68 [Wh/SF-day]. As part of the process to calibrate the model to utility bills, this energy consumption may be modified ± 30% by adjusting either the installed wattage or hours of operation.

Apartment lighting that is being retrofitted must be modeled with the operating hours in Table 9-1 below based on the room type [10]. Alternatively, 3.2 hours/day runtime may be assumed for the existing incandescent lamps retrofitted with screw-in LEDs and 2.5 hours per day may be assumed for all other existing fixtures that are replaced [55, p.151]. Alternative assumptions may be used but must be accompanied by the proper references and are subject to program review.

Existing or proposed lighting controls, including occupancy sensors and timers, may be modeled as a reduction in the hours of operation or as an equivalent adjustment to the installed lighting power from Table 9-2 [14, 15]. Alternative reductions in hours may be used but must be accompanied by the proper references and are subject to program review.

Table 9-1. In-Unit Lighting

In-Unit Lighting

Room Type	**Average Lighting Usage (hrs/day)**
Kitchen/Dining	3.5
Living Room	3.5
Hall	2.5
In-unit laundry/utility room	2.5
Bedroom	2.0
Bathroom	2.0

Table 9-2. Common Area Lighting

Common Area Lighting

Space Type	Power Adjustment Percentage Reduction in Operating Hours
Hallways/Corridors	25%
All other spaces intended for 24-hour use	10%

9.3 Improvements

If an improvement includes installation of fixtures that will use screw-in CFLs, then the modeled wattage of proposed fixtures must be equal to the maximum rated fixture wattage, regardless of the wattage of the proposed bulbs. For example, if a new fixture can use either incandescent bulbs or CFL, the wattage of the fixture's maximum allowable incandescent bulb must be used in the model.

When replacing incandescent lighting with fluorescent lights or CFLs, the lighting energy savings should be based on no more than 3.4:1 reduction in wattage [53, p.7,11]. For example, wattage of CFL that replaces 60W incandescent bulb should be modeled as no less than 60/3.4 = 18W. . This is different from what is suggested by CFL manufacturers' packaging, which often recommends a 4:1 reduction, or even more. In addition, care must be taken with special populations (such as seniors) to provide appropriate lighting levels.

When replacing incandescent lighting with LEDs, the lighting energy savings should be based on no more than 4.5:1 reduction in wattage [54]. For example, the wattage of an LED that replaces a 60W incandescent bulb should be modeled as no less than 60/4.5 = 13.3W. This is different from what is suggested by LED manufacturers' packaging, which often recommends a 6:1 reduction, or even more. In addition, care must be taken with special populations (such as seniors) to provide appropriate lighting levels.

LED fixtures can be more efficient than comparable fluorescent and high intensity discharge (HID) fixtures. However, there is significant overlap in fixture efficacy: some fluorescent and HID fixtures are more efficient than some LED fixtures. When replacing fluorescent or HID fixtures with LEDs, if the efficacy of the existing fixtures is unknown, then a wattage reduction of no more than 1/3 should be assumed [54]. For example, for a generic 150W HID fixture, a minimum of 100W must be modeled for the improvement LED upgrade. For more details see MPP Technical Topic: *LED Lighting Recommendations* in Appendix G.

Without evidence of significant over-lighting, reductions in light output should not be included as part of energy savings projections from LED retrofits. For more details see MPP Technical Topic: *LED Lighting Recommendations* in Appendix G.

For estimating proposed energy usage from lighting controls, see section 9.2.d and Table 9-2.

10 Envelope Components

10.1 Surfaces

If different cross-sections through non steel-framed surfaces have different R-values, then the overall effective R-value for those surfaces must be calculated by first calculating the U-values of each cross-section and then pro-rating the U-value by the corresponding fraction of surface area as described in the calculation example in the MPP Technical Topic on *Calculating the U-values of a Surface* released for New Construction projects. Construction libraries of approved simulation tools may be used but must represent the combined thermal properties of the frame and cavity sections.

Effective R-values of metal frame constructions must be based on the tables in ASHRAE Standard 90.1-2013 reproduced in Appendix B of this document. If the pre-retrofit or post-retrofit conditions include insulation that has an intermediate R-value between those provided in the tables reproduced in Appendix B, then it is legitimate to interpolate between the framing/cavity R-values shown in the table. For example, if cavity insulation was determined to be R-20, but Appendix B only provides effective R-value for R-19 and R-21 cavity insulation for the given construction, then the average of these values may be used to model a surface with R-20 cavity insulation.

If gaps or other defects in the existing insulation are discovered, then its U-value must be de-rated. The de-rating procedure must be explained in the SAV-IT.

For portions of envelope where construction cannot be determined, the following assumptions may be used [53, p.29]:

- Old, poorly insulated / un-insulated wall – R-7
- Existing wall with average insulation – R-11
- Old, poorly insulated roof – R-11
- Existing roof with average insulation – R-19

Libraries available in the simulation tools include many common constructions. If the exact match for the existing or proposed construction cannot be found (for example, if there is no matching entry in the TREAT library), then the effective R-value for the surface, including de-rating for insulation defects, should be calculated outside of the simulation tool. If software (such as TREAT) does not allow entering custom constructions, then the surface with the closest effective R-value must be selected from the library. An attempt should be made to select a surface assembly which also has a similar thermal mass. For example, if the actual wall has block construction, it is preferable that the surface assembly selected from the library to represent this wall includes a block layer.

10.2 Fenestration

Existing Condition

The following properties must be used to model existing windows unless building-specific information is available [53, p.33]:

- Single pane windows: solar heat gain coefficient of 0.87 and U-value of 1.2 Btu/hr-SF-deg F
- Double pane windows: solar heat gain coefficient of 0.77 and U-value of 0.87 Btu/hr-SF-deg F

Proposed windows

Where scope of work calls for Energy Star windows, but the window manufacturer and model number is not specified, windows with U-0.28 and SHGC of 0.32 must be modeled, based on EPA minimum performance criteria for these products as of January 2016. If Energy Star windows are not available for the installation, then the actual properties of the specified window must be used.

11 Domestic Hot Water

11.1 Domestic Hot Water Heating Systems

Water Heating Equipment Categories

Residential Storage Water Heaters. This category includes electric heaters with input ≤ 12kW, gas heaters with input ≤ 75,000 BTU/h, and Oil heaters with input ≤ 105,000BTU/h, and storage capacity below 120 gallons.

Residential Instantaneous Water Heaters. This category includes gas heaters with input ≤ 75,000 BTU/h and oil heaters with input ≤ 210,000BTU/h.

Larger storage and instantaneous heaters are categorized as Non-residential.

Water Heating Equipment Performance Characteristics

Efficiency of water heating equipment is described through one or more of the following parameters:

Recovery Efficiency (RE) – heat absorbed by the water divided by the heat input to the heating unit during the period that water temperature is raised from inlet temperature to final temperature.

Recovery Rate – the amount of hot water that a residential water heater can continually produce, usually reported as flow rate in gallons per hour, which can be maintained for a specified temperature rise through the water heater.

Energy Factor (EF) – a measure of water heater overall efficiency determined by comparing the energy supplied in heated water to the total daily energy consumption of the water heater determined following DOE test procedure (10 CFR Part 430). The energy factor represents the fraction of all heat that was used to heat the water and maintain the temperature of that water in the face of standby losses that is still present in the water when it flows into the distribution system. It can never be higher than the thermal efficiency (see below).

Standby loss (SL), as applied to a tank type water heater under test conditions with no water flow, is the average hourly energy consumption divided by the average hourly heat energy contained in the stored water expressed as percent per hour. This may be converted to the average Btu/hr energy consumption required to maintain any water-air temperature difference by multiplying the percent by the temperature difference, 8.25 Btu/gal*F (a nominal specific heat for water), the tank capacity, and then dividing by 100.

Thermal Efficiency (Et) is the heat in the water flowing from the heater outlet divided by the heat input over a specific period of steady-state conditions. E_t accounts for the flue losses and the loss through the heater (boiler) jacket when boiler is firing.

Residential water heaters (storage and instantaneous) have performance specified by the energy factor, EF. Non-residential water heaters with storage volume <10 gal usually have thermal efficiency E_t available. Water heaters with larger storage capacity have standby loss ratings in addition to thermal efficiency. For unfired storage tanks, R-value of tank insulation is usually specified.

Evaluating Performance of the Existing Water Heaters

If performance of the existing water heater is unknown, combustion efficiency E_c should be measured. This value should be reduced by 3 percentage points to estimate thermal efficiency E_t [39].

$E_t=E_c-0.03$

For all instantaneous water heaters, assume negligible standby losses SL=0 and $EF=E_t$.

For residential water heaters, the following relationship may be used to estimate EF [38]:

EF=0.62-0.0019*Rated Storage Tank Volume

For commercial storage water heaters, use the following relationship to estimate SL [38]:

$$SL=\frac{Q}{800}+\frac{110}{\sqrt{V}}$$

Q[Btu/hr] - rated input power

V[gallons] - rated storage tank volume

eQuest requires that user enters Heat Input Ratio (HIR), tank volume in gallons, and tank UA [38]. These shall be determined as follows:

$HIR = 100/E_t$

$UA=SL*E_t/70$

Part load performance degradation must be based on default DOE2 performance curves. If simulation tool allows specifying water heater efficiency using different parameters, such as in TREAT, the same efficiency descriptors must be used for both baseline and proposed equipment where possible.

11.2 Existing DHW Demand

Overall Hot Water Consumption

The typical usage reported in the ASHRAE Applications Handbook is 14-54 gal/day/person. This is based on studies by Goldner and Price [46], which also demonstrate that a middle-range is 30 gal/day/person. This middle range is a good starting point for modeling. Demographic characteristics affecting hot water consumption are shown in Table 11-1.

Consumption above 54 gal/day/person is possible and was observed in some field studies [46]; however, if the model is using a high-water consumption to calibrate the model, then other possible factors affecting DHW usage must also be considered and justification must be included in the SAV-IT. Examples of factors affecting DHW demand and/or DHW energy consumption could be the DHW temperature, equipment efficiency, standby and distribution losses, and water leaks.

Table 11-1. Demographic Characteristics Correlating to DHW Consumption

Demographic Characteristics	**Average daily DHW usage (gallons/day per person)**
No occupants work Public assistance & low income (mix) Family & single parent households (mix) High % of Children Low income	54
Families Public assistance Singles Single-parent households	30
Couples Higher population density Middle income Seniors One person works, one stays home. All occupants work.	14

Note: These gallons are for DHW set at a temperature that will achieve 120°F at the tap.

Example: Site Conditions: A building has 15 apartments and is occupied mostly by low income families with children, with an average of three people per apartment.

Modeling Approach: Model hot water usage as being up to 54 gal/day-person*3 person/apt=162 gal/day/apartment. If proper calibration is still not achieved, then other factors affecting hot water heating energy consumption must be considered, including the DHW temperature, equipment efficiency, standby and distribution losses, water leaks, etc., before a further increase in hot water demand is modeled.

Allocation of demand to the correct end uses.

If the SAV-IT includes any measure that claims energy savings from reducing DHW consumption, then the base-building DHW consumption must be determined by calibrating the modeled DHW-related energy usage and by modeling all clothes washers and dishwashers on site. Modeling of existing clothes washers and dishwashers is required for modeling the installation of faucet aerators or showerheads. This will assist in validating the portion of total hot water consumption that is allocated to the non-appliance usage in the base-building model.

Clothes Washers

The assumed hot water consumption of existing clothes washers shall be determined as follows:

Determination of annual loads per washer. Use actual measured annual loads per washer when available, such as from coin income receipts. Otherwise, use the typical loads per washer as defined below.
Common area washers. The number of annual wash cycles per each washer located in a common area shall be determined per the formula below, or as 2,738 cycles/year per washer, whichever is less:

$$L_{common} = \frac{(Number\,of\,occupants\,with\,no\,washer\,in\,apt.)}{(Number\,of\,common\,area\,washers)} \times 36.5$$

L_{common} = Annual number of loads per each washer located in a shared common area laundry room [47].

Number of occupants with no washer in apartment is equal to the total number of residents at the site multiplied by the percentage of apartments that do not have in-unit clothes washers.

Number of common area washers is equal to the total number of washers located in common areas, not just the washers intended for replacement.

The number of loads per washer shall be equally distributed among all common area washers.

*In-apartment washers***.** The number of wash cycles for an in-apartment washing machine shall be modeled as being between 110 to 146 loads per occupant per year, multiplied by the number of occupants in that apartment [47] (the average number of occupants per apartment may be used). If the apartment has more than one washing machine, then the result should be divided by the number of washers to determine annual loads per washer.

Determination of hot water consumption per load. Hot water consumption per load shall be determined by multiplying the rated *total* gallons per load (hot and cold water combined) by the following percentages [48]:

- For non-EnergyStar® models, multiply the total rated water consumption per load by 29%.
- For EnergyStar® models, multiply the total rated water consumption per load by 21%.

Rated total gallons per load (hot and cold water combined) is equal to the rated water factor multiplied by the washer volume (cubic feet). If only the EPA rating for gallons per year is known, such as for residential models, then divide gallons per year by 392 to determine gallons per load (both hot and cold water).

Dishwashers

See discussion of dishwashers in Plug Loads section of this document.

11.3 DHW Improvements

Low-flow devices

If the installation of low-flow faucet aerators or showerheads is included in the SAV-IT, then:

- The flow rate of existing fixtures must be documented and based on measurements in a sample of apartments
- All existing dishwashers and clothes washers must also be modeled in the base-building model per these guidelines
- Post-retrofit flow rates much be modeled at a minimum of 1.5 gpm

If the simulation tool allows for explicit modeling of water heating energy savings associated with low-flow device installation (such as TREAT), then the tool functionality must be used to calculate the savings. If the reduction in annual hot water consumption due to low flow fixture installation must be calculated externally (for example, when using eQUEST) the DHW Reduction must be calculated as described below, and applied to the existing modeled flow rate:

DHW Reduction= $100\% - \left[36\% + 54\%\left(\frac{LFS}{PS}\right) + 10\%\left(\frac{LFF}{PF}\right)\right]$

DHW Reduction = % reduction in annual DHW usage

LFS [GPM] = average weighted flow rate of low-flow showerheads

PS [GPM] = average weighted flow rate of pre-retrofit showerhead

LFF [GPM] = average weighted flow rate of low-flow faucet

PF [GPM] = average weighted flow rate of pre-retrofit faucet

The calculation is based on the study by Hwang et al. http://enduse.lbl.gov/Info/LBNL-34046.pdf, that investigated volume-dominated (i.e., filling containers) versus flow-dominated water loads (i.e., showers, hand-washing). The flow rates of existing fixtures that are being replaced must be measured and included in the SAV-IT.

EnergyStar® clothes washers.

Annual loads per washer shall be modeled as described in Section 12.2. Hot water consumption per load for new EnergyStar® models shall be determined by multiplying the rated *total* gallons per load (hot and cold water combined) by 21% [48].

EnergyStar® dishwashers.

Simulation guidelines for dishwasher DHW consumption and savings are shown in the Plug Loads section of this document.

12 Elevators

12.1 Existing Conditions

Elevator energy consumption for a specific building is difficult to estimate. Even when the type and size of the motor can be determined, the actual consumption depends on many variables, including building type, population type, hoist mechanism, weights of the load and counter balance, speed of travel, etc. Best practice for determining the electricity consumption of a specific elevator is to monitor its electricity consumption for several weeks using data logging equipment that can record actual energy consumption.

If actual electricity consumption cannot be determined through data monitoring, pre-retrofit elevator energy use should be modeled as 2% - 7% of whole building electricity use (excluding electric heating and/or electric hot water), unless additional documentation is provided.

Table 12-1. The Relative Efficiency Between Different Types of Elevators

Elevator Type	
DC Motor with Motor Generator Set	Least Efficient
DC Motor with Rectifier	
AC Geared Motor	
AC Geared Motor with VVVF	
AC Gearless Motor with VVVF	
AC Gearless Motor with VVVF and Regenerative Braking	Most Efficient

The MPP Technical Topic, *Elevator Energy Use and Other Essentials* (see Appendix H), provides a more detail review of the different types of elevators and their associated energy use.

12.2 Improvements

Total projected electrical savings from elevator replacement, motor and/or controls, should not exceed more than 60% of the total elevator electricity consumption pre-retrofit. This maximum reduction assumes that the least efficient type of elevator (DC Motor with Motor Generator Set) is being replaced with the most efficient type of elevator (AC Gearless Motor with VVVF and Regenerative Braking). See Table 12-1 above for the relative efficiencies between different types of elevators. If savings are greater than 60%, they must be clearly documented and supported.

13 Plug Loads

13.1 Existing Conditions

With the exception of refrigerators and dishwashers, kitchen appliances that *are not targeted for replacement* in the SAV-IT may be modeled using the appropriate software defaults or as specified for pre-retrofit conditions in the Improvements section below. Usage of such appliances may be adjusted ±30% as part of model calibration.

The provider must sample a reasonable number of existing refrigerators, and must use data from the manufacturer, the appliance Energy Guide label, the Association of Home Appliance Manufacturers (AHAM) directory, or from the online databases such as http://www.kouba-cavallo.com/refrig1.html based on the actual models found in the building. If data on energy consumption based on the model numbers is not available in the sources listed above, the provider must monitor a reasonable sample of refrigerators.

Loads from miscellaneous small kitchen appliances, home entertainment equipment, computers, etc, *may* be combined into one category and modeled as 1.37 kWh/yr per square foot of finished floor area of living space [26]. This usage may be adjusted ±30% as part of the process of calibrating the model to utility bills. Alternatively, the actual equipment may be modeled as recorded during the audit and documented usage assumptions.

Miscellaneous electric loads in non-apartment spaces *may* either be based on Table 13-1 [27] or loads from actual equipment found during the audit and documented usage assumptions.

Table 13-1. Miscellaneous Electric Loads in Non-Apartment Spaces

Space Type	Annual Electricity Usage
Corridors, restrooms, stairs and support areas	0.7 kWh/SF
Offices	4.9 kWh/SF
All Other	1.0 kWh/SF

13.2 Improvements

If the SAV-IT includes installation of EnergyStar® refrigerators, the post-retrofit usage must be based on data from http://www.energystar.gov/index.cfm?fuseaction=refrig.display_products_html.

If the SAV-IT includes the installation of EnergyStar® dishwashers, then pre- and post-retrofit usage must be based on data for the existing and proposed models from the manufacturer, taken from the appliance Energy Guide label, or as published by Association of Home Appliance Manufacturers (AHAM). If the data for the pre- or post-retrofit dishwasher is unknown, then values from Table 13.2 may be used, based on the calculator accessible from http://www.energystar.gov/index.cfm?c=dishwash.pr_dishwashers. The usage is based on 215 cycles per year.

Table 13-2. Pre- and Post-Retrofit Energy Usage for Dishwashers

Annual Fuel Usage per Unit	Energy Star® Dishwasher	Existing Dishwasher
Electricity consumption	187 kWh	264 kWh
Water Heating Gas / Electric	6 therm /144 kWh	19 therm / 203 kWh

If the SAV-IT includes the installation of EnergyStar® clothes washer, then information about the existing and proposed washer models must be provided, including manufacturer, model number, the rated total ***motor*** electricity consumption as listed by the manufacturer or current EnergyStar® publications, and documentation of the typical kWh consumed per cycle for each model. The associated water heating savings shall be modeled as described in Section 11.

14 References

[1] Emmerich, S. J. and Persily, A. K., (1998), "Energy Impacts of Infiltration & Ventilation in U.S. Office Buildings Using Multizone Airflow Simulation," Proceedings of IAQ and Energy 98 Conf., New Orleans, LA 22-27 Oct. 1998. IAQ and Energy 98, pages 191-203.

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[11/2017]

Appendix A: Lighting Power Tables

The following tables are from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures Version 5, July 7, 2017 [55] and show typical lighting power for various fixtures and their ballast/lamp combinations.

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
CF10/2D	CFD10W	Compact Fluorescent, 2D, (1) 10W lamp	Mag-STD	1	10	16
CF10/2D-L	CFD10W	Compact Fluorescent, 2D, (1) 10W lamp	Electronic	1	10	12
CF11/1	CF11W	Compact Fluorescent, (1) 11W lamp	Mag-STD	1	11	13
CF11/2	CF11W	Compact Fluorescent, (2) 11W lamp	Mag-STD	2	11	26
CF16/2D	CFD16W	Compact Fluorescent, 2D, (1) 16W lamp	Mag-STD	1	16	26
CF16/2D-L	CFD16W	Compact Fluorescent, 2D, (1) 16W lamp	Electronic	1	16	18
CF18/3-L	CF18W	Compact Fluorescent, (3) 18W lamp	Electronic	3	18	60
CF21/2D	CFD21W	Compact Fluorescent, 2D, (1) 21W lamp	Mag-STD	1	21	26
CF21/2D-L	CFD21W	Compact Fluorescent, 2D, (1) 21W lamp	Electronic	1	21	22
CF23/1	CF23W	Compact Fluorescent, (1) 23W lamp	Mag-STD	1	23	29
CF23/1-L	CF23W	Compact Fluorescent, (1) 23W lamp	Electronic	1	23	25
CF26/3-L	CF26W	Compact Fluorescent, (3) 26W lamp	Electronic	3	26	82
CF26/4-L	CF26W	Compact Fluorescent, (4) 26W lamp	Electronic	4	26	108
CF26/6-L	CF26W	Compact Fluorescent, (6) 26W lamp	Electronic	6	26	162
CF26/8-L	CF26W	Compact Fluorescent, (8) 26W lamp	Electronic	8	26	216
CF28/2D	CFD28W	Compact Fluorescent, 2D, (1) 28W lamp	Mag-STD	1	28	35
CF28/2D-L	CFD28W	Compact Fluorescent, 2D, (1) 28W lamp	Electronic	1	28	28
CF32/3-L	CF32W	Compact Fluorescent, (3) 32W lamp	Electronic	3	32	114

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
CF32/4-L	CF32W	Compact Fluorescent, (4) 32W lamp	Electronic	4	32	152
CF32/6-L	CF32W	Compact Fluorescent, (6) 32W lamp	Electronic	6	32	228
CF32/8-L	CF32W	Compact Fluorescent, (8) 32W lamp	Electronic	8	32	304
CF38/2D	CFD38W	Compact Fluorescent, 2D, (1) 38W lamp	Mag-STD	1	38	46
CF38/2D-L	CFD38W	Compact Fluorescent, 2D, (1) 38W lamp	Electronic	1	38	36
CF42/1-L	CF42W	Compact Fluorescent, (1) 42W lamp	Electronic	1	42	48
CF42/2-L	CF42W	Compact Fluorescent, (2) 42W lamp	Electronic	2	42	100
CF42/3-L	CF42W	Compact Fluorescent, (3) 42W lamp	Electronic	3	42	141
CF42/4-L	CF42W	Compact Fluorescent, (4) 42W lamp	Electronic	4	42	188
CF42/6-L	CF42W	Compact Fluorescent, (6) 42W lamp	Electronic	6	42	282
CF42/8-L	CF42W	Compact Fluorescent, (8) 42W lamp	Electronic	8	42	376
CFQ10/1	CFQ10W	Compact Fluorescent, quad, (1) 10W lamp	Mag-STD	1	10	15
CFQ13/1	CFQ13W	Compact Fluorescent, quad, (1) 13W lamp	Mag-STD	1	13	17
CFQ13/1-L	CFQ13W	Compact Fluorescent, quad, (1) 13W lamp, BF=1.05	Electronic	1	13	15
CFQ13/2	CFQ13W	Compact Fluorescent, quad, (2) 13W lamp	Mag-STD	2	13	31
CFQ13/2-L	CFQ13W	Compact Fluorescent, quad, (2) 13W lamp, BF=1.0	Electronic	2	13	28
CFQ13/3	CFQ13W	Compact Fluorescent, quad, (3) 13W lamp	Mag-STD	3	13	48
CFQ15/1	CFQ15W	Compact Fluorescent, quad, (1) 15W lamp	Mag-STD	1	15	20
CFQ17/1	CFQ17W	Compact Fluorescent, quad, (1) 17W lamp	Mag-STD	1	17	24
CFQ17/2	CFQ17W	Compact Fluorescent, quad, (2) 17W lamp	Mag-STD	2	17	48
CFQ18/1	CFQ18W	Compact Fluorescent, quad, (1) 18W lamp	Mag-STD	1	18	26
CFQ18/1-L	CFQ18W	Compact Fluorescent, quad, (1) 18W lamp, BF=1.0	Electronic	1	18	20

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
CFQ18/2	CFQ18W	Compact Fluorescent, quad, (2) 18W lamp	Mag-STD	2	18	45
CFQ18/2-L	CFQ18W	Compact Fluorescent, quad, (2) 18W lamp, BF=1.0	Electronic	2	18	38
CFQ18/4	CFQ18W	Compact Fluorescent, quad, (4) 18W lamp	Mag-STD	2	18	90
CFQ20/1	CFQ20W	Compact Fluorescent, quad, (1) 20W lamp	Mag-STD	1	20	23
CFQ20/2	CFQ20W	Compact Fluorescent, quad, (2) 20W lamp	Mag-STD	2	20	46
CFQ22/1	CFQ22W	Compact Fluorescent, quad, (1) 22W lamp	Mag-STD	1	22	24
CFQ22/2	CFQ22W	Compact Fluorescent, quad, (2) 22W lamp	Mag-STD	2	22	48
CFQ22/3	CFQ22W	Compact Fluorescent, quad, (3) 22W lamp	Mag-STD	3	22	72
CFQ25/1	CFQ25W	Compact Fluorescent, quad, (1) 25W lamp	Mag-STD	1	25	33
CFQ25/2	CFQ25W	Compact Fluorescent, quad, (2) 25W lamp	Mag-STD	2	25	66
CFQ26/1	CFQ26W	Compact Fluorescent, quad, (1) 26W lamp	Mag-STD	1	26	33
CFQ26/1-L	CFQ26W	Compact Fluorescent, quad, (1) 26W lamp, BF=0.95	Electronic	1	26	27
CFQ26/2	CFQ26W	Compact Fluorescent, quad, (2) 26W lamp	Mag-STD	2	26	66
CFQ26/2-L	CFQ26W	Compact Fluorescent, quad, (2) 26W lamp, BF=0.95	Electronic	2	26	50
CFQ26/3	CFQ26W	Compact Fluorescent, quad, (3) 26W lamp	Mag-STD	3	26	99
CFQ26/6-L	CFQ26W	Compact Fluorescent, quad, (6) 26W lamp, BF=0.95	Electronic	6	26	150
CFQ28/1	CFQ28W	Compact Fluorescent, quad, (1) 28W lamp	Mag-STD	1	28	33
CFQ9/1	CFQ9W	Compact Fluorescent, quad, (1) 9W lamp	Mag-STD	1	9	14
CFQ9/2	CFQ9W	Compact Fluorescent, quad, (2) 9W lamp	Mag-STD	2	9	23
CFS7/1	CFS7W	Compact Fluorescent, spiral, (1) 7W lamp	Electronic	1	7	7
CFS9/1	CFS9W	Compact Fluorescent, spiral, (1) 9W lamp	Electronic	1	9	9
CFS11/1	CFS11W	Compact Fluorescent, spiral, (1) 11W lamp	Electronic	1	11	11

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
CFS15/1	CFS15W	Compact Fluorescent, spiral, (1) 15W lamp	Electronic	1	15	15
CFS20/1	CFS20W	Compact Fluorescent, spiral, (1) 20W lamp	Electronic	1	20	20
CFS23/1	CFS23W	Compact Fluorescent, spiral, (1) 23W lamp	Electronic	1	23	23
CFS27/1	CFS27W	Compact Fluorescent, spiral, (1) 27W lamp	Electronic	1	27	27
CFT13/1	CFT13W	Compact Fluorescent, twin, (1) 13W lamp	Mag-STD	1	13	17
CFT13/2	CFT13W	Compact Fluorescent, twin, (2) 13W lamp	Mag-STD	2	13	31
CFT13/3	CFT13W	Compact Fluorescent, twin, (3) 13 W lamp	Mag-STD	3	13	48
CFT18/1	CFT18W	Compact Fluorescent, long twin., (1) 18W lamp	Mag-STD	1	18	24
CFT22/1	CFT22W	Compact Fluorescent, twin, (1) 22W lamp	Mag-STD	1	22	27
CFT22/2	CFT22W	Compact Fluorescent, twin, (2) 22W lamp	Mag-STD	2	22	54
CFT22/4	CFT22W	Compact Fluorescent, twin, (4) 22W lamp	Mag-STD	4	22	108
CFT24/1	CFT24W	Compact Fluorescent, long twin, (1) 24W lamp	Mag-STD	1	24	32
CFT28/1	CFT28W	Compact Fluorescent, twin, (1) 28W lamp	Mag-STD	1	28	33
CFT28/2	CFT28W	Compact Fluorescent, twin, (2) 28W lamp	Mag-STD	2	28	66
CFT32/1-L	CFM32W	Compact Fluorescent, twin or multi, (1) 32W lamp	Electronic	1	32	34
CFT32/2-L	CFM32W	Compact Fluorescent, twin or multi, (2) 32W lamp	Electronic	2	32	62
CFT32/6-L	CFM32W	Compact Fluorescent, twin or multi, (2) 32W lamp	Electronic	6	32	186
CFT36/1	CFT36W	Compact Fluorescent, long twin, (1) 36W lamp	Mag-STD	1	36	51
CFT36/4-BX	CFT36W	Compact Fluorescent, Biax, (4) 36W lamp	Electronic	4	36	148
CFT36/6-BX	CFT36W	Compact Fluorescent, Biax, (6) 36W lamp	Electronic	6	36	212
CFT36/6-L	CFT36W	Compact Fluorescent, long Twin, (6) 36W lamp	Electronic	6	36	198

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
CFT36/6-L	CFT36W	Compact Fluorescent, long Twin, (6) 36W lamp/ High Ballast Factor	Electronic	6	36	210
CFT36/8-BX	CFT36W	Compact Fluorescent, Biax, (8) 36W lamp	Electronic	8	36	296
CFT36/8-L	CFT36W	Compact Fluorescent, long Twin, (8) 36W lamp	Electronic	8	36	270
CFT36/8-L	CFT36W	Compact Fluorescent, long Twin, (8) 36W lamp/ High Ballast Factor	Electronic	8	36	286
CFT36/9-BX	CFT36W	Compact Fluorescent, Biax, (9) 36W lamp	Electronic	9	36	318
CFT40/1	CFT40W	Compact Fluorescent, twin, (1) 40W lamp	Mag-STD	1	40	46
CFT40/12-BX	CFT40W	Compact Fluorescent, Biax, (12) 40W lamp	Electronic	12	40	408
CFT40/1-BX	CFT40W	Compact Fluorescent, Biax, (1) 40W lamp	Electronic	1	40	46
CFT40/1-L	CFT40W	Compact Fluorescent, long twin, (1) 40W lamp	Electronic	1	40	43
CFT40/2	CFT40W	Compact Fluorescent, twin, (2) 40W lamp	Mag-STD	2	40	85
CFT40/2-BX	CFT40W	Compact Fluorescent, Biax, (2) 40W lamp	Electronic	2	40	72
CFT40/2-L	CFT40W	Compact Fluorescent, long twin, (2) 40W lamp	Electronic	2	40	72
CFT40/3	CFT40W	Compact Fluorescent, twin, (3) 40 W lamp	Mag-STD	3	40	133
CFT40/3-BX	CFT40W	Compact Fluorescent, Biax, (3) 40W lamp	Electronic	3	40	102
CFT40/3-L	CFT40W	Compact Fluorescent, long twin, (3) 40W lamp	Electronic	3	40	105
CFT40/4-BX	CFT40W	Compact Fluorescent, Biax, (4) 40W lamp	Electronic	4	40	144
CFT40/5-BX	CFT40W	Compact Fluorescent, Biax, (5) 40W lamp	Electronic	5	40	190
CFT40/6-BX	CFT40W	Compact Fluorescent, Biax, (6) 40W lamp	Electronic	6	40	204
CFT40/6-L	CFT40W	Compact Fluorescent, long Twin, (6) 40W lamp	Electronic	6	40	220
CFT40/6-L	CFT40W	Compact Fluorescent, long Twin, (6) 40W lamp/ High Ballast Factor	Electronic	6	40	233

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
CFT40/8-BX	CFT40W	Compact Fluorescent, Biax, (8) 40W lamp	Electronic	8	40	288
CFT40/8-L	CFT40W	Compact Fluorescent, long Twin, (8) 40W lamp	Electronic	8	40	300
CFT40/8-L	CFT40W	Compact Fluorescent, long Twin, (8) 40W lamp/ High Ballast Factor	Electronic	8	40	340
CFT40/9-BX	CFT40W	Compact Fluorescent, Biax, (9) 40W lamp	Electronic	9	40	306
CFT5/1	CFT5W	Compact Fluorescent, twin, (1) 5W lamp	Mag-STD	1	5	9
CFT5/2	CFT5W	Compact Fluorescent, twin, (2) 5W lamp	Mag-STD	2	5	18
CFT50/12-BX	CFT50W	Compact Fluorescent, Biax, (12) 50W lamp	Electronic	12	50	648
CFT50/1-BX	CFT50W	Compact Fluorescent, Biax, (1) 50W lamp	Electronic	1	50	54
CFT50/2-BX	CFT50W	Compact Fluorescent, Biax, (2) 50W lamp	Electronic	2	50	108
CFT50/3-BX	CFT50W	Compact Fluorescent, Biax, (3) 50W lamp	Electronic	3	50	162
CFT50/4-BX	CFT50W	Compact Fluorescent, Biax, (4) 50W lamp	Electronic	4	50	216
CFT50/5-BX	CFT50W	Compact Fluorescent, Biax, (5) 50W lamp	Electronic	5	50	270
CFT50/6-BX	CFT50W	Compact Fluorescent, Biax, (6) 50W lamp	Electronic	6	50	324
CFT50/8-BX	CFT50W	Compact Fluorescent, Biax, (8) 50W lamp	Electronic	8	50	432
CFT50/9-BX	CFT50W	Compact Fluorescent, Biax, (9) 50W lamp	Electronic	9	50	486
CFT55/12-BX	CFT55W	Compact Fluorescent, Biax, (12) 55W lamp	Electronic	12	55	672
CFT55/1-BX	CFT55W	Compact Fluorescent, Biax, (1) 55W lamp	Electronic	1	55	56
CFT55/2-BX	CFT55W	Compact Fluorescent, Biax, (2) 55W lamp	Electronic	2	55	112
CFT55/3-BX	CFT55W	Compact Fluorescent, Biax, (3) 55W lamp	Electronic	3	55	168
CFT55/4-BX	CFT55W	Compact Fluorescent, Biax, (4) 55W lamp	Electronic	4	55	224
CFT55/5-BX	CFT55W	Compact Fluorescent, Biax, (5) 55W lamp	Electronic	5	55	280

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
CFT55/6-BX	CFT55W	Compact Fluorescent, Biax, (6) 55W lamp	Electronic	6	55	336
CFT55/6-L	CFT55W	Compact Fluorescent, long Twin, (6) 55W lamp	Electronic	6	55	352
CFT55/6-L	CFT55W	Compact Fluorescent, long Twin, (6) 55W lamp/ High Ballast Factor	Electronic	6	55	373
CFT55/8-BX	CFT55W	Compact Fluorescent, Biax, (8) 55W lamp	Electronic	8	55	448
CFT55/8-L	CFT55W	Compact Fluorescent, long Twin, (8) 55W lamp	Electronic	8	55	468
CFT55/8-L	CFT55W	Compact Fluorescent, long Twin, (8) 55W lamp/ High Ballast Factor	Electronic	8	55	496
CFT55/9-BX	CFT55W	Compact Fluorescent, Biax, (9) 55W lamp	Electronic	9	55	504
CFT7/1	CFT7W	Compact Fluorescent, twin, (1) 7W lamp	Mag-STD	1	7	10
CFT7/2	CFT7W	Compact Fluorescent, twin, (2) 7W lamp	Mag-STD	2	7	21
CFT9/1	CFT9W	Compact Fluorescent, twin, (1) 9W lamp	Mag-STD	1	9	11
CFT9/2	CFT9W	Compact Fluorescent, twin, (2) 9W lamp	Mag-STD	2	9	23
CFT9/3	CFT9W	Compact Fluorescent, twin, (3) 9W lamp	Mag-STD	3	9	34
1.51LS	F15T8	Fluorescent, (1) 18" T8 lamp	Mag-STD	1	15	19
F1.51SS	F15T12	Fluorescent, (1) 18" T12 lamp	Mag-STD	1	15	19
F1.52LS	F15T8	Fluorescent, (2) 18" T8 lamp	Mag-STD	2	15	36
F1.52SS	F15T12	Fluorescent, (2) 18", T12 lamp	Mag-STD	2	15	36
F21HS	F24T12/HO	Fluorescent, (1) 24", HO lamp	Mag-STD	1	35	62
F21ILL	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	17	20
F21ILL/T2	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	17	17

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F21ILL/T2-R	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 2 Lamp Ballast	Electronic	1	17	15
F21ILL/T3	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	17	16
F21ILL/T3-R	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 3 Lamp Ballast	Electronic	1	17	14
F21ILL/T4	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	17	15
F21ILL/T4-R	F17T8	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 4 Lamp Ballast	Electronic	1	17	14
F21ILX-R	F17T8	Fluorescent, (1) 24", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	1	17	15
F21ILX	F17T8	Fluorescent, (1) 24", T-8 lamp, HE Instant/Program Start Ballast, NLO (BF: .85- .95)	Electronic	1	17	16
F21LL	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	1	17	16
F21LL/T2	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	17	16
F21LL/T3	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	17	17
F21LL/T4	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	17	17
F21LL-R	F17T8	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	1	17	15
F21LS	F17T8	Fluorescent, (1) 24", T8 lamp, Standard Ballast	Mag-STD	1	17	24
F21GL	F24T5	Fluorescent, (1) 24", STD T5 lamp	Electronic	1	14	18
F21SE	F20T12	Fluorescent, (1) 24", STD lamp	Mag-ES	1	20	26

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F21SS	F20T12	Fluorescent, (1) 24", STD lamp	Mag-STD	1	20	28
F21GHL	F24T5/HO	Fluorescent, (1) 24", STD HO T5 lamp	Electronic	1	24	29
F22SHS	F24T12/HO	Fluorescent, (2) 24", HO lamp	Mag-STD	2	35	90
F22GHL	F24T5/HO	Fluorescent, (2) 24", STD HO T5 lamp	Electronic	2	24	55
F22ILE	F17T8	Fluorescent, (2) 24", T-8 Instant Start lamp, Energy Saving Magnetic Ballast	Mag-ES	2	17	45
F22ILL	F17T8	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	17	33
F22ILL/T4	F17T8	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	17	31
F22ILL/T4-R	F17T8	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 4 Lamp Ballast	Electronic	2	17	28
F22ILL-R	F17T8	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	17	29
F22ILX-R	F17T8	Fluorescent, (2) 24", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	2	17	27
F22ILX	F17T8	Fluorescent, (2) 24", T-8 lamp, HE Instant/Program Start Ballast, NLO (BF: .85- .95)	Electronic	2	17	31
F22LL	F17T8	Fluorescent, (2) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	2	17	31
F22LL/T4	F17T8	Fluorescent, (2) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	17	34
F22LL-R	F17T8	Fluorescent, (2) 24", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	2	17	28
F22GL	F24T5	Fluorescent, (2) 24", STD T5 lamp	Electronic	2	14	35
F22SE	F20T12	Fluorescent, (2) 24", STD lamp	Mag-ES	2	20	51

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F22SS	F20T12	Fluorescent, (2) 24", STD lamp	Mag-STD	2	20	56
F23ILL	F17T8	Fluorescent, (3) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	17	47
F23ILL-H	F17T8	Fluorescent, (3) 24", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	3	17	49
F23ILL-R	F17T8	Fluorescent, (3) 24", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	17	43
F23ILX	F17T8	Fluorescent, (3) 24", T-8 lamp, HE Instant/Program Start Ballast, NLO (BF: .85- .95)	Electronic	3	17	45
F23ILX-R	F17T8	Fluorescent, (3) 24", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	3	17	40
F23LL	F17T8	Fluorescent, (3) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	3	17	52
F23LL-R	F17T8	Fluorescent, (3) 24", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	3	17	41
F23SE	F20T12	Fluorescent, (3) 24", STD lamp	Mag-ES	3	20	77
F23SS	F20T12	Fluorescent, (3) 24", STD lamp	Mag-STD	3	20	84
F24ILL	F17T8	Fluorescent, (4) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	17	61
F24ILL-R	F17T8	Fluorescent, (4) 24", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	17	55
F24ILX-R	F17T8	Fluorescent, (4) 24", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	4	17	53
F24LL	F17T8	Fluorescent, (4) 24", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	4	17	68
F24LL-R	F17T8	Fluorescent, (4) 24", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	4	17	57

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F24SE	F20T12	Fluorescent, (4) 24", STD lamp	Mag-ES	4	20	102
F24SS	F20T12	Fluorescent, (4) 24", STD lamp	Mag-STD	4	20	112
F26SE	F20T12	Fluorescent, (6) 24", STD lamp	Mag-ES	6	20	153
F26SS	F20T12	Fluorescent, (6) 24", STD lamp	Mag-STD	6	20	168
F31EE	F30T12/ES	Fluorescent, (1) 36", ES lamp	Mag-ES	1	25	38
F31EE/T2	F30T12/ES	Fluorescent, (1) 36", ES lamp, Tandem wired	Mag-ES	1	25	33
F31EL	F30T12/ES	Fluorescent, (1) 36", ES lamp	Electronic	1	25	26
F31ES	F30T12/ES	Fluorescent, (1) 36", ES lamp	Mag-STD	1	25	42
F31ES/T2	F30T12/ES	Fluorescent, (1) 36", ES lamp, Tandem wired	Mag-STD	1	25	37
F31ILL	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	25	26
F31ILL/T2	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	25	23
F31ILL/T2-H	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, HLO (BF: .96-1.1), Tandem 2 Lamp Ballast	Electronic	1	25	24
F31ILL/T2-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	25	23
F31ILL/T3	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	25	22
F31ILL/T3-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 3 Lamp Ballast	Electronic	1	25	22
F31ILL/T4	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	25	22
F31ILL/T4-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 4 Lamp Ballast	Electronic	1	25	22

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F31ILL-H	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	25	28
F31ILL-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	25	27
F31LL	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	1	25	24
F31LL/T2	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	25	23
F31LL/T3	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	25	24
F31LL/T4	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	25	22
F31LL-H	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	1	25	26
F31LL-R	F25T8	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	1	25	23
F31ILX-R	F25T8	Fluorescent, (1) 36", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	1	25	21
F31SE/T2	F30T12	Fluorescent, (1) 36", STD lamp, Tandem wired	Mag-ES	1	30	37
F31GHL	F36T5/HO	Fluorescent, (1) 36", STD HO T5 lamp	Electronic	1	39	43
F31SHS	F36T12/HO	Fluorescent, (1) 36", HO lamp	Mag-STD	1	50	70
F31SL	F30T12	Fluorescent, (1) 36", STD lamp	Electronic	1	30	31
F31GL	F36T5	Fluorescent, (1) 36", STD T5 lamp	Electronic	1	21	27
F31SS	F30T12	Fluorescent, (1) 36", STD lamp	Mag-STD	1	30	46
F31SS/T2	F30T12	Fluorescent, (1) 36", STD lamp, Tandem wired	Mag-STD	1	30	41

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F32EE	F30T12/ES	Fluorescent, (2) 36", ES lamp	Mag-ES	2	25	66
F32EL	F30T12/ES	Fluorescent, (2) 36", ES lamp	Electronic	2	25	50
F32ES	F30T12/ES	Fluorescent, (2) 36", ES lamp	Mag-STD	2	25	73
F32ILL	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	25	46
F32ILL/T4	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	25	44
F32ILL/T4-R	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 4 Lamp Ballast	Electronic	2	25	43
F32ILL-H	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	2	25	48
F32ILL-R	F25T8	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	25	46
F32ILX-R	F25T8	Fluorescent, (2) 36", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	2	25	39
F32LE	F25T8	Fluorescent, (2) 36", T-8 lamp	Mag-ES	2	25	65
F32LL	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	2	25	46
F32LL/T4	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	25	45
F32LL-H	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	2	25	50
F32LL-R	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	2	25	42
F32LL-V	F25T8	Fluorescent, (2) 36", T-8 lamp, Rapid Start Ballast, VHLO (BF>1.1)	Electronic	2	25	70

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F32SE	F30T12	Fluorescent, (2) 36", STD lamp	Mag-ES	2	30	74
F32GHL	F36T5/HO	Fluorescent, (1) 36", STD HO T5 lamp	Electronic	2	39	85
F32SHS	F36T12/HO	Fluorescent, (2) 36", HO, lamp	Mag-STD	2	50	114
F32SL	F30T12	Fluorescent, (2) 36", STD lamp	Electronic	2	30	58
F32GL	F36T5	Fluorescent, (1) 36", STD T5 lamp	Electronic	2	21	52
F32SS	F30T12	Fluorescent, (2) 36", STD lamp	Mag-STD	2	30	81
F33ES	F30T12/ES	Fluorescent, (3) 36", ES lamp	Mag-STD	3	25	115
F33ILL	F25T8	Fluorescent, (3) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	25	67
F33ILL-R	F25T8	Fluorescent, (3) 36", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	25	66
F33LL	F25T8	Fluorescent, (3) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	3	25	72
F33LL-R	F25T8	Fluorescent, (3) 36", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	3	25	62
F33SE	F30T12	Fluorescent, (3) 36", STD lamp, (1) STD ballast and (1) ES ballast	Mag-ES	3	30	120
F33SS	F30T12	Fluorescent, (3) 36", STD lamp	Mag-STD	3	30	127
F34ILL	F25T8	Fluorescent, (4) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	25	87
F34ILL-R	F25T8	Fluorescent, (4) 36", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	25	86
F34LL	F25T8	Fluorescent, (4) 36", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	4	25	89
F34LL-R	F25T8	Fluorescent, (4) 36", T-8 lamp, Rapid Start Ballast, RLO	Electronic	4	25	84

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
		(BF<0.85)				
F34SE	F30T12	Fluorescent, (4) 36", STD lamp	Mag-ES	4	30	148
F34SL	F30T12	Fluorescent, (4) 36", STD lamp	Electronic	4	30	116
F34SS	F30T12	Fluorescent, (4) 36", STD lamp	Mag-STD	4	30	162
F36EE	F30T12/ES	Fluorescent, (6) 36", ES lamp	Mag-ES	6	25	198
F36ILL-R	F25T8	Fluorescent, (6) 36", T-8 lamp, Instant Start Ballast, RLO (BF<.85)	Electronic	6	25	134
F36SE	F30T12	Fluorescent, (6) 36", STD lamp	Mag-ES	6	30	238
F40EE/D1	None	Fluorescent, (0) 48" lamp, Completely delamped fixture with (1) hot ballast	Mag-ES	0	0	4
F40EE/D2	None	Fluorescent, (0) 48" lamp, Completely delamped fixture with (2) hot ballast	Mag-ES	0	0	8
F41EE	F40T12/ES	Fluorescent, (1) 48", ES lamp	Mag-ES	1	34	43
F41EE/D2	F40T12/ES	Fluorescent, (1) 48", ES lamp, 2 ballast	Mag-ES	1	34	43
F41EE/T2	F40T12/ES	Fluorescent, (1) 48", ES lamp, tandem wired, 2-lamp ballast	Mag-ES	1	34	36
F41EHS	F48T12/HO/ES	Fluorescent, (1) 48", ES HO lamp	Mag-STD	1	55	80
F41EIS	F48T12/ES	Fluorescent, (1) 48" ES Instant Start lamp. Magnetic ballast	Mag-STD	1	30	51
F41EL	F40T12/ES	Fluorescent, (1) 48", T12 ES lamp, Electronic Ballast	Electronic	1	34	32
F41EL/T2	F40T12/ES	Fluorescent, (1) 48", T-12 ES lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	34	32
F41ES	F40T12/ES	Fluorescent, (1) 48", ES lamp	Mag-STD	1	34	50
F41EVS	F48T12/VHO/ES	Fluorescent, (1) 48", VHO ES lamp	Mag-STD	1	123	
F41IAL	F25T12	Fluorescent, (1) 48", F25T12 lamp, Instant Start Ballast	Electronic	1	25	25

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F41IAL/T2-R	F25T12	Fluorescent, (1) 48", F25T12 lamp, Instant Start, Tandem 2-Lamp Ballast, RLO (BF<0.85)	Electronic	1	25	19
F41IAL/T3-R	F25T12	Fluorescent, (1) 48", F25T12 lamp, Instant Start, Tandem 3-Lamp Ballast, RLO (BF<0.85)	Electronic	1	25	20
F41ILL	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	32	31
F41SILL	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	30	28
F41SILL/T2	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	30	27
F41SILL/T3	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	30	27
F41SILL/T4	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	30	26
F41SILL-R	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	30	25
F41SILL/T2-R	F30T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 2 Lamp Ballast	Electronic	1	30	24
F41SILL/T3-R	F30T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 3 Lamp Ballast	Electronic	1	30	24
F41SILL/T4-R	F30T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	1	30	23
F41SILL-H	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	30	37
F41SILL/T2-H	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 2 Lamp Ballast	Electronic	1	30	36
F41SILL/T3-H	F30T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO	Electronic	1	30	36

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
		(BF:.96-1.1), Tandem 3 Lamp Ballast				
F41SSILL	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	28	26
F41SSILL/T2	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	28	25
F41SSILL/T3	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	28	25
F41SSILL/T4	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	28	24
F41SSILL-R	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	28	23
F41SSILL/T2-R	F28T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 2 Lamp Ballast	Electronic	1	28	22
F41SSILL/T3-R	F28T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 3 Lamp Ballast	Electronic	1	28	22
F41SSILL/T4-R	F28T8	Fluorescent, (1) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	1	28	21
F41SSILL-H	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	28	33
F41SSILL/T2-H	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 2 Lamp Ballast	Electronic	1	28	32
F41SSILL/T3-H	F28T8	Fluorescent, (1) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 3 Lamp Ballast	Electronic	1	28	32
F41ILL/T2	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	32	30
F41ILL/T2-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 2 Lamp Ballast	Electronic	1	32	33

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F41ILL/T2-R	F32T8	Fluorescent, (1) 48", T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 2 Lamp Ballast	Electronic	1	32	26
F41ILL/T3	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	32	30
F41ILL/T3-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1), Tandem 3 Lamp Ballast	Electronic	1	32	31
F41ILL/T3-R	F32T8	Fluorescent, (1) 48", T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 3 Lamp Ballast	Electronic	1	32	26
F41ILL/T4	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	32	28
F41ILL/T4-R	F32T8	Fluorescent, (1) 48", T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	1	32	26
F41ILL-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	32	36
F41ILX-H	F32T8	Fluorescent, (1) 48", T-8 lamp, HE Instant/Program Start Ballast, HLO (BF:.96- 1.1)	Electronic	1	32	35
F41ILX-R	F32T8	Fluorescent, (1) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	1	32	25
F41LE	F32T8	Fluorescent, (1) 48", T-8 lamp	Mag-ES	1	32	35
F41LL	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	1	32	32
F41LL/T2	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	32	30
F41LL/T2-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1), Tandem 2 Lamp Ballast	Electronic	1	32	39
F41LL/T2-R	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85), Tandem 2 Lamp Ballast	Electronic	1	32	27

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F41LL/T3	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	32	31
F41LL/T3-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1), Tandem 3 Lamp Ballast	Electronic	1	32	33
F41LL/T3-R	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85), Tandem 3 Lamp Ballast	Electronic	1	32	25
F41LL/T4	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	32	30
F41LL/T4-R	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	1	32	26
F41LL-H	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	1	32	39
F41LL-R	F32T8	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	1	32	27
F41SE	F40T12	Fluorescent, (1) 48", STD lamp	Mag-ES	1	40	50
F41GHL	F48T5/HO	Fluorescent, (1) 48", STD HO T5 lamp	Electronic	1	54	59
F41SHS	F48T12/HO	Fluorescent, (1) 48", STD HO lamp	Mag-STD	1	60	85
F41SIL	F48T12	Fluorescent, (1) 48", STD IS lamp, Electronic ballast	Electronic	1	39	46
F41SIL/T2	F48T12	Fluorescent, (1) 48", STD IS lamp, Electronic ballast, tandem wired	Electronic	1	39	37
F41SIS	F48T12	Fluorescent, (1) 48", STD IS lamp	Mag-STD	1	39	60
F41SIS/T2	F48T12	Fluorescent, (1) 48", STD IS lamp, tandem to 2-lamp ballast	Mag-STD	1	39	52
F41GL	F48T5	Fluorescent, (1) 48", STD T5 lamp	Electronic	1	28	32
F41SL/T2	F40T12	Fluorescent, (1) 48", T-12 STD lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	40	36

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F41SS	F40T12	Fluorescent, (1) 48", STD lamp	Mag-STD	1	40	57
F41SVS	F48T12/VHO	Fluorescent, (1) 48", STD VHO lamp	Mag-STD	1	110	135
F41TS	F40T10	Fluorescent, (1) 48", T-10 lamp	Mag-STD	1	40	51
F42EE	F40T12/ES	Fluorescent, (2) 48", ES lamp	Mag-ES	2	34	72
F42EE/D2	F40T12/ES	Fluorescent, (2) 48", ES lamp, 2 Ballasts (delamped)	Mag-ES	2	34	76
F42EHS	F48T12/HO/ES	Fluorescent, (2) 42", HO lamp (3.5' lamp)	Mag-STD	2	55	135
F42EIS	F48T12/ES	Fluorescent, (2) 48" ES Instant Start lamp. Magnetic ballast	Mag-STD	2	30	82
F42EL	F40T12/ES	Fluorescent, (2) 48", T12 ES lamps, Electronic Ballast	Electronic	2	34	60
F42ES	F40T12/ES	Fluorescent, (2) 48", ES lamp	Mag-STD	2	34	80
F42EVS	F48T12/VHO/ES	Fluorescent, (2) 48", VHO ES lamp	Mag-STD	2	210	
F42IAL/T4-R	F25T12	Fluorescent, (2) 48", F25T12 lamp, Instant Start, Tandem 4-Lamp Ballast, RLO (BF<0.85)	Electronic	2	25	40
F42IAL-R	F25T12	Fluorescent, (2) 48", F25T12 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	25	39
F42ILL	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	32	59
F42SILL	F30T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	30	53
F41SILL/T4	F30T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	30	52
F42SILL-R	F30T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	30	47
F41SILL/T4-R	F30T8	Fluorescent, (2) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	30	46

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F42SILL-H	F30T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-2.2)	Electronic	2	30	72
F42SSILL	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	28	48
F41SSILL/T4	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	28	47
F42SSILL-R	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	28	45
F41SSILL/T4-R	F28T8	Fluorescent, (2) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	28	44
F42SSILL-H	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-2.2)	Electronic	2	28	67
F42ILL/T4	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	32	56
F42ILL/T4-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	32	51
F42ILL-H	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	2	32	65
F42ILL-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	32	52
F42ILL-V	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, VHLO (BF>1.1)	Electronic	2	32	79
F42ILX-H	F32T8	Fluorescent, (2) 48", T-8 lamp, HE Instant/Program Start Ballast, HLO (BF:.96- 1.1)	Electronic	2	32	63
F42ILX-R	F32T8	Fluorescent, (2) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	2	32	48
F42ILX-V	F32T8	Fluorescent, (2) 48", T-8 lamp, HE Instant/Program Start	Electronic	2	32	74

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
		Ballast, VHLO (BF>1.1)				
F42LE	F32T8	Fluorescent, (2) 48", T-8 lamp	Mag-ES	2	32	71
F42LL	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	2	32	60
F42LL/T4	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	32	59
F42LL/T4-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	32	53
F42LL-H	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	2	32	70
F42LL-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	2	32	54
F42LL-V	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, VHLO (BF>1.1)	Electronic	2	32	85
F42SE	F40T12	Fluorescent, (2) 48", STD lamp	Mag-ES	2	40	86
F42GHL	F48T5/HO	Fluorescent, (2) 48", STD HO T5 lamp	Electronic	2	54	117
F42SHS	F48T12/HO	Fluorescent, (2) 48", STD HO lamp	Mag-STD	2	60	145
F42SIL	F48T12	Fluorescent, (2) 48", STD IS lamp, Electronic ballast	Electronic	2	39	74
F42SIS	F48T12	Fluorescent, (2) 48", STD IS lamp	Mag-STD	2	39	103
F42GL	F48T5	Fluorescent, (2) 48", STD T5 lamp	Electronic	2	28	63
F42SS	F40T12	Fluorescent, (2) 48", STD lamp	Mag-STD	2	40	94
F42SVS	F48T12/VHO	Fluorescent, (2) 48", STD VHO lamp	Mag-STD	2	110	242
F43EE	F40T12/ES	Fluorescent, (3) 48", ES lamp	Mag-ES	3	34	115
F43EHS	F48T12/HO/ES	Fluorescent, (3) 48", ES HO lamp (3.5' lamp)	Mag-STD	3	55	215

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F43EIS	F48T12/ES	Fluorescent, (3) 48" ES Instant Start lamp. Magnetic ballast	Mag-STD	3	30	133
F43EL	F40T12/ES	Fluorescent, (3) 48", T12 ES lamps, Electronic Ballast	Electronic	3	34	92
F43ES	F40T12/ES	Fluorescent, (3) 48", ES lamp	Mag-STD	3	34	130
F43EVS	F48T12/VHO/ES	Fluorescent, (3) 48", VHO ES lamp	Mag-STD	3	333	
F43IAL-R	F25T12	Fluorescent, (3) 48", F25T12 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	25	60
F43ILL	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	32	89
F43SILL	F30T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	30	78
F43SILL-R	F30T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	30	70
F43SILL-H	F30T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-3.3)	Electronic	3	30	105
F43SSILL	F28T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	28	72
F43SSILL-R	F28T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	28	66
F43SSILL-H	F28T8	Fluorescent, (3) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-3.3)	Electronic	3	28	98
F43ILL/2	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), (2) ballast	Electronic	3	32	90
F43ILL-H	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	3	32	93
F43ILL-R	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	3	32	78

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F43ILL-V	F32T8	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, VHLO (BF>1.1)	Electronic	3	32	112
F43ILX-H	F32T8	Fluorescent, (3) 48", T-8 lamp, HE Instant/Program Start Ballast, HLO (BF:.96- 1.1)	Electronic	3	32	90
F43ILX-R	F32T8	Fluorescent, (3) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	3	32	73
F43ILX-R/2	F32T8	Fluorescent, (3) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85), (2) ballast	Electronic	3	32	73
F43LE	F32T8	Fluorescent, (3) 48", T-8 lamp	Mag-ES	3	32	110
F43LL	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	3	32	93
F43LL/2	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), (2) ballast	Electronic	3	32	92
F43LL-H	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	3	32	98
F43LL-R	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	3	32	76
F43SE	F40T12	Fluorescent, (3) 48", STD lamp	Mag-ES	3	40	136
F43GHL	F48T5/HO	Fluorescent, (3) 48", STD HO T5 lamp	Electronic	3	54	177
F43SHS	F48T12/HO	Fluorescent, (3) 48", STD HO lamp	Mag-STD	3	60	230
F43SIL	F40T12	Fluorescent, (3) 48", STD IS lamp, Electronic ballast	Electronic	3	39	120
F43SIS	F48T12	Fluorescent, (3) 48", STD IS lamp	Mag-STD	3	39	162
F43SS	F40T12	Fluorescent, (3) 48", STD lamp	Mag-STD	3	40	151
F43SVS	F48T12/VHO	Fluorescent, (3) 48", STD VHO lamp	Mag-STD	3	110	377
F44EE	F40T12/ES	Fluorescent, (4) 48", ES lamp	Mag-ES	4	34	144

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F44EE/D4	F40T12/ES	Fluorescent, (4) 48", ES lamp, 4 Ballasts (delamped)	Mag-ES	4	34	152
F44EHS	F48T12/HO/ES	Fluorescent, (4) 48", ES HO lamp	Mag-STD	4	55	270
F44EIS	F48T12/ES	Fluorescent, (4) 48" ES Instant Start lamp, Magnetic ballast	Mag-STD	4	30	164
F44EL	F40T12/ES	Fluorescent, (4) 48", T12 ES lamp, Electronic Ballast	Electronic	4	34	120
F44ES	F40T12/ES	Fluorescent, (4) 48", ES lamp	Mag-STD	4	34	160
F44EVS	F48T12/VHO/ES	Fluorescent, (4) 48", VHO ES lamp	Mag-STD	4	420	
F44IAL-R	F25T12	Fluorescent, (4) 48", F25T12 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	25	80
F44ILL	F32T8	Fluorescent, (4) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	32	112
F44SILL	F30T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	30	105
F44SILL-R	F30T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	30	91
F44SILL-H	F30T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-4.4)	Electronic	4	30	140
F44SSILL	F28T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	28	96
F44SSILL-R	F28T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	28	86
F44SSILL-H	F28T8	Fluorescent, (4) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-4.4)	Electronic	4	28	131
F44ILL/2	F32T8	Fluorescent, (4) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), (2) ballast	Electronic	4	32	118
F44ILL-R	F32T8	Fluorescent, (4) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	4	32	102

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F44ILX-R	F32T8	Fluorescent, (4) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	4	32	96
F44ILX-R/2	F32T8	Fluorescent, (4) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85), (2) ballast	Electronic	4	32	96
F44LE	F32T8	Fluorescent, (4) 48", T-8 lamp	Mag-ES	4	32	142
F44LL	F32T8	Fluorescent, (4) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	4	32	118
F44LL/2	F32T8	Fluorescent, (4) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), (2) ballast	Electronic	4	32	120
F44LL-R	F32T8	Fluorescent, (4) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	4	32	105
F44SE	F40T12	Fluorescent, (4) 48", STD lamp	Mag-ES	4	40	172
F44GHL	F48T5/HO	Fluorescent, (4) 48", STD HO T5 lamp	Electronic	4	54	234
F44SHS	F48T12/HO	Fluorescent, (4) 48", STD HO lamp	Mag-STD	4	60	290
F44SIL	F48T12	Fluorescent, (4) 48", STD IS lamp, Electronic ballast	Electronic	4	39	148
F44SIS	F48T12	Fluorescent, (4) 48", STD IS lamp	Mag-STD	4	39	204
F44SS	F40T12	Fluorescent, (4) 48", STD lamp	Mag-STD	4	40	188
F44SVS	F48T12/VHO	Fluorescent, (4) 48", STD VHO lamp	Mag-STD	4	110	484
F45ILL	F32T8	Fluorescent, (5) 48", T-8 lamp, (1) 3-lamp IS ballast and (1) 2-lamp IS ballast, NLO (BF: .85-.95)	Electronic	5	32	148
F45GHL	F48T5/HO	Fluorescent, (5) 48", STD HO T5 lamp	Electronic	5	54	294
F46EE	F40T12/ES	Fluorescent, (6) 48", ES lamp	Mag-ES	6	34	216
F46EL	F40T12/ES	Fluorescent, (6) 48", ES lamp	Electronic	6	34	186
F46ES	F40T12/ES	Fluorescent, (6) 48", ES lamp	Mag-STD	6	34	236

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F46ILL	F32T8	Fluorescent, (6) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	6	32	175
F46ILL-R	F32T8	Fluorescent, (6) 48", T-8 lamp, Instant Start Ballast, RLO (BF< .85)	Electronic	6	32	156
F46ILX-R	F32T8	Fluorescent, (6) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF< .85)	Electronic	6	32	146
F46LL	F32T8	Fluorescent, (6) 48", T-8 lamp, NLO (BF: .85- .95)	Electronic	6	32	182
F46GHL	F48T5/HO	Fluorescent, (6) 48", STD HO T5 lamp	Electronic	6	54	351
F46SE	F40T12	Fluorescent, (6) 48", STD lamp	Mag-ES	6	40	258
F46SS	F40T12	Fluorescent, (6) 48", STD lamp	Mag-STD	6	40	282
F48EE	F40T12/ES	Fluorescent, (8) 48", ES lamp	Mag-ES	8	34	288
F48ILL	F32T8	Fluorescent, (8) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	8	32	224
F48ILL-R	F32T8	Fluorescent, (8) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	8	32	204
F48ILX-R	F32T8	Fluorescent, (8) 48", T-8 lamp, HE Instant/Program Start Ballast, RLO (BF<0.85)	Electronic	8	32	192
F48GHL	F48T5/HO	Fluorescent, (8) 48", STD HO T5 lamp	Electronic	8	54	468
F51ILHL	F60T12/HO	Fluorescent, (1) 60", T-8 HO lamp, Instant Start Ballast	Electronic	1	55	59
F51ILL	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	40	36
F51ILL/T2	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	40	36
F51ILL/T3	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 3 Lamp Ballast	Electronic	1	40	35

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F51ILL/T4	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	1	40	34
F51ILL-R	F40T8	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	40	43
F51SHE	F60T12/HO	Fluorescent, (1) 60", STD HO lamp	Mag-ES	1	75	88
F51SHL	F60T12/HO	Fluorescent, (1) 60", STD HO lamp	Electronic	1	75	69
F51GHL	F60T5/HO	Fluorescent, (1) 60", STD HO T5 lamp	Electronic	1	80	89
F51SHS	F60T12/HO	Fluorescent, (1) 60", STD HO lamp	Mag-STD	1	75	92
F51SL	F60T12	Fluorescent, (1) 60", STD lamp	Electronic	1	50	44
F51GL	F60T5	Fluorescent, (1) 60", STD T5 lamp	Electronic	1	35	39
F51SS	F60T12	Fluorescent, (1) 60", STD lamp	Mag-STD	1	50	63
F51SVS	F60T12/VHO	Fluorescent, (1) 60", VHO ES lamp	Mag-STD	1	135	165
F52ILHL	F60T12/HO	Fluorescent, (2) 60", T-8 HO lamp, Instant Start Ballast	Electronic	2	55	123
F52ILL	F40T8	Fluorescent, (2) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	40	72
F52ILL/T4	F40T8	Fluorescent, (2) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	2	40	67
F52ILL-H	F40T8	Fluorescent, (2) 60", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	2	40	80
F52ILL-R	F40T8	Fluorescent, (2) 60", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	40	73
F52SHE	F60T12/HO	Fluorescent, (2) 60", STD HO lamp	Mag-ES	2	75	176
F52SHL	F60T12/HO	Fluorescent, (2) 60", STD HO lamp	Electronic	2	75	138
F52GHL	F60T5/HO	Fluorescent, (2) 60", STD HO T5 lamp	Electronic	2	49	106

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F52SHS	F60T12/HO	Fluorescent, (2) 60", STD HO lamp	Mag-STD	2	75	168
F52SL	F60T12	Fluorescent, (2) 60", STD lamp	Electronic	2	50	88
F52GL	F60T5	Fluorescent, (2) 60", STD T5 lamp	Electronic	2	35	76
F52SS	F60T12	Fluorescent, (2) 60", STD lamp	Mag-STD	2	50	128
F52SVS	F60T12/VHO	Fluorescent, (2) 60", VHO ES lamp	Mag-STD	2	135	310
F53ILL	F40T8	Fluorescent, (3) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	40	106
F53ILL-H	F40T8	Fluorescent, (3) 60", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	3	40	108
F54ILL	F40T8	Fluorescent, (4) 60", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	40	134
F54ILL-H	F40T8	Fluorescent, (4) 60", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	4	40	126
F61ISL	F72T12	Fluorescent, (1) 72", STD lamp, IS electronic ballast	Electronic	1	55	68
F61SE	F72T12	Fluorescent, (1) 72", STD lamp	Mag-ES	1	55	76
F61SHS	F72T12/HO	Fluorescent, (1) 72", STD HO lamp	Mag-STD	1	85	120
F61SS	F72T12	Fluorescent, (1) 72", STD lamp	Mag-STD	1	55	90
F61SVS	F72T12/VHO	Fluorescent, (1) 72", VHO lamp	Mag-STD	1	160	180
F62ILHL	F72T8	Fluorescent, (2) 72", T-8 HO lamp, Instant Start Ballast	Electronic	2	65	147
F62ISL	F72T12	Fluorescent, (2) 72", STD lamp, IS electronic ballast	Electronic	2	55	108
F62SE	F72T12	Fluorescent, (2) 72", STD lamp	Mag-ES	2	55	122
F62SHE	F72T12/HO	Fluorescent, (2) 72", STD HO lamp	Mag-ES	2	85	194
F62SHS	F72T12/HO	Fluorescent, (2) 72", STD HO lamp	Mag-STD	2	85	220

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F62SL	F72T12	Fluorescent, (2) 72", STD lamp	Electronic	2	55	108
F62SS	F72T12	Fluorescent, (2) 72", STD lamp	Mag-STD	2	55	145
F62SVS	F72T12/VHO	Fluorescent, (2) 72", VHO lamp	Mag-STD	2	160	330
F63ISL	F72T12	Fluorescent, (3) 72", STD lamp, IS electronic ballast	Electronic	3	55	176
F63SS	F72T12	Fluorescent, (3) 72", STD lamp	Mag-STD	3	55	202
F64ISL	F72T12	Fluorescent, (4) 72", STD lamp, IS electronic ballast	Electronic	4	55	216
F64SE	F72T12	Fluorescent, (4) 72", STD lamp	Mag-ES	4	55	230
F64SHE	F72T12/HO	Fluorescent, (4) 72", STD HO lamp	Mag-ES	4	85	388
F64SS	F72T12	Fluorescent, (4) 72", STD lamp	Mag-STD	4	55	244
F81EE/T2	F96T12/ES	Fluorescent, (1) 96", ES lamp, tandem to 2- lamp ballast	Mag-ES	1	60	62
F81EHL	F96T12/HO/ES	Fluorescent, (1) 96", ES HO lamp	Electronic	1	95	80
F81EHL/T2	F96T12/HO/ES	Fluorescent, (1) 96", ES HO lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	95	85
F81EHS	F96T12/HO/ES	Fluorescent, (1) 96", ES HO lamp	Mag-STD	1	95	125
F81EL	F96T12/ES	Fluorescent, (1) 96", ES lamp	Electronic	1	60	60
F81EL/T2	F96T12/ES	Fluorescent, (1) 96", ES lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	60	55
F81ES	F96T12/ES	Fluorescent, (1) 96", ES lamp	Mag-STD	1	60	83
F81ES/T2	F96T12/ES	Fluorescent, (1) 96", ES lamp, tandem to 2- lamp ballast	Mag-STD	1	60	64
F81EVS	F96T12/VHO/ES	Fluorescent, (1) 96", ES VHO lamp	Mag-STD	1	185	200
F81ILL	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	59	58
F81ILL/T2	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, NLO (BF:	Electronic	1	59	55

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
		.85-.95), Tandem 2 Lamp Ballast				
F81ILL/T2-R	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, RLO (BF<.85), Tandem 2 Lamp Ballast	Electronic	1	59	49
F81ILL-H	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	1	59	68
F81ILL-R	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	1	59	57
F81ILL-V	F96T8	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, VHLO (BF>1.1)	Electronic	1	59	71
F81LHL	F96T8/HO	Fluorescent, (1) 96", T8 HO lamp	Electronic	1	86	85
F81LHL/T2	F96T8/HO	Fluorescent, (1) 96", T8 HO lamp, tandem wired to 2-lamp ballast	Electronic	1	86	80
F81SE	F96T12	Fluorescent, (1) 96", STD lamp	Mag-ES	1	75	91
F81EHS	F96T12/HO	Fluorescent, (1) 96", ES HO lamp	Mag-STD	1	95	125
F81SHE	F96T12/HO	Fluorescent, (1) 96", STD HO lamp	Mag-ES	1	110	132
F81SHL/T2	F96T12/HO	Fluorescent, (1) 96", STD HO lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	110	98
F81SHS	F96T12/HO	Fluorescent, (1) 96", STD HO lamp	Mag-STD	1	110	145
F81SL	F96T12	Fluorescent, (1) 96", STD lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	1	75	70
F81SL/T2	F96T12	Fluorescent, (1) 96", STD lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 2 Lamp Ballast	Electronic	1	75	67
F81SS	F96T12	Fluorescent, (1) 96", STD lamp	Mag-STD	1	75	100
F81SVS	F96T12/VHO	Fluorescent, (1) 96", STD VHO lamp	Mag-STD	1	215	230
F82EE	F96T12/ES	Fluorescent, (2) 96", ES lamp	Mag-ES	2	60	123

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F82EHE	F96T12/HO/ES	Fluorescent, (2) 96", ES HO lamp	Mag-ES	2	95	207
F82EHL	F96T12/HO/ES	Fluorescent, (2) 96", ES HO lamp	Electronic	2	95	170
F82EHS	F96T12/HO/ES	Fluorescent, (2) 96", ES HO lamp	Mag-STD	2	95	227
F82EL	F96T12/ES	Fluorescent, (2) 96", ES lamp	Electronic	2	60	110
F82ES	F96T12/ES	Fluorescent, (2) 96", ES lamp	Mag-STD	2	60	138
F82EVS	F96T12/VHO/ES	Fluorescent, (2) 96", ES VHO lamp	Mag-STD	2	185	390
F82ILL	F96T8	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	59	109
F82ILL-R	F96T8	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	59	98
F82LHL	F96T8/HO	Fluorescent, (2) 96", T8 HO lamp	Electronic	2	86	160
F82SE	F96T12	Fluorescent, (2) 96", STD lamp	Mag-ES	2	75	158
F82SHE	F96T12/HO	Fluorescent, (2) 96", STD HO lamp	Mag-ES	2	110	237
F82SHL	F96T12/HO	Fluorescent, (2) 96", STD HO lamp	Electronic	2	110	195
F82SHS	F96T12/HO	Fluorescent, (2) 96", STD HO lamp	Mag-STD	2	110	257
F82SL	F96T12	Fluorescent, (2) 96", STD lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	75	134
F82SS	F96T12	Fluorescent, (2) 96", STD lamp	Mag-STD	2	75	173
F82SVS	F96T12/VHO	Fluorescent, (2) 96", STD VHO lamp	Mag-STD	2	215	450
F83EE	F96T12/ES	Fluorescent, (3) 96", ES lamp	Mag-ES	3	60	210
F83EHE	F96T12/HO/ES	Fluorescent, (3) 96", ES HO lamp, (1) 2-lamp ES Ballast, (1) 1-lamp STD Ballast	Mag ES/STD	3	95	319
F83EHS	F96T12/HO/ES	Fluorescent, (3) 96", ES HO lamp	Mag-STD	3	95	352

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F83EL	F96T12/ES	Fluorescent, (3) 96", ES lamp	Electronic	3	60	179
F83ES	F96T12/ES	Fluorescent, (3) 96", ES lamp	Mag-STD	3	60	221
F83EVS	F96T12/VHO/ES	Fluorescent, (3) 96", ES VHO lamp	Mag-STD	3	185	590
F83ILL	F96T8	Fluorescent, (3) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	3	59	167
F83SHS	F96T12/HO	Fluorescent, (3) 96", STD HO lamp	Mag-STD	3	110	392
F83SS	F96T12	Fluorescent, (3) 96", STD lamp	Mag-STD	3	75	273
F83SVS	F96T12/VHO	Fluorescent, (3) 96", STD VHO lamp	Mag-STD	3	215	680
F84EE	F96T12/ES	Fluorescent, (4) 96", ES lamp	Mag-ES	4	60	246
F84EHE	F96T12/HO/ES	Fluorescent, (4) 96", ES HO lamp	Mag-ES	4	95	414
F84EHL	F96T12/HO/ES	Fluorescent, (4) 96", ES HO lamp	Electronic	4	95	340
F84EHS	F96T12/HO/ES	Fluorescent, (4) 96", ES HO lamp	Mag-STD	4	95	454
F84EL	F96T12/ES	Fluorescent, (4) 96", ES lamp	Electronic	4	60	220
F84ES	F96T12/ES	Fluorescent, (4) 96", ES lamp	Mag-STD	4	60	276
F84EVS	F96T12/VHO/ES	Fluorescent, (4) 96", ES VHO lamp	Mag-STD	4	185	780
F84ILL	F96T8	Fluorescent, (4) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	59	219
F84LHL	F96T8/HO	Fluorescent, (4) 96", T8 HO lamp	Electronic	4	86	320
F84SE	F96T12	Fluorescent, (4) 96", STD lamp	Mag-ES	4	75	316
F84SHE	F96T12/HO	Fluorescent, (4) 96", STD HO lamp	Mag-ES	4	110	474
F84SHL	F96T12/HO	Fluorescent, (3) 96", STD HO lamp	Electronic	4	110	390
F84SHS	F96T12/HO	Fluorescent, (4) 96", STD HO lamp	Mag-STD	4	110	514

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
F84SL	F96T12	Fluorescent, (4) 96", STD lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	4	75	268
F84SS	F96T12	Fluorescent, (4) 96", STD lamp	Mag-STD	4	75	346
F84SVS	F96T12/VHO	Fluorescent, (4) 96", STD VHO lamp	Mag-STD	4	215	900
F86EHS	F96T12/HO/ES	Fluorescent, (6) 96", ES HO lamp	Mag-STD	6	95	721
F86ILL	F96T8	Fluorescent, (6) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	6	59	328
FC12/1	FC12T9	Fluorescent, (1) 12" circular lamp, RS ballast	Mag-STD	1	32	31
FC12/2	FC12T9	Fluorescent, (2) 12" circular lamp, RS ballast	Mag-STD	2	32	62
FC16/1	FC16T9	Fluorescent, (1) 16" circular lamp	Mag-STD	1	40	35
FC20	FC6T9	Fluorescent, Circlite, (1) 20W lamp, Preheat ballast	Mag-STD	1	20	20
FC22/1	FC8T9	Fluorescent, Circlite, (1) 22W lamp, preheat ballast	Mag-STD	1	22	20
FC22/32/1	FC22/32T9	Fluorescent, Circlite, (1) 22W/32W lamp, preheat ballast	Mag-STD	1	22/32	58
FC32/1	FC12T9	Fluorescent, Circline, (1) 32W lamp, preheat ballast	Mag-STD	1	32	40
FC32/40/1	FC32/40T9	Fluorescent, Circlite, (1) 32W/40W lamp, preheat ballast	Mag-STD	1	32/40	80
FC40/1	FC16T9	Fluorescent, Circline, (1) 32W lamp, preheat ballast	Mag-STD	1	32	42
FC44/1	FC44T9	Fluorescent, Circlite, (1) 44W lamp, preheat ballast	Mag-STD	1	44	46
FC6/1	FC6T9	Fluorescent, (1) 6" circular lamp, RS ballast	Mag-STD	1	20	25
FC8/1	FC8T9	Fluorescent, (1) 8" circular lamp, RS ballast	Mag-STD	1	22	26
FC8/2	FC8T9	Fluorescent, (2) 8" circular lamp, RS ballast	Mag-STD	2	22	52
FU1EE	FU40T12/ES	Fluorescent, (1) U-Tube, ES lamp	Mag-ES	1	34	43
FU1ILL	FU31T8/6	Fluorescent, (1) U-Tube, T-8 lamp, Instant Start ballast	Electronic	1	32	31
FU1LL	FU31T8/6	Fluorescent, (1) U-Tube, T-8 lamp	Electronic	1	32	32

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
FU1LL-R	FU31T8/6	Fluorescent, (1) U-Tube, T-8 lamp, RLO (BF<0.85)	Electronic	1	31	27
FU1ILX-R	FU31T8/6	Fluorescent, (1) U-Tube, T-8 lamp, HE Instant/Program Start Ballast RLO (BF<0.85)	Electronic	1	31	25
FU2SS	FU40T12	Fluorescent, (2) U-Tube, STD lamp	Mag-STD	2	40	96
FU2SE	FU40T12	Fluorescent, (2) U-Tube, STD lamp	Mag-ES	2	40	85
FU2EE	FU40T12/ES	Fluorescent, (2) U-Tube, ES lamp	Mag-ES	2	34	72
FU2ES	FU40T12/ES	Fluorescent, (2) U-Tube, ES lamp	Mag-STD	2	34	82
FU2ILL	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start Ballast	Electronic	2	32	59
FU2ILL/T4	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start Ballast, tandem wired	Electronic	2	32	56
FU2ILL/T4-R	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start Ballast, RLO, tandem wired	Electronic	2	32	51
FU2ILL-H	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start HLO Ballast	Electronic	2	32	65
FU2ILL-R	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Instant Start RLO Ballast	Electronic	2	32	52
FU2ILX-R	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, HE Instant/Program Start Ballast RLO (BF<0.85)	Electronic	2	31	48
FU2LL	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp	Electronic	2	32	60
FU2LL/T2	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, Tandem 4 lamp ballast	Electronic	2	32	59
FU2LL-R	FU31T8/6	Fluorescent, (2) U-Tube, T-8 lamp, RLO (BF<0.85)	Electronic	54	31	54
FU3EE	FU40T12/ES	Fluorescent, (3) U-Tube, ES lamp	Mag-ES	3	35	115
FU3ILL	FU31T8/6	Fluorescent, (3) U-Tube, T-8 lamp, Instant Start Ballast	Electronic	3	32	89
FU3ILL-R	FU31T8/6	Fluorescent, (3) U-Tube, T-8 lamp, Instant Start RLO Ballast	Electronic	3	32	78
I100/1	I100	Incandescent, (1) 100W lamp	N/A	1	100	100

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
I100/2	I100	Incandescent, (2) 100W lamp	N/A	2	100	200
I100/3	I100	Incandescent, (3) 100W lamp	N/A	3	100	300
I100/4	I100	Incandescent, (4) 100W lamp	N/A	4	100	400
I100/5	I100	Incandescent, (5) 100W lamp	N/A	5	100	500
I1000/1	I1000	Incandescent, (1) 1000W lamp	N/A	1	1000	1000
I100E/1	I100/ES	Incandescent, (1) 100W ES lamp	N/A	1	90	90
I100EL/1	I100/ES/LL	Incandescent, (1) 100W ES/LL lamp	N/A	1	90	90
I120/1	I120	Incandescent, (1) 120W lamp	N/A	1	120	120
I120/2	I120	Incandescent, (2) 120W lamp	N/A	2	120	240
I125/1	I125	Incandescent, (1) 125W lamp	N/A	1	125	125
I135/1	I135	Incandescent, (1) 135W lamp	N/A	1	135	135
I135/2	I135	Incandescent, (2) 135W lamp	N/A	2	135	270
I15/1	I15	Incandescent, (1) 15W lamp	N/A	1	15	15
I15/2	I15	Incandescent, (2) 15W lamp	N/A	2	15	30
I150/1	I150	Incandescent, (1) 150W lamp	N/A	1	150	150
I150/2	I150	Incandescent, (2) 150W lamp	N/A	2	150	300
I1500/1	I1500	Incandescent, (1) 1500W lamp	N/A	1	1500	1500
I150E/1	I150/ES	Incandescent, (1) 150W ES lamp	N/A	1	135	135
I150EL/1	I150/ES/LL	Incandescent, (1) 150W ES/LL lamp	N/A	1	135	135
I170/1	I170	Incandescent, (1) 170W lamp	N/A	1	170	170
I20/1	I20	Incandescent, (1) 20W lamp	N/A	1	20	20
I20/2	I20	Incandescent, (2) 20W lamp	N/A	2	20	40

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
I200/1	I200	Incandescent, (1) 200W lamp	N/A	1	200	200
I200/2	I200	Incandescent, (2) 200W lamp	N/A	2	200	400
I2000/1	I2000	Incandescent, (1) 2000W lamp	N/A	1	2000	2000
I200L/1	I200/LL	Incandescent, (1) 200W LL lamp	N/A	1	200	200
I25/1	I25	Incandescent, (1) 25W lamp	N/A	1	25	25
I25/2	I25	Incandescent, (2) 25W lamp	N/A	2	25	50
I25/4	I25	Incandescent, (4) 25W lamp	N/A	4	25	100
I250/1	I250	Incandescent, (1) 250W lamp	N/A	1	250	250
I300/1	I300	Incandescent, (1) 300W lamp	N/A	1	300	300
I34/1	I34	Incandescent, (1) 34W lamp	N/A	1	34	34
I34/2	I34	Incandescent, (2) 34W lamp	N/A	2	34	68
I36/1	I36	Incandescent, (1) 36W lamp	N/A	1	36	36
I40/1	I40	Incandescent, (1) 40W lamp	N/A	1	40	40
I40/2	I40	Incandescent, (2) 40W lamp	N/A	2	40	80
I400/1	I400	Incandescent, (1) 400W lamp	N/A	1	400	400
I40E/1	I40/ES	Incandescent, (1) 40W ES lamp	N/A	1	34	34
I40EL/1	I40/ES/LL	Incandescent, (1) 40W ES/LL lamp	N/A	1	34	34
I42/1	I42	Incandescent, (1) 42W lamp	N/A	1	42	42
I448/1	I448	Incandescent, (1) 448W lamp	N/A	1	448	448
I45/1	I45	Incandescent, (1) 45W lamp	N/A	1	45	45
I50/1	I50	Incandescent, (1) 50W lamp	N/A	1	50	50
I50/2	I50	Incandescent, (2) 50W lamp	N/A	2	50	100

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
I500/1	I500	Incandescent, (1) 500W lamp	N/A	1	500	500
I52/1	I52	Incandescent, (1) 52W lamp	N/A	1	52	52
I52/2	I52	Incandescent, (2) 52W lamp	N/A	2	52	104
I54/1	I54	Incandescent, (1) 54W lamp	N/A	1	54	54
I54/2	I54	Incandescent, (2) 54W lamp	N/A	2	54	108
I55/1	I55	Incandescent, (1) 55W lamp	N/A	1	55	55
I55/2	I55	Incandescent, (2) 55W lamp	N/A	2	55	110
I60/1	I60	Incandescent, (1) 60W lamp	N/A	1	60	60
I60/2	I60	Incandescent, (2) 60W lamp	N/A	2	60	120
I60/3	I60	Incandescent, (3) 60W lamp	N/A	3	60	180
I60/4	I60	Incandescent, (4) 60W lamp	N/A	4	60	240
I60/5	I60	Incandescent, (5) 60W lamp	N/A	5	60	300
I60E/1	I60/ES	Incandescent, (1) 60W ES lamp	N/A	1	52	52
I60EL/1	I60/ES/LL	Incandescent, (1) 60W ES/LL lamp	N/A	1	52	52
I65/1	I65	Incandescent, (1) 65W lamp	N/A	1	65	65
I65/2	I65	Incandescent, (2) 65W lamp	N/A	2	65	130
I67/1	I67	Incandescent, (1) 67W lamp	N/A	1	67	67
I67/2	I67	Incandescent, (2) 67W lamp	N/A	2	67	134
I67/3	I67	Incandescent, (3) 67W lamp	N/A	3	67	201
I69/1	I69	Incandescent, (1) 69W lamp	N/A	1	69	69
I7.5/1	I7.5	Tungsten exit light, (1) 7.5 W lamp, used in night light application	N/A	1	7.5	8

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
I7.5/2	I7.5	Tungsten exit light, (2) 7.5 W lamp, used in night light application	N/A	2	7.5	15
I72/1	I72	Incandescent, (1) 72W lamp	N/A	1	72	72
I75/1	I75	Incandescent, (1) 75W lamp	N/A	1	75	75
I75/2	I75	Incandescent, (2) 75W lamp	N/A	2	75	150
I75/3	I75	Incandescent, (3) 75W lamp	N/A	3	75	225
I75/4	I75	Incandescent, (4) 75W lamp	N/A	4	75	300
I750/1	I750	Incandescent, (1) 750W lamp	N/A	1	750	750
I75E/1	I75/ES	Incandescent, (1) 75W ES lamp	N/A	1	67	67
I75EL/1	I75/ES/LL	Incandescent, (1) 75W ES/LL lamp	N/A	1	67	67
I80/1	I80	Incandescent, (1) 80W lamp	N/A	1	80	80
I85/1	I85	Incandescent, (1) 85W lamp	N/A	1	85	85
I90/1	I90	Incandescent, (1) 90W lamp	N/A	1	90	90
I90/2	I90	Incandescent, (2) 90W lamp	N/A	2	90	180
I90/3	I90	Incandescent, (3) 90W lamp	N/A	3	90	270
I93/1	I93	Incandescent, (1) 93W lamp	N/A	1	93	93
I95/1	I95	Incandescent, (1) 95W lamp	N/A	1	95	95
I95/2	I95	Incandescent, (2) 95W lamp	N/A	2	95	190
H100/1	H100	Halogen Incandescent, (1) 100W lamp	N/A	1	100	100
H1000/1	H1000	Halogen Incandescent, (1) 1000W lamp	N/A	1	1000	1000
H1200/1	H1200	Halogen Incandescent, (1) 1200W lamp	N/A	1	1200	1200
H150/1	H150	Halogen Incandescent, (1) 150W lamp	N/A	1	150	150

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
H150/2	H150	Halogen Incandescent, (2) 150W lamp	N/A	2	150	300
H1500/1	H1500	Halogen Incandescent, (1) 1500W lamp	N/A	1	1500	1500
H200/1	H200	Halogen Incandescent, (1) 200W lamp	N/A	1	200	200
H250/1	H250	Halogen Incandescent, (1) 250W lamp	N/A	1	250	250
H300/1	H300	Halogen Incandescent, (1) 300W lamp	N/A	1	300	300
H35/1	H35	Halogen Incandescent, (1) 35W lamp	N/A	1	35	35
H350/1	H350	Halogen Incandescent, (1) 350W lamp	N/A	1	350	350
H40/1	H40	Halogen Incandescent, (1) 40W lamp	N/A	1	40	40
H400/1	H400	Halogen Incandescent, (1) 400W lamp	N/A	1	400	400
H42/1	H42	Halogen Incandescent, (1) 42W lamp	N/A	1	42	42
H425/1	H425	Halogen Incandescent, (1) 425W lamp	N/A	1	425	425
H45/1	H45	Halogen Incandescent, (1) 45W lamp	N/A	1	45	45
H45/2	H45	Halogen Incandescent, (2) 45W lamp	N/A	2	45	90
H50/1	H50	Halogen Incandescent, (1) 50W lamp	N/A	1	50	50
H50/2	H50	Halogen Incandescent, (2) 50W lamp	N/A	2	50	100
H500/1	H500	Halogen Incandescent, (1) 500W lamp	N/A	1	500	500
H52/1	H52	Halogen Incandescent, (1) 52W lamp	N/A	1	52	52
H55/1	H55	Halogen Incandescent, (1) 55W lamp	N/A	1	55	55
H55/2	H55	Halogen Incandescent, (2) 55W lamp	N/A	2	55	110
H60/1	H60	Halogen Incandescent, (1) 60W lamp	N/A	1	60	60
H72/1	H72	Halogen Incandescent, (1) 72W lamp	N/A	1	72	72
H75/1	H75	Halogen Incandescent, (1) 75W lamp	N/A	1	75	75

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
H75/2	H75	Halogen Incandescent, (2) 75W lamp	N/A	2	75	150
H750/1	H750	Halogen Incandescent, (1) 750W lamp	N/A	1	750	750
H90/1	H90	Halogen Incandescent, (1) 90W lamp	N/A	1	90	90
H90/2	H90	Halogen Incandescent, (2) 90W lamp	N/A	2	90	180
H900/1	H900	Halogen Incandescent, (1) 900W lamp	N/A	1	900	900
HLV20/1	H20/LV	Halogen Low Voltage Incandescent, (1) 20W lamp	N/A	1	20	30
HLV25/1	H25/LV	Halogen Low Voltage Incandescent, (1) 25W lamp	N/A	1	25	35
HLV35/1	H35/LV	Halogen Low Voltage Incandescent, (1) 35W lamp	N/A	1	35	45
HLV42/1	H42/LV	Halogen Low Voltage Incandescent, (1) 42W lamp	N/A	1	42	52
HLV50/1	H50/LV	Halogen Low Voltage Incandescent, (1) 50W lamp	N/A	1	50	60
HLV65/1	H65/LV	Halogen Low Voltage Incandescent, (1) 65W lamp	N/A	1	65	75
HLV75/1	H75/LV	Halogen Low Voltage Incandescent, (1) 75W lamp	N/A	1	75	85
QL55/1	QL55	QL Induction, (1) 55W lamp	Generator	1	55	55
QL85/1	QL85	QL Induction, (1) 85W lamp	Generator	1	85	85
QL165/1	QL165	QL Induction, (1) 165W lamp	Generator	1	165	165
HPS100/1	HPS100	High Pressure Sodium, (1) 100W lamp	CWA	1	100	138
HPS1000/1	HPS1000	High Pressure Sodium, (1) 1000W lamp	CWA	1	1000	1100
HPS150/1	HPS150	High Pressure Sodium, (1) 150W lamp	CWA	1	150	188
HPS200/1	HPS200	High Pressure Sodium, (1) 200W lamp	CWA	1	200	250
HPS225/1	HPS225	High Pressure Sodium, (1) 225W lamp	CWA	1	225	275
HPS250/1	HPS250	High Pressure Sodium, (1) 250W lamp	CWA	1	250	295
HPS310/1	HPS310	High Pressure Sodium, (1) 310W lamp	CWA	1	310	365

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
HPS35/1	HPS35	High Pressure Sodium, (1) 35W lamp	CWA	1	35	46
HPS360/1	HPS360	High Pressure Sodium, (1) 360W lamp	CWA	1	360	414
HPS400/1	HPS400	High Pressure Sodium, (1) 400W lamp	CWA	1	400	465
HPS50/1	HPS50	High Pressure Sodium, (1) 50W lamp	CWA	1	50	66
HPS600/1	HPS600	High Pressure Sodium, (1) 600W lamp	CWA	1	600	675
HPS70/1	HPS70	High Pressure Sodium, (1) 70W lamp	CWA	1	70	95
HPS750/1	HPS750	High Pressure Sodium, (1) 750W lamp	CWA	1	750	835
MH100/1	MH100	Metal Halide, (1) 100W lamp	CWA	1	100	128
MH1000/1	MH1000	Metal Halide, (1) 1000W lamp	CWA	1	1000	1080
MH150/1	MH150	Metal Halide, (1) 150W lamp	CWA	1	150	190
MH1500/1	MH1500	Metal Halide, (1) 1500W lamp	CWA	1	1500	1610
MH175/1	MH175	Metal Halide, (1) 175W lamp	CWA	1	175	215
MH1800/1	MH1800	Metal Halide, (1) 1800W lamp	CWA	1	1800	1875
MH200/1	MH200	Metal Halide, (1) 200W lamp	CWA	1	200	232
MH250/1	MH250	Metal Halide, (1) 250W lamp	CWA	1	250	295
MH32/1	MH32	Metal Halide, (1) 32W lamp	CWA	1	32	43
MH300/1	MH300	Metal Halide, (1) 300W lamp	CWA	1	300	342
MH320/1	MH320	Metal Halide, (1) 320W lamp	CWA	1	320	365
MH350/1	MH350	Metal Halide, (1) 350W lamp	CWA	1	350	400
MH360/1	MH360	Metal Halide, (1) 360W lamp	CWA	1	360	430
MH400/1	MH400	Metal Halide, (1) 400W lamp	CWA	1	400	458
MH400/2	MH400	Metal Halide, (2) 400W lamp	CWA	2	400	916

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
MH450/1	MH450	Metal Halide, (1) 450W lamp	CWA	1	450	508
MH35/1	MH35	Metal Halide, (1) 35W lamp	CWA	1	35	44
MH50/1	MH50	Metal Halide, (1) 50W lamp	CWA	1	50	72
MH70/1	MH70	Metal Halide, (1) 70W lamp	CWA	1	70	95
MH750/1	MH750	Metal Halide, (1) 750W lamp	CWA	1	750	850
MHPS/LR/100/1	MHPS100	Metal Halide Pulse Start, (1) 100W lamp w/ Linear Reactor Ballast	LR	1	100	118
MHPS/LR/150/1	MHPS150	Metal Halide Pulse Start, (1) 150W lamp w/ Linear Reactor Ballast	LR	1	150	170
MHPS/LR/175/1	MHPS175	Metal Halide Pulse Start, (1) 175W lamp w/ Linear Reactor Ballast	LR	1	175	194
MHPS/LR/200/1	MHPS200	Metal Halide Pulse Start, (1) 200W lamp w/ Linear Reactor Ballast	LR	1	200	219
MHPS/LR/250/1	MHPS250	Metal Halide Pulse Start, (1) 250W lamp w/ Linear Reactor Ballast	LR	1	250	275
MHPS/LR/300/1	MHPS300	Metal Halide Pulse Start, (1) 300W lamp w/ Linear Reactor Ballast	LR	1	300	324
MHPS/LR/320/1	MHPS320	Metal Halide Pulse Start, (1) 320W lamp w/ Linear Reactor Ballast	LR	1	320	349
MHPS/LR/350/1	MHPS350	Metal Halide Pulse Start, (1) 350W lamp w/ Linear Reactor Ballast	LR	1	350	380
MHPS/LR/400/1	MHPS400	Metal Halide Pulse Start, (1) 400W lamp w/ Linear Reactor Ballast	LR	1	400	435
MHPS/LR/450/1	MHPS450	Metal Halide Pulse Start, (1) 450W lamp w/ Linear Reactor Ballast	LR	1	450	485
MHPS/LR/750/1	MHPS750	Metal Halide Pulse Start, (1) 750W lamp w/ Linear Reactor	LR	1	750	805

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
		Ballast				
MHPS/SCWA/100/1	MHPS100	Metal Halide Pulse Start, (1) 100W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	100	128
MHPS/SCWA/1000/1	MHPS1000	Metal Halide Pulse Start, (1) 1000W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	1000	1080
MHPS/SCWA/150/1	MHPS150	Metal Halide Pulse Start, (1) 150W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	150	190
MHPS/SCWA/175/1	MHPS175	Metal Halide Pulse Start, (1) 175W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	175	208
MHPS/SCWA/200/1	MHPS200	Metal Halide Pulse Start, (1) 200W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	200	232
MHPS/SCWA/250/1	MHPS250	Metal Halide Pulse Start, (1) 250W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	250	288
MHPS/SCWA/300/1	MHPS300	Metal Halide Pulse Start, (1) 300W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	300	342
MHPS/SCWA/320/1	MHPS320	Metal Halide Pulse Start, (1) 320W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	320	368
MHPS/SCWA/350/1	MHPS350	Metal Halide Pulse Start, (1) 350W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	350	400
MHPS/SCWA/400/1	MHPS400	Metal Halide Pulse Start, (1) 400W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	400	450
MHPS/SCWA/450/1	MHPS450	Metal Halide Pulse Start, (1) 450W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	450	506
MHPS/SCWA/750/1	MHPS750	Metal Halide Pulse Start, (1) 750W lamp w/ Super Constant Wattage Autotransformer Ballast	SCWA	1	750	815
MV100/1	MV100	Mercury Vapor, (1) 100W lamp	CWA	1	100	125

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
MV1000/1	MV1000	Mercury Vapor, (1) 1000W lamp	CWA	1	1000	1075
MV175/1	MV175	Mercury Vapor, (1) 175W lamp	CWA	1	175	205
MV250/1	MV250	Mercury Vapor, (1) 250W lamp	CWA	1	250	290
MV40/1	MV40	Mercury Vapor, (1) 40W lamp	CWA	1	40	50
MV400/1	MV400	Mercury Vapor, (1) 400W lamp	CWA	1	400	455
MV400/2	MV400	Mercury Vapor, (2) 400W lamp	CWA	2	400	910
MV50/1	MV50	Mercury Vapor, (1) 50W lamp	CWA	1	50	74
MV700/1	MV700	Mercury Vapor, (1) 700W lamp	CWA	1	700	780
MV75/1	MV75	Mercury Vapor, (1) 75W lamp	CWA	1	75	93
ECF5/1	CFT5W	EXIT Compact Fluorescent, (1) 5W lamp	Mag-STD	1	5	9
ECF5/2	CFT5W	EXIT Compact Fluorescent, (2) 5W lamp	Mag-STD	2	5	20
ECF7/1	CFT7W	EXIT Compact Fluorescent, (1) 7W lamp	Mag-STD	1	7	10
ECF7/2	CFT7W	EXIT Compact Fluorescent, (2) 7W lamp	Mag-STD	2	7	21
ECF8/1	F8T5	EXIT T5 Fluorescent, (1) 8W lamp	Mag-STD	1	8	12
ECF8/2	F8T5	EXIT T5 Fluorescent, (2) 8W lamp	Mag-STD	2	8	24
ECF9/1	CFT9W	EXIT Compact Fluorescent, (1) 9W lamp	Mag-STD	1	9	12
ECF9/2	CFT9W	EXIT Compact Fluorescent, (2) 9W lamp	Mag-STD	2	9	20
EI10/2	I10	EXIT Incandescent, (2) 10W lamp		2	10	20
EI15/1	I15	EXIT Incandescent, (1) 15W lamp		1	15	15
EI15/2	I15	EXIT Incandescent, (2) 15W lamp		2	15	30
EI20/1	I20	EXIT Incandescent, (1) 20W lamp		1	20	20
EI20/2	I20	EXIT Incandescent, (2) 20W lamp		2	20	40

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
EI25/1	I25	EXIT Incandescent, (1) 25W lamp		1	25	25
EI25/2	I25	EXIT Incandescent, (2) 25W lamp		2	25	50
EI34/1	I34	EXIT Incandescent, (1) 34W lamp		1	34	34
EI34/2	I34	EXIT Incandescent, (2) 34W lamp		2	34	68
EI40/1	I40	EXIT Incandescent, (1) 40W lamp		1	40	40
EI40/2	I40	EXIT Incandescent, (2) 40W lamp		2	40	80
EI5/1	I5	EXIT Incandescent, (1) 5W lamp		1	5	5
EI5/2	I5	EXIT Incandescent, (2) 5W lamp		2	5	10
EI50/2	I50	EXIT Incandescent, (2) 50W lamp		2	50	100
EI7.5/1	I7.5	EXIT Tungsten, (1) 7.5 W lamp		1	7.5	8
EI7.5/2	I7.5	EXIT Tungsten, (2) 7.5 W lamp		2	7.5	15
ELED0.5/1	LED0.5W	EXIT Light Emitting Diode, (1) 0.5W lamp, Single Sided		1	0.5	0.5
ELED0.5/2	LED0.5W	EXIT Light Emitting Diode, (2) 0.5W lamp, Dual Sided		2	0.5	1
ELED1.5/1	LED1.5W	EXIT Light Emitting Diode, (1) 1.5W lamp, Single Sided		1	1.5	1.5
ELED1.5/2	LED1.5W	EXIT Light Emitting Diode, (2) 1.5W lamp, Dual Sided		2	1.5	3
ELED10.5/1	LED10.5W	EXIT Light Emitting Diode, (1) 10.5W lamp, Single Sided		1	10.5	10.5
ELED10.5/2	LED10.5W	EXIT Light Emitting Diode, (2) 10.5W lamp, Dual Sided		2	10.5	21
ELED2/1	LED2W	EXIT Light Emitting Diode, (1) 2W lamp, Single Sided		1	2	2
ELED2/2	LED2W	EXIT Light Emitting Diode, (2) 2W lamp, Dual Sided		2	2	4
ELED3/1	LED3W	EXIT Light Emitting Diode, (1) 3W lamp, Single Sided		1	3	3
ELED3/2	LED3W	EXIT Light Emitting Diode, (2) 3W lamp, Dual Sided		2	3	6
ELED5/1	LED5W	EXIT Light Emitting Diode, (1) 5W lamp, Single Sided		1	5	5

Fixture Code	Lamp Code	Description	Ballast	Lamp/ Fixture	Watt/ Lamp	Watt/ Fixture
ELED5/2	LED5W	EXIT Light Emitting Diode, (2) 5W lamp, Dual Sided		2	5	10
ELED8/1	LED8W	EXIT Light Emitting Diode, (1) 8W lamp, Single Sided		1	8	8
ELED8/2	LED8W	EXIT Light Emitting Diode, (2) 8W lamp, Dual Sided		2	8	16

Appendix B: Effective Insulation Tables

The following tables are from the ASHRAE Standard 90.1 2013 Appendix A and are reproduced with permission of ASHRAE. The permission is conveyed through Copyright Clearance Center, Inc.

TABLE A9.2-1 Effective Insulation/Framing Layer R-Values for Roof and Floor Insulation Installed Between Metal Framing (4 ft on Center)

Rated R-Value of Insulation	Correction Factor	Framing/Cavity R-Value	Rated R-Value of Insulation	Correction Factor	Framing/Cavity R-Value
0.00	1.00	0.00	20.00	0.85	17.00
4.00	0.97	3.88	21.00	0.84	17.64
5.00	0.96	4.80	24.00	0.82	19.68
8.00	0.94	7.52	25.00	0.81	20.25
10.00	0.92	9.20	30.00	0.79	23.70
11.00	0.91	10.01	35.00	0.76	26.60
12.00	0.90	10.80	38.00	0.74	28.12
13.00	0.90	11.70	40.00	0.73	29.20
15.00	0.88	13.20	45.00	0.71	31.95
16.00	0.87	13.92	50.00	0.69	34.50
19.00	0.86	16.34	55.00	0.67	36.85

TABLE A9.2-2 Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

Nominal Depth of Cavity, in.	Actual Depth of Cavity, in.	Rated R-Value of Airspace or Insulation	Effective Framing/Cavity R-Value at 16 in. on Center	Effective Framing/Cavity R-Value at 24 in. on Center
Empty Cavity, No Insulation				
4	3.5	R-0.91	0.79	0.91
Insulated Cavity				
4	3.5	R-11	5.5	6.6
4	3.5	R-13	6.0	7.2
4	3.5	R-15	6.4	7.8
6	6.0	R-19	7.1	8.6
6	6.0	R-21	7.4	9.0
8	8.0	R-25	7.8	9.6

Appendix C: Effective Leakage Area Tables

Location	Building Component	ELA, SqIn/unit	Unit
Ceiling/ Ceiling Penetrations	General Ceiling (well-sealed)	0.011	ft^2
	General Ceiling (average)	0.026	ft^2
	General Ceiling (very-leaky)	0.04	ft^2
	Ceiling/ Flue vents (well-sealed)	4.3	each
	Ceiling/ Flue vents (average to very leaky)	4.8	each
	Lights, Recessed (well-sealed)	0.23	each
	Lights, Recessed (average)	1.6	each
	Lights, Recessed (very leaky)	3.3	each
	Lights, Surface Mounted (average)	0.13	each
Crawl Space	Crawl Space/ Open chase (well- sealed)	0.1	ft^2
	Crawl Space/ Open chase (average)	0.144	ft^2
	Crawl Space/ Open chase (very leaky)	0.24	ft^2
Doors	Framing- General (well-sealed)	0.37	each
	Framing- General (average)	1.9	each
	Framing- General (very leaky)	3.9	each
	Framing- Masonry, caulked	0.014	ft^2
	Framing- Masonry, not caulked	0.024	ft^2
	Framing- Wood, caulked	0.004	ft^2
	Framing- Wood, not caulked	0.024	ft^2
	Attic/ Crawl Space, weatherstripped	2.8	each
	Attic/ Crawl Space, not weatherstripped	4.6	each
	Attic Hatch, not weatherstripped	6.8	each
	Attic Hatch, weatherstripped	3.4	each
	Attic Hatch, weatherstripped, insulated	0.6	each
	Elevator (well-sealed)	0.022	each
	Elevator (average)	0.04	each
	Double, weatherstripped	0.12	ft^2
	Double, not weatherstripped	0.16	ft^2

Location	Building Component	ELA, SqIn/unit	Unit
	Interior Stairs (well-sealed)	0.012	ft (crack)
	Interior Stairs (average)	0.04	ft (crack)
	Interior Stairs (leaky)	0.07	ft (crack)
	Replacement Doors, cfm/ft known (enter cfm/ft in Additional Info)	-	ft
	Replacement Doors, cfm/sq ft known (enter cfm/sq ft in Additional Info)	-	sq ft
	Single, weatherstripped	1.9	each
	Single, not weatherstripped	3.3	each
	Sliding Exterior Glass Patio (well-sealed)	0.46	each
	Sliding Exterior Glass Patio (average)	3.4	each
	Sliding Exterior Glass Patio (very leaky)	9.3	each
	Storm (select in addition to other doors)	-0.9	each
	Vestibule (select in addition to other door)	-1.6	each
Electrical Outlets	Elec outlets/ switches w/ gaskets	0.023	each
	Elec outlets/switches w/o gaskets	0.38	each
Exterior Wall	Clay brick Cavity Wall	0.0098	ft^2
	Continuous Air Infiltration Barrier	0.0022	ft^2
	Heavyweight concrete block	0.0036	ft^2
	Lightweight concrete block, unfinished	0.05	ft^2
	Lightweight concrete block, painted or stucco	0.016	ft^2
	Rigid Sheathing	0.005	ft^2
	Wood frame w/ dense packed or wet cellulose	0.004 [2]	ft^2
	Wood-frame w/o Air Barrier System (average)	0.0071 [2]	ft^2
	Wood-frame w/o Air Barrier System (leaky)	0.01 [2]	ft^2
Fireplace	With open damper	5.04	ft^2
	With closed damper	0.62	ft^2
	With glass door	0.58	ft^2
Floor Over Crawl Space	Floor over Crawl Space (well- sealed)	0.006	ft^2
	Floor over Crawl Space (average)	0.032	ft^2
	Floor over Crawl Space (very leaky)	0.071	ft^2

Location	Building Component	ELA, SqIn/unit	Unit
Joints	Joint- Floor/Wall caulked	0.04	ft (crack)
	Joint- Floor/Wall uncaulked	0.2	ft (crack)
	Joint- Ceiling/Wall (well-sealed)	0.0075	ft (crack)
	Joint- Ceiling/Wall (average)	0.07	ft (crack)
	Joint- Ceiling/Wall (very leaky)	0.12	ft (crack)
Penetrations	Penetrations- Pipes/Wiring, caulked (any size)	0.3	each
	Penetrations- Pipes/Wiring, uncaulked	0.9	each
	Penetrations- Pipes/Wiring, uncaulked (large)	3.7	each
	Air-conditioner Sleeve, caulked	1.9 [*3*]	each
	Air-conditioner Sleeve, uncaulked	3.9 [*3*]	each
Windows	Framing- masonry, caulked	0.019	ft^2
	Framing- masonry, uncaulked	0.094	ft^2
	Framing- wood, caulked	0.004	ft^2
	Framing- wood, uncaulked	0.025	ft^2
	Awning/ Hopper, weatherstripped	0.012	ft^2
	Awning/ Hopper, not weatherstripped	0.023	ft^2
	Casement, weatherstripped	0.011	ft (crack)
	Casement, not weatherstripped	0.013	ft (crack)
	Double hung, with storm, weatherstripped	0.031 [*1*]	ft (crack)
	Double hung, with storm, not weatherstripped	0.046	ft (crack)
	Double hung, weatherstripped	0.037 [*1*]	ft (crack)
	Double hung, not weatherstripped	0.12	ft (crack)
	Double horizontal slider, wood, weatherstripped	0.026	ft (crack)
	Double horizontal slider, aluminum, weatherstripped	0.034	ft (crack)
	Double horizontal slider, not weatherstripped	0.052	ft (crack)
	Replacement Windows (enter NFRC AL under Additional Info)	-	ft^2
	Sill (well-sealed)	0.0065	ft (crack)
	Sill (average)	0.0099	ft (crack)
	Sill (very leaky)	0.01	ft (crack)
	Single hung, weatherstripped	0.041	ft (sash)

Location	Building Component	ELA, SqIn/unit	Unit
	Single horizontal slider, aluminum	0.04	ft (sash)
	Single horizontal slider, wood	0.021	ft (sash)
	Storm Inside, flexible sheet with a mechanical seal	0.0072	ft (sash)
	Storm Inside, rigid sheet with magnetic seal	0.0056	ft (sash)
	Storm Inside, rigid sheet with mechanical seal	0.019	ft (sash)
	Storm Outside, pressurized track	0.025	ft (sash)
Vent	Bathroom with damper closed	1.6	each
	Bathroom with damper open	3.1	each
	Ceiling/ Flue vents (well-sealed)	4.3	each
	Ceiling/ Flue vents (average to very leaky)	4.8	each
	Dryer with damper	0.46	each
	Dryer without damper	2.3	each
	Kitchen with tight gasket	0.16	each
	Kitchen with damper closed	0.8	each
	Kitchen with damper open	6.2	each

In ASHRAE table, double hung with storm is leakier than double hung without storm. Flipped the values for consistency.

Estimated based on the following references:

- 2001 ASHRAE Handbook- Fundamentals. Atlanta: American Society of heating, Refrigerating and Air-Conditioning Engineers, Inc.
- TenWolde, Anton, Charles Carll, Vyto Malinauskas. 1998. Air Pressures in Wood Frame Walls. Thermal Performance of the Exterior Envelopes of Buildings VII. Clearwater beach, FL.
- Canada Mortgage and Housing Corporation. Research and Highlight Developments- Wet sprayed cellulose insulation in Wood frame construction. Technical Series 90-240

Estimated assuming leakage through caulked/un-caulked AC sleeve is similar to leakage through average/very leaky general door framing.

Appendix D: Summary of Changes

From Version 6 to 8 [10/2017]

Section 6.1.3

Provided guidance for modeling condensing boiler efficiencies.

Section 10

Added LED lighting information to Lighting section. Removed Lighting Power Density Requirement. Removed references to the previously used ERP Tool.

Section 11.3.1

Added language requiring faucets and showerhead flow rates to be modeled at a minimum of 1.5 GPM post-retrofit.

Section 12

Added section on Elevators.

Appendix A

Updated lighting power table.

Appendix B

Updated Effective Insulation Reference Tables to ASHRAE 90.1 2013.

Appendix G

Added Technical Topic – LED Screw-in Replacements.

From Version 5.2 to 6 [11/18/2014]

Section 8.2: Updated Improvements section to provide guidance on how to model the installation of common building-level temperature controls (EMS, outdoor reset, night setback).

From Version 5 to 5.2

Section 7.2.2: Updated Grashof's equation.

From Version 4 to Version 5

Section 4.1.b: Clarified calculation approach in the Example.
Clarified definition of "similar mechanical ventilation rates.

Section 7.3: Added Section 7.3.1 Variable Frequency Drives.
Added section 7.3.2 Steam Trap Replacements.

From Version 3 to Version 4 - September 2010

These Simulation Guidelines have been updated to align with the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Multifamily Programs (aka "Technical Manual").

Section 7.2 – Cooling Equipment

- Added default efficiency of existing cooling equipment when actual cannot be obtained from the nameplate. The defaults are from p.41, 44, and73 of Technical Manual (TM)
- Added refrigeration charge correction improvement, to be modeled as 10% increase in cooling efficiency (TM p.58).

Section 8.2 – Heating/Cooling Temperature Schedule Improvement

- Changed programming thermostat modeling assumption from 2F setback to 3F setback, per TM p.55.

Section 10 - Lighting

- Added option for 3.2 hr/day runtime for screw-in CFL (TM p.7) and 2.5 hr/day for pin-based CFM fixture (TM p.11)
- Changed limit to incandescent/CFL wattage from 3:1 to 3.4:1 (TM p.7,11)
- Removed 25% retention penalty.

Section 11 – Envelope

- Added default R-values for existing walls / roofs when more detailed data cannot be obtained for portions of envelope, based on TM p.29
- Added default existing fenestration U-value and SHGC based on number of window panes, to be used when more precise information is not available (TM p.33)

Added Energy Star® window U-value and SHGC when generic Energy Star window is specified in ERP and model number is not provided.

Appendix E: Technical Topic—Boiler Efficiency Definitions

Technical Topic – Boiler Efficiency Definitions

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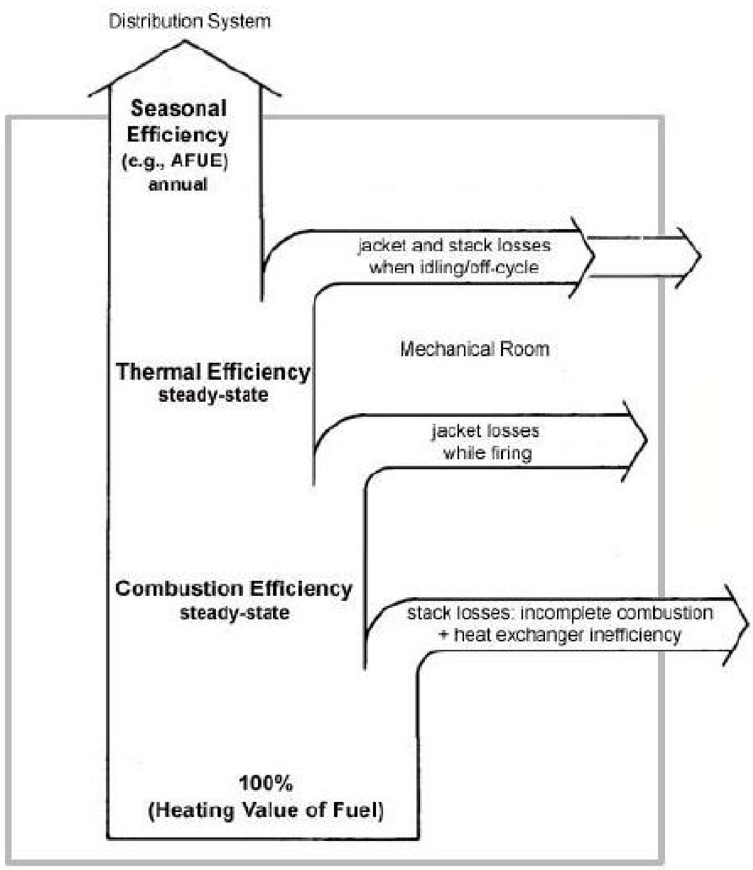
Boiler Efficiency Definitions



There are many different terms to describe the efficiency of heating systems, and some of those terms have more than one definition. When you see "combustion efficiency," "thermal efficiency," or "boiler efficiency" it is important to understand what definition was intended.

For the purpose of NYSERDA's Multifamily Performance Program, the critical distinction is between descriptions of steady state efficiency and descriptions of seasonal or annual efficiency.

This information is provided as a summary to the Tech Tips discussion on April 17, 2008.

Combustion efficiency and thermal efficiency describe steady state efficiency. Annual Fuel Utilization Efficiency (AFUE) and other measures of seasonal or annual efficiency are non-steady state measures that include a boiler's performance when it is operating at part load and idling between calls for heat.

Working with Efficiency Ratings

ASHRAE Standard 90.1-2004 describes the minimum acceptable ratings for new

boilers: Boiler Btu/hour input	Standard Used for Minimum Rating
<300,000	AFUE
300,000 - 2,500,000	Thermal Efficiency (E_t)
>2,500,000	Combustion Efficiency (E_c)

The Hydronics Institute Division of GAMA (HI) provides directories listing these ratings at GAMA Product Directories.[1] Specifically, see the directories for Residential [2] and Commercial [3] boilers.

Combustion Efficiency % = ((Fuel Input – Stack Losses) ÷ Fuel Input) x 100

Combustion efficiency is most commonly defined as shown above and usually describes the results of a combustion efficiency field test on an existing combustion appliance. Combustion efficiency does not account for jacket losses or off-cycle losses. The test estimates the heat lost up the stack when the combustion appliance has been firing long enough to reach equilibrium. Stack heat loss is assessed by measuring:

- Net stack temperature, the difference between the temperature in the flue and the temperature in the mechanical room
- Carbon dioxide concentration or oxygen concentration in the flue gas (%)

Carbon monoxide is also often measured, as an indication of unburned flue gases.

Combustion efficiency measurements for an installed combustion appliance account for any inefficiency of the heat exchanger due to soot, scale, or poor maintenance, because heat that fails to transfer through the heat exchanger goes up the stack.

The Hydronics Institute Testing Standard BTS-2000 provides a test procedure for rating the combustion efficiency of new boilers. The BTS-2000 combustion efficiency test is a more precise version of the combustion efficiency field test. Values for combustion efficiency measured using this standard are given in the Hydronics Institute commercial boiler directory referenced above.

Thermal Efficiency % = (Output / Input) x 100

The definition of thermal efficiency shown above is also from BTS-2000. When a boiler nameplate provides the input and output btus, the ratio of those numbers expresses the thermal efficiency. Thermal efficiency cannot be tested in the field; it requires metering the fuel input and measuring the

[1] http://www.gamanet.org/gama/inforesources.nsf/vContentEntries/Product+Directories?OpenDocument

[2] http://www.gamanet.org/gama/inforesources.nsf/vAttachmentLaunch/C2E0C5B4405EB75385256FA1008396CC/$FILE/01-08_RBR.pdf

[3] http://www.gamanet.org/gama/inforesources.nsf/vAttachmentLaunch/E9E5FC7199EBB1BE85256FA100838435/$FILE/01-08_CBR.pdf

pounds of steam, rate of hot water production, and condensate produced (for steam boilers or condensing boilers). The biggest difference between combustion efficiency and thermal efficiency is that thermal efficiency accounts for the heat lost through the boiler jacket during boiler firing.

Annual or Seasonal Efficiency

Seasonal efficiency cannot be tested in the field, nor can it be described with a simple equation. In addition to stack losses and jacket losses, seasonal efficiency accounts for heat loss during periods that the boiler is "idling" to maintain its internal temperature while the building is not calling for heat.

The AFUE rating system applies to boilers up to 300,000 Btu per hour input. ASHRAE is working on Standard 155P, a similar rating system for larger boilers and boiler systems. Values for AFUE are given in the Hydronics Institute residential boiler directory referenced above.

ASHRAE/ANSI Standard 103-1993 describes the procedure used to calculate AFUE, which includes assumptions such as:

- Varying outdoor temperatures in order to simulate a "typical" winter. Although this is a typical winter for the entire United States, not a typical New York State winter, it does model boiler performance at part load.
- An oversizing factor, which means the boiler does not run at full capacity, even on the coldest day.

An accurate description of seasonal efficiency would be the closest approximation of the boiler's actual performance in a particular building. The AFUE rating system makes simplifying assumptions that may not apply to a particular installation, but as a single number to represent seasonal efficiency, it comes closer than any other rating system currently available.

Appendix F: Technical Topic—Energy Management Systems

Technical Topic - Energy Management Systems

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Introduction

In an effort to cost-effectively reduce building-wide overheating, some multifamily building owners choose to install an energy management system (EMS) to control the boiler. The primary function of an EMS in multifamily buildings is to monitor indoor temperatures using a network of temperature sensors and then to use that information to control the heating system. This tech tip focuses on how to use an EMS to better control the run time of the boiler or the temperature of the water circulated through the building.

Background

Many multifamily buildings across New York State are overheated in the winter. In general, the most severe overheating is found in buildings heated by steam and hot water. Frequent causes of overheating are:

- degraded heating distribution systems
- inadequate or improperly calibrated heating system controls
- the complicated reality of heating multifamily buildings

Both New York State Code and New York City Code require a minimum indoor temperature of 68°F during the winter for multifamily buildings. For the purpose of this discussion, we define "overheated" as anything above code minimum, but many building owners aim for a minimum of 70°F to ensure tenant comfort. A range of temperatures is expected, but temperatures more than 72°F are widely considered overheated.

There are many boiler control strategies used to maintain this minimum temperature, and they vary widely in their ability to do so while conserving energy and keeping fuel costs low. Many centralized boiler controls operate without any feedback from indoor temperature sensors, which limits their ability to achieve all three goals. Controls that allow the tenants to adjust the amount of heat coming from a radiator, such as thermostatic radiator valves (TRVs) or thermostats, can reduce both overheating and tenant complaints, but they can be expensive to install. They also typically rely on tenant cooperation to achieve savings. This can make them unappealing for energy conservation retrofits because savings may be unreliable.

NYS and NYC Code Requirements

New York State – Heat supply. Every owner and operator of any building who rents, leases or lets one or more dwelling unit, rooming unit, dormitory or guestroom on terms, either expressed or implied, to furnish heat to the occupants thereof shall supply heat during the period from September 15th to May 31st to maintain a temperature of not less than 68°F (20°C) in all habitable rooms, bathrooms and toilet rooms. (Section 602.3)

New York City – Heat must be supplied from October 1 through May 31 to tenants in multiple dwellings. If the outdoor temperature falls below 55°F between the hours of six a.m. and ten p.m., each apartment must be heated to a temperature of at least 68°F. If the outdoor temperature falls below 40°F between the hours of ten p.m. and six a.m., each apartment must be heated to a temperature of at least 55°F. (Multiple Dwelling Law § 79; Multiple Residence Law § 173; NYC Admin. Code § 27-2029.)

Figure 1: Central computers of Energy Management Systems installed in the field and manufactured (from left to right) by Heat-Timer, U.S. Energy, EnTech, and Intech 21. Photo credits: Far left and left by Taitem Engineering; right and far right by the Association for Energy Affordability.

Description of Energy Management Systems

Energy management systems have two main functions that differentiate them from other types of boiler controls:

First, many EMSs can **monitor a wide array of data** types and display the data in a computer program or on a website. Depending on the model, data points that can be monitored include domestic hot water temperature, fuel consumption, fuel oil tank level, boiler stack temperature, boiler water usage, and more. Although these monitoring capabilities are often emphasized in marketing materials and can be a useful tool for some boiler operators, they do not produce any energy savings by themselves. Action by the boiler opera-tor is required to turn any of the information listed above into potential ener-gy savings.

Second, EMSs use **a network of temperature sensors** to better control the run time of the boiler or the temperature of the water circulated through the building. One temperature sensor monitors outdoor air temperature. It determines whether the building should be heated at any given time, where on the outdoor reset curve the boiler should operate, or which curve should be used. Additionally a series of sensors is installed in a sample of apartments to monitor the temperature inside the building.

Multiple temperature sensors are recommended to get an accurate picture of what is going on in the building. Measuring temperatures in several apartments reduces the impact of anomalies caused by open windows, electric heaters, and tenants who shut off their radiators. **Best practice:** Install sensors in a representative sample of no fewer than 10% of the apartments; this provides adequate redundancy while keeping costs reasonable. **Best practice:** Install the sensors in apartments on different floors and lines to take into account differences in temperature between upper and lower floors, sunny and shaded sides, and windward and leeward sides of the building. Many EMS manufacturers offer wireless sensors which can reduce installation costs.

The indoor sensors are used to calculate an approximate average building temperature, which the EMS uses to control the boiler. **In steam systems,** this average temperature is used to prevent unnecessary firing when the building's target temperature is already met. That is, the apartment sensors "vote." If enough sensors indicate apartments are warm enough, the EMS keeps the boiler off, and if enough indicate apartments are too cool, the EMS allows the boiler to fire.

In hot water systems, instead of turning the boiler on and off, the EMS uses the apartment temperature data to adjust the outdoor reset curve. For example, if the outdoor reset curve calls for a supply water temperature of 160°F, but the average indoor temperature is close to the setpoint, the outdoor reset curve might be adjusted to provide supply water at 150°F.

Most EMSs can be programmed to lower the indoor temperature at night, which can result in additional savings. We recommend implementing night setback, if permitted by code.

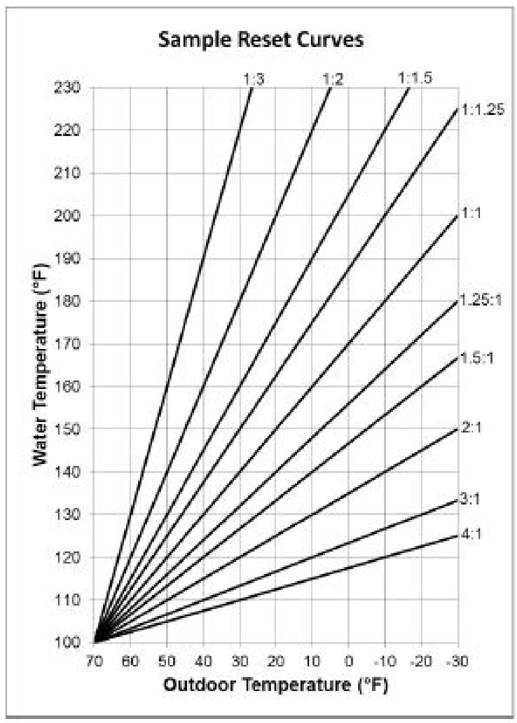
For both steam and hot water systems, the primary result of implementing an EMS is to reduce the average indoor temperature. Keep in mind that the EMS alone cannot supply more heat to specific cold apartments nor reduce the heat supplied to specific hot apartments.

Outdoor Reset Control

*In buildings heated with **hot water**, the use of outdoor reset curves can reduce overheating and save energy by varying the temperature of the water circulating through the building. In general, as the outdoor temperature decreases, warmer water is circulated. Actual water temperatures required are building-specific.*

***Example:** A building might require 140°F circulating water when it is 55°F outside, but 180°F water when it is 20°F outside.*

The outdoor reset ratio defines how much the water temperature is increased per degree of outdoor temperature decrease. For example, with a 1:1 ratio, the water temperature is increased 1°F when the outdoor temperature falls 1°F. With a 1:1.25 ratio, the water temperature is increased 1.25°F for every 1°F the outdoor temperature falls.



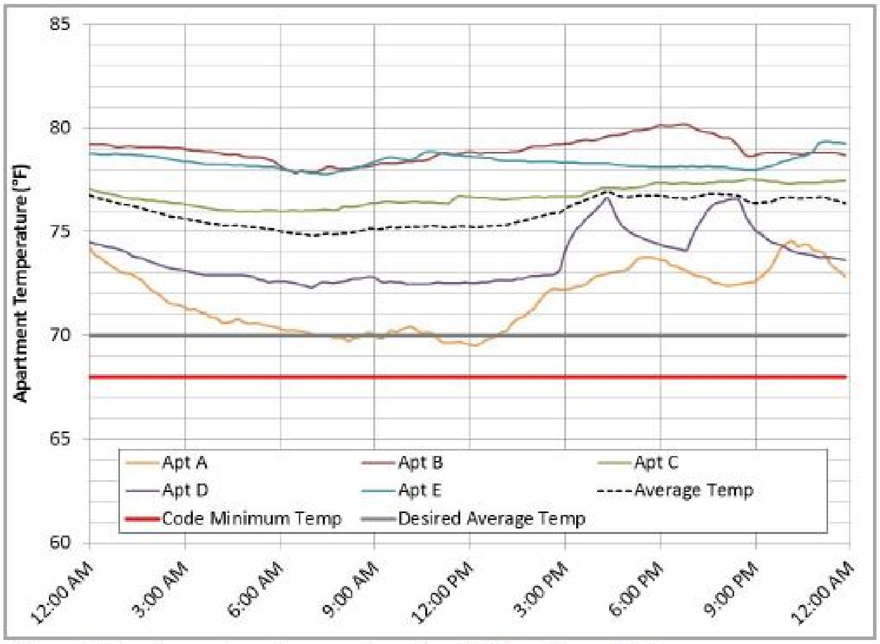


Figure 2: Sample apartment temperatures in a building with no EMS.

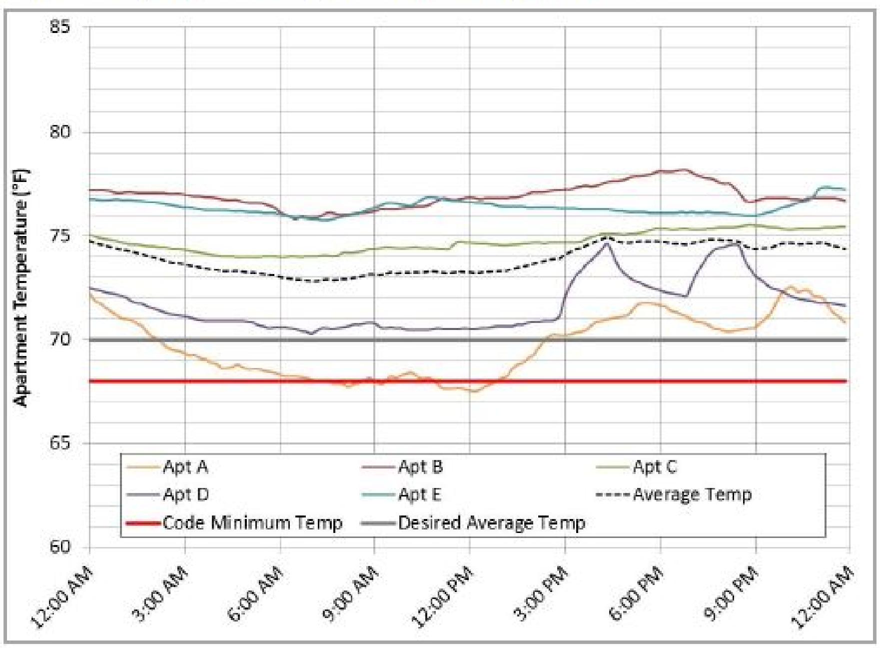


Figure 3: Temperatures in the sample apartments, altered to show the effect of installing an EMS on the boiler.

Main Drawback of EMS

Figure 2 shows the temperature in five apartments for a typical 24-hour period in a building without an EMS. Note that at a few points during the day there is a difference of almost 10°F between the hottest and coldest apartments.

Figure 3 shows the temperatures for the same five apartments, altered to show what the temperature profile might look like in the same building on the same day if an EMS was controlling the boiler. Note that all of the apartment temperatures have decreased by approximately 2°F and the average building temperature has also decreased. The difference between the hottest and coldest apartment is still nearly 10°F at some points. Also, the coolest apartment occasionally dips below the code-minimum 68°F. If the EMS were to decrease the indoor temperature further, the temperature in Apartment A would no longer meet code.

Figures 2 and 3 illustrate the **main drawback** of EMSs: Because they are not able to direct more or less heat to specific apartments, some apartments will continue to be overheated and some savings will be unrealized. Balancing the distribution system so that the apartments are heated more evenly is therefore critical to maximizing savings. Most heating systems were designed to supply heat to all apartments at approximately the same time. Over the years, however, systems may be altered and key components may degrade or fail. The result is that heat may now reach some apartments more slowly than others. These heating imbalances can have many causes, including failed or clogged air vents, failed steam traps, sediment build-up in distribution pipes, removed radiation, removal of vacuum pumps, and others.

Figure 4 shows what might happen to apartment temperatures in our sample building if an EMS were installed and the distribution system were balanced. Note the much smaller range of temperatures between the hottest and coldest apartments (4°F maximum), and no significantly overheated apartments. Achieving maximum savings with an EMS can only be realized in conjunction with balancing the distribution system.

Predicting Energy Savings

To calculate potential energy savings, you must first estimate and enter the reduction in average building temperature into the building energy model. In a recent study of mid-rise steam and hot water heated buildings, energy management systems were successful in reducing average building temperatures in twelve out of fifteen buildings.[1] The average reduction in building temperature was 2.5°F for steam-heated buildings and 0.6°F for hot water heated buildings (Table 1). However, even when the boilers were controlled by EMSs, between 67% and 100% of the apartments in each building were found to be overheated. As expected, there was a strong positive correlation between how overheated a building was without the EMS operating and how much the average temperature was reduced by turning on the EMS. That is, buildings with the highest average temperature when the EMS was deactivated had the largest reduction in average building temperature when the EMS was reactivated.

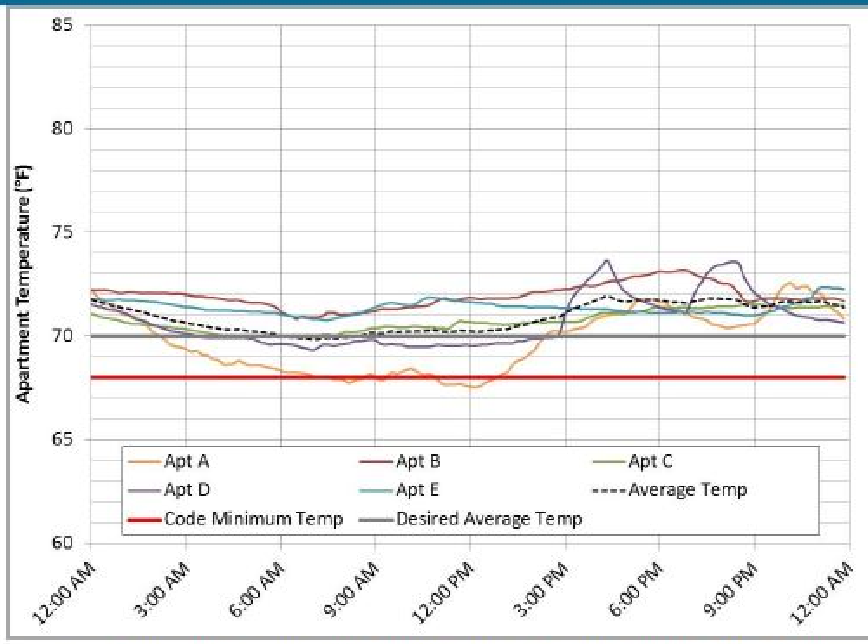


*Figure 4: Temperatures in our sample building adjusted to show what is likely to happen when an EMS is installed **and** the distribution system is balanced.*

	Average Reductions in Building Temperature			Number of Buildings
	Average	Minimum	Maximum	
1-Pipe Steam	2.5°F	-0.5°F	5.9°F	12
Hot Water	0.6°F	-1.6°F	2.6°F	3

Table 1: Reductions in building temperature achieved when the EMSs were activated.

The study did not track fuel consumption, so heating fuel and cost savings results must be extrapolated. A U.S. Department of Energy publication from 2013[2] stated that overheating increases annual heating energy consumption by approximately 3% per degree Fahrenheit per day. Using this DOE estimate and the average temperature reductions found by Dentz, et al., 7% heating energy savings for steam buildings and 2% savings for hot water buildings are likely when an EMS is installed in a building. EMS manufacturers predict at least 10% heating energy savings, which they claim is conservative, from upgrading boiler controls from an outdoor reset to an EMS. Compared to the temperature reductions achieved by Dentz, et al., 10% heating energy savings should not be considered a conservative estimate but it may be useful instead as an upper limit for achievable savings.

[1]Dentz, J., Varshney, K., and Henderson, H. (2013). Overheating in Hot Water- and Steam-Heated Multifamily Buildings. The full text of this study is available online in the Building America Program Publication and Product Library.

[2]U.S. Department of Energy. (2013, 11 26). Thermostats. Retrieved 1 9, 2014, from Energy.gov: http://energy.gov/energysaver/articles/thermostats-and-control-systems

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Modeling Protocols for Implementing EMS on Heating Systems in Multifamily Buildings

The following modeling protocols are intended to help energy modelers accurately and conservatively calculate potential savings from implementing Energy Management Systems on steam and hot water systems.

STEAM SYSTEMS

Existing	Proposed	Modeling Protocol - Steam
On/off control only; no outdoor reset Note that outdoor reset for steam systems is defined as a control that adjusts the length of the steam cycle as the outdoor temperature changes.	Outdoor reset	Model as a temperature reduction. Do not model "outdoor reset" as this option only applies to hot water system or vacuum steam systems. Must provide details of existing controls and evidence that outdoor reset is not currently being utilized. 1°F maximum temperature reduction
Outdoor reset; heating imbalances observed	EMS with indoor temperature sensors; distribution imbalances not addressed	2°F maximum temperature reduction
Outdoor reset; heating imbalances observed	EMS with indoor temperature sensors; distribution balanced	3°F maximum temperature reduction
Outdoor reset; no heating imbalances	EMS with indoor temperature sensors	3°F maximum temperature reduction

HOT WATER SYSTEMS

Existing	Proposed	Modeling Protocol – Hot Water
On/off control only, no outdoor reset	Outdoor reset and EMS with indoor temperature sensors	Model as outdoor reset control on hot water loop. Must provide details of existing controls and evidence that outdoor reset is not currently being utilized. System must be able to operate with outdoor reset (condensing boilers and/or boilers separated from heating loop). Additionally, model a temperature reduction of 1°F maximum if the outdoor reset curve (i.e. the hot water loop set point) will be adjusted based on feedback from apartment sensors.
Outdoor reset	EMS with indoor temperature sensors	Model as a temperature reduction if outdoor reset curve (hot water loop set point) will be adjusted based on feedback from apartment sensors. 1°F maximum temperature reduction

Note: Steam boilers that supply a hot water loop are to be considered a hot water system.

Best Practices to Achieve Savings

Energy management systems can reduce heating energy use in multifamily buildings. Taking the following steps will help maximize savings.

1. Identify pre-existing temperature control problems. Measure and record building temperatures in a variety of apartments during the heating season. Interview the superintendent, manager, owner, and residents to gain an understanding of heating issues in the building.
2. Evaluate loads on the building. Determine whether there are other factors causing the apartments to be over- or under-heated such as solar loads, wind loads, removed or oversized radiators, etc.
3. Gain a general understanding of the distribution system layout. Then look for patterns in heating imbalances.
4. Consider implementing comprehensive rebalancing if heating imbalances are observed. Savings will be limited without rebalancing.
5. Identify all components of the existing boiler control system. Make sure that the existing controls are unable to provide indoor temperature feedback. Determine whether night setback and outdoor reset controls are in place.
6. Model predicted savings using the modeling protocols above.
7. Review the plan for the new controls, including a careful examination of sensor locations, set points, and zones. Ensure that the proposed EMS provides a significantly different control strategy than the old control system; otherwise, savings will not be achieved. In 2-pipe and hot water systems, sensors should be installed in no fewer than 10% of apartments and on a variety of floors and in a variety of apartment lines. In 1-pipe steam systems, sensors should be installed in no fewer than 25% of apartments and on a variety of floors, and there must be a sensor in the apartment at the end of each steam line.
8. Inspect the installation. Ensure that the sensors are located in apartments that represent average building temperatures and that they are installed on interior walls, out of direct sunlight, and away from sources of drafts or heat.
9. Review the EMS settings; make sure they have been adjusted to reflect the needs of the building. Note that in general, the target setpoint for the EMS will need to be several degrees warmer than the minimum temperature required by code to ensure that the coldest apartments meet code. If you are working in a building where tenants are likely to resist a temperature change, consider reducing the temperature slowly, across several months. Also consider adjusting the temperatures seasonally, to be warmer in deep winter and cooler in the fall and spring.
10. If balancing work was performed, create a plan for continued maintenance. Train building staff on how to maintain the distribution system.
11. Train staff thoroughly on how to properly operate the new EMS, or consider restricting their access to the controls. If the building does not currently have a protocol for addressing tenant heating complaints, develop one that involves correcting all other potential reasons for low temperatures before turning up the EMS setpoints. Emphasize that staff should not override the system or increase the temperature in the whole building just because of a single tenant complaint.

Conclusion

Energy management systems can be an effective tool for reducing the high average temperatures often found in multifamily buildings and they can lead to substantial energy and cost savings. It is important, however, to understand the capabilities and limitations of EMS controls. EMSs cannot correct temperature differences in apartments that are caused by heating system imbalances; as a result, the overall temperature reduction possible in a given building is limited by the temperature of the coldest apartments. In order to maximize savings, comprehensive balancing work must be performed in conjunction with an EMS installation.

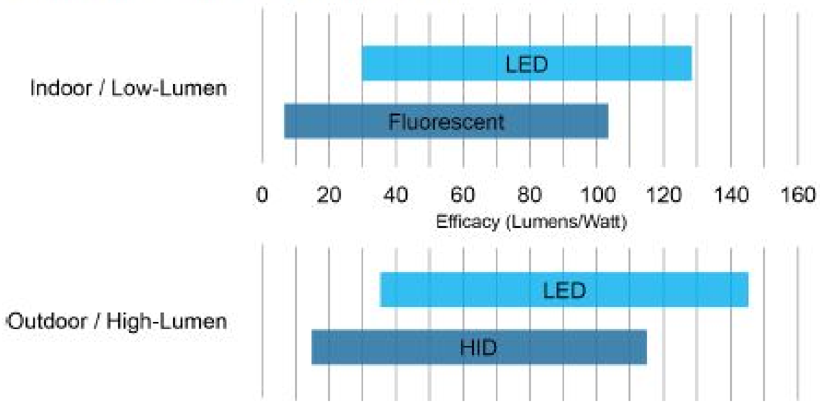
Appendix G: Technical Topic—LED Screw-In Replacements

Technical Topic – LED Lighting

LED lighting efficiency is advancing rapidly, which can be challenging when predicting energy savings and specifying upgrades. This tech tip is intended to help energy auditors avoid insufficient light levels or over-predicted energy savings. Fixture efficacy is defined as usable lumens per watt, and a familiarity with the efficacy ranges for light fixtures currently available will help auditors make reasonable assumptions when comparing LED fixtures to traditional lighting technologies.

LED fixtures can be more efficient than comparable fluorescent and high intensity discharge (HID) fixtures. However, as shown in the following graphic, there is significant overlap in fixture efficacy: some fluorescent and HID fixtures are more efficient than some LED fixtures.

Typical Efficacy Ranges for Different Fixture Types



When replacing fluorescent or HID fixtures with LEDs, if the efficacy of the existing fixtures is unknown, then **a wattage reduction of no more than 1/3 should be assumed.**

For example, for a generic 150W HID fixture, assume 100W for the LED upgrade.

This reduction is based on a comparison of LED, HID and fluorescent fixtures for a range of fixture types and wattage levels, and assumes that the existing light levels will be maintained.

Needed for Existing Fixture	Needed for Proposed Fixture
• Existing light output and how measured • Existing wattage and how measured • Make and model number of fixture, lamp, and ballast	Cut sheet with following information • Model number • Wattage • Mean lumen output

LED fixtures are more efficient in part because their directionality allows a higher percentage of the light to reach the intended surface. There is less of the wasted light that is characteristic of non-LED lighting types. This increase in illumination efficiency is built into the rated wattage and lumen output that are provided in LED fixture cut sheets and is accounted for in the 1/3 wattage reduction recommendation in this tech tip.

Energy auditors frequently overpredict energy savings from replacing fluorescent or HID with LED lighting by basing calculations on fixtures with significantly lower light output than the existing fixtures. If implemented as specified, insufficient light levels will typically be the result. Without evidence of significant over-lighting, reductions in light output should not be included as part of energy savings projections from LED retrofits.

To find data about certified lighting products:

- Residential fixtures (LED and CFL) – ENERGY STAR Certified Light Fixture Product Finder: http://j.mp/EstarFixtures
- Screw-in bulb replacements (LED and CFL) – ENERGY STAR Certified Light Bulb Product Finder: http://j.mp/EstarBulbs
- Commercial fixtures and bulbs (LED Only) – Design Lights Consortium – Qualified Products List:

Appendix H: Technical Topic—Elevator Energy Use and Other Essentials

Technical Topic – Elevators: Energy Use and Other Essentials

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This tech tip provides an overview of the energy consumption of elevators in multifamily buildings. Methods for estimating usage are discussed. The various types of elevator systems are reviewed. Existing codes and standards governing elevator energy consumption are summarized. The relative efficiencies of elevator drives and controls are given; and finally, several methods of reducing elevator energy consumption are presented.

ELEVATOR ENERGY CONSUMPTION

Elevator energy consumption for a specific building is difficult to estimate. Even when the type and size of the motor can be determined, the actual consumption depends on many variables, including building type, population type, hoist mechanism, weights of the load and counter balance, speed of travel, etc. The literature on elevator energy consumption says that elevators consume 2-10% of whole building electricity usage. This range is not differentiated by building type, and it is likely that elevators in office buildings consume more electricity than elevators in multifamily buildings.

Best practice for determining the electricity consumption of a specific elevator is to monitor its electricity consumption for several weeks using data logging equipment that can record actual energy consumption. This is especially important when claiming energy savings from elevator improvements.

In general, elevators use relatively small amounts of electricity in multifamily buildings. For example, in the Energy Star Multifamily High Rise Program, if elevator consumption is not calculated by a model, the Simulation Guidelines provide the following as the total energy consumption for all elevators in the building (Table 1).

# of apts.	Hydraulic (1-6 stories)	Geared Traction (7-20 stories)	Gearless Traction (21+ stories)
<7	1,910	NA	NA
7-20	2,150	NA	NA
21-50	2,940	3,150	NA
50+	4,120	4,550	7,570

Table 1: Annual Elevator Energy Consumption (kWh/year)

Researchers in the European Union measured the electricity consumption of 30 elevators in multifamily buildings and found those elevators consume 600-6,800 kWh/yr.[1] More interestingly, they found that the energy consumption when the elevators were in standby mode (i.e. when the cab was not in motion) accounted for an average of 70% of the total annual energy consumption and varied from 15 to 90%. They measured elevator standby power in multifamily buildings to be 50-700W. Significant amounts of electricity are being consumed when elevators are not being used, and potential savings are substantial.[2]

IDENTIFYING ELEVATOR SYSTEMS

Elevator systems can be classified by the type of hoist mechanism. A hydraulic elevator is raised by a column of oil pressurized by a pump. A traction elevator is raised by wire ropes (cables) wrapped around a pulley turned by a motor.

Hydraulic Elevators

In a hydraulic elevator, the cab sits on a piston that is raised and lowered by pressurized hydraulic fluid. In general, an AC motor is used to turn a pump that pressurizes the reservoir of hydraulic fluid to raise the cab. To lower the cab, a relief valve is opened to decrease the pressure in the fluid. Hydraulic elevators only use energy when the cab is being raised.

Hydraulic elevators are very common in buildings up to six stories and are almost never seen in taller buildings. They are characterized by slow up and down movement. The best visual clue for identifying a hydraulic elevator is that the machine room will have a large tank that will normally be identified as containing hydraulic fluid. Hydraulic systems can also generally be identified by the absence of an elevator room at the top of the building, especially in older buildings, but that is not an absolute. Machine room-less traction elevators (described below) also lack an elevator room at the top of the building, so especially in newer buildings, the absence of a machine room at the top of the building does not always imply a hydraulic elevator.

Hydraulic elevators use the most electricity per trip of any kind of elevator. However, they are often installed because they have a lower installed cost than traction elevators.

Traction Elevators

The cab of a traction elevator is suspended from wire ropes that wrap around a pulley. The pulley is driven by a motor that uses either alternating current (AC) or direct current (DC).

DC Traction Systems

When an elevator is moved by a DC motor, the DC power is supplied by either a motor-generator set or a rectifier.

DC motor with a motor generator set: A motor-generator set (aka "MG set" or "gen set") is an AC motor coupled to a DC generator to produce DC power. The DC output is used to power the elevator controller and a DC motor that turns the pulley to raise and lower the elevator. DC power was historically used because it is easy to vary the speed of the motor and elevator.

The visual clue for a DC motor with a motor-generator set is that there are two separate large devices per elevator in the elevator machine room. The motors connected to the hoist may be stamped "DC" on the nameplate. Motor-generator sets will often have nameplates labeled "motor generator" or will list AC volts and current as "inputs" and DC volts and current as "outputs."

DC motor with rectifier: A rectifier is another method of providing DC power. Rectifiers convert AC power to DC power. Figures 2a and 2b show two different types (and ages) of rectifiers.

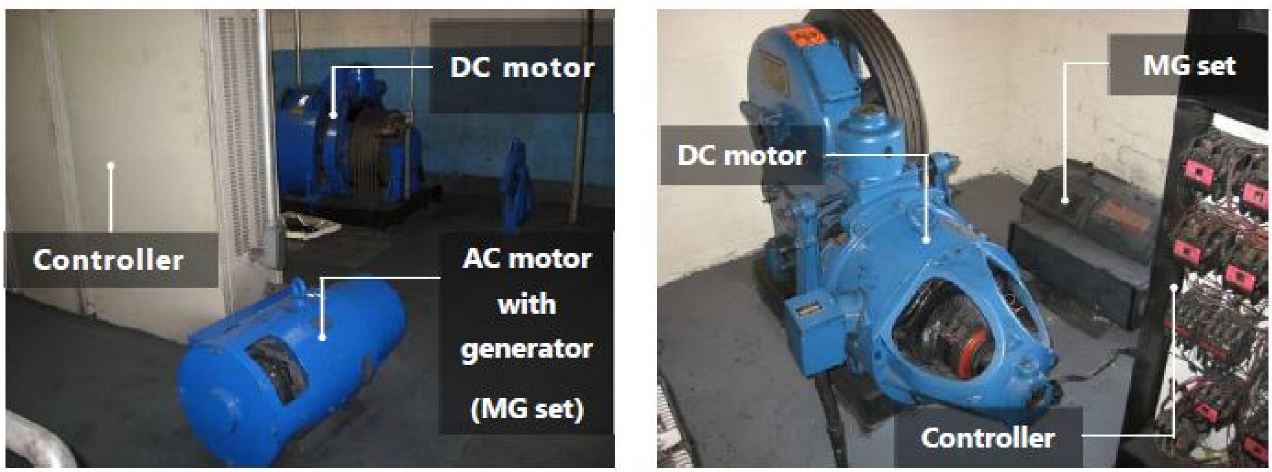

Figure 1: Examples of motor generator sets—DC motors and elevator controllers

Elevators with DC motors and motor-generator sets are generally found in buildings over 30 years old. This is the least efficient traction drive system. The motor-generator set draws as much as 12% of full load power when the motor-generator is idling and the elevator is not moving.[3] Motor-generator sets are often equipped with automatic timers to limit idle time to 3-10 minutes, but can idle continuously if there is no timer or if the timer is not functioning correctly. (See section on Energy Conservation Measures for more information on timers.)

If there is no old-style rectifier in the elevator machine room, a good way to determine whether the motor is AC or DC is to look at the nameplate on the motor attached to the elevator hoist. These nameplates are often stamped with "AC" or "DC." Also be sure to open the controller panel to see if there is an SCR inside.

Figure 2a: Rectifier, not solid state. This old-style rectifier is roughly the size of an under-counter refrigerator

Figure 2b: Elevator control with solid state rectifier—the controller panel has been opened to show the interior. Silicon-controlled rectifiers (SCRs) are a common form of solid state rectifier. The SCR serves the same function as the older-style rectifier (Figure 2a).

AC Traction Systems

AC systems have no motor-generator set or rectifier. Instead, an AC motor drives the hoist pulley (or the hydraulic pump, as described above). Elevators that use AC motors have many variations, including what kind of controls are used, and whether there are gears between the motor and the pulley. Note that it may not be simple – or necessary – to identify the specific type of AC elevator system. If that information is required, you may need to ask the building maintenance staff, review product literature if any can be found on-site, or call the elevator maintenance company.

Geared vs gearless: Traction elevators can be further classified as being geared or gearless. A geared system has reduction gears between the shaft of the drive motor and the pulley that raises and lowers the cab. In a gearless elevator, the shaft of the drive motor is connected directly to the pulley.

There are inherent losses in a system with gears, so geared elevators are less efficient and slower than gearless elevators. However, a direct connection between the motor and the pulley requires large amounts of torque at low speed, necessitating a bigger motor for gearless elevators.

Until recently, larger motors for gearless elevators have been considered cost effective only in tall buildings (more than approximately 20 floors) with high elevator speeds. Recent developments in elevator technologies, including the development of permanent-magnet motors and new cable materials that allow for a smaller pulley, have made it more cost-effective to install gearless systems in new buildings of all heights.

AC motor control systems: Without the ability to vary the speed of the motor, an elevator cab experiences jerky movement as it starts and stops. Historically, it was more difficult to vary the speed of an AC motor than of a DC motor. As power distribution standardized on AC, motor-generator sets were used in elevator installations to take advantage of the easily-controlled DC motors. But as discussed above, motor-generator sets are inefficient.

For approximately the last 20 years, many elevator installations have used variable voltage variable frequency (VVVF) controls that allow the speed of AC motors to be varied. (See Figure 3.) More recently, a method called pulse width modulation has been developed. It uses power transistors that are rapidly cycled on and off to control the speed of the motor. Pulse width modulation can be used for DC or AC motors, but in elevator applications it is more common on AC motors.

Figure 3: AC motor with VVVF control

Regenerative braking: In order to reduce the power needed to move an elevator cab, a counterweight is hung from the cable on the opposite side of the pulley. Counterweights typically weigh as much as the cab plus half the capacity of the elevator. Therefore, when there are fewer than two or three people in the cab, more energy is needed to lower the cab (and to raise the heavier counterweight) than to raise it. When the heavier side needs to be lowered, its decreasing potential energy is normally dissipated as heat. With a regenerative braking system, the potential energy can be converted to electricity that is fed back to the building's electrical system, thereby reducing the amount of electricity purchased from the utility. Regenerative braking is expensive and therefore is not a common option in elevator upgrades but rather is used primarily in new construction. Elevator systems with regenerative braking are the most efficient currently available.

Machine room less (MRL) elevators: A recent development in elevator systems is to mount the elevator motor in the hoistway, which eliminates the need for a penthouse. In the United States most MRL elevators have been installed since 2000 and are therefore most common in new buildings or existing buildings that have undergone major renovations. MRL elevator systems make the replacement of a hydraulic elevator with a traction elevator less costly than a traditional traction installation, which would require a machine room be built on the roof.

CODES AND STANDARDS

In the last five years, several organizations have published standards on the energy consumption of elevators. While none of these is currently required in the US, they are useful for determining how to make elevators more efficient. They can also be used to specify the most energy efficient options for a variety of elevator components when designing an elevator installation or upgrade.

ASHRAE 90.1: Prior to 2010, elevators were considered an unregulated load in the ASHRAE 90.1 standard, and therefore no guidance for energy efficiency improvements was given. However, ASHRAE 90.1-2010 addresses the standby energy used by elevators as a regulated load. Section 10.4.3 defines the energy consumption of three parts of the elevator:

10.4.3.1 Lighting – All cab lighting systems shall have an efficacy of not less than 35 lumens per watt.

10.4.3.2 Ventilation – Cab ventilation fans for elevators without air-conditioning shall not consume over 0.33 W/CFM at maximum speed.

10.4.3.3 Standby Mode – When stopped and unoccupied with doors closed for over 15 minutes, cab interior lighting and ventilation shall be de-energized until required for operation.

2015 International Energy Conservation Code (IECC): Section C405.9 of the IECC has identical requirements to Section 10.4.3 of ASHRAE 90.1. In addition to those requirements that directly affect elevator energy consumption, the IECC also has several requirements about airsealing the elevator shaft:

1. Doors to elevator lobbies shall be gasketed or weather-stripped. (Section C402.5.4)
2. Elevator shaft vents shall be provided with a motorized damper that is automatically controlled to be closed whenever possible. (Sections C402.5.5 and C403.2.4.3)

2012 International Green Construction Code (IgCC): Section 609.2.1 of the IgCC gives several requirements for elevator energy consumption. The requirements for lighting (Section 609.2.1.1) and ventilation (Section 609.2.1.3) are identical to ASHRAE 90.1 Section 10.4.3. The IgCC gives additional guidance for the following parts of the elevator:

609.2.1.2 Power conversion system for traction elevators:

609.2.1.2.1 Motor – Induction motors with a Class IE2 efficiency rating, as defined by IEC EN 60034-30, or alternative technologies, such as permanent magnet synchronous motors that have equal or better efficiency, shall be used.

609.2.1.2.2 Transmission – Transmissions shall not reduce the efficiency of the combined motor/transmission below that shown for the Class IE2 motor. Gearless machines shall be assumed to have a 100-percent transmission efficiency.

609.2.1.2.3 Drive – Potential energy released during motion shall be recovered.

609.2.1.4 Standby mode – When the elevator is stopped, not occupied, and with doors closed, lighting, ventilation, and cab displays shall be capable of being de-energized within 5 minutes of stopping, and re-energized prior to opening the doors. Power shall cease to be applied to the door motor after the elevator is stopped, lighting is de-energized, and no one is in the cab, and re-energized upon the next passenger arrival. In buildings with multiple elevators serving the same floors, not less than half of the elevators shall be capable of switching to sleep, low-power mode, during periods of low traffic.

609.2.1.5 Guides – Elevator car guides shall be of the roller type, in order to reduce frictional energy losses. Counterweights with sliding guides shall be balanced in order to minimize frictional losses associated with the counterweight guides.

VDI 4707: The German association of engineers, Verein Deutscher Ingenieure (VDI), published VDI 4707 in 2009 (Part 1) and 2013 (Part 2). These comprehensive guidelines cover all parts of elevator energy consumption, including the percentage of time that the elevator is in motion, how much energy the elevator consumes in both standby and travel modes, and how to measure and calculate electricity consumption. The guidelines divide elevators into classes based on how much energy they consume. Classes are labeled A-G, with A using the least amount of energy. Table 2 gives the energy demand for each class for both standby and travel mode.

Class	Standby power (watts)	Travel power (mWh/kg-m)
A	≤ 50	≤ 0.8
B	≤ 100	≤ 1.2
C	≤ 200	≤ 1.8
D	≤ 400	≤ 2.7
E	≤ 800	≤ 4.0
F	≤ 1600	≤ 6.0
G	> 1600	> 6.0

Table 2: VDI 4707 Energy Demand by Class

ISO 25745: This standard is reportedly similar in scope to VDI 4707.[4]

RECOMMENDED ENERGY CONSERVATION MEASURES

Replacing elevator drive systems for energy savings alone has not been shown to be cost-effective (that is, to have a savings-to-investment ratio greater than 1.0). There are two issues: first, elevators do not use very much electricity, and therefore even elevator replacements that save 40-60% of the total elevator electricity consumption will only save an estimated "few thousand kilowatt-hours per year for a single elevator."[5] One study of an elevator replacement in a hotel found a reduction in energy consumption of 45% and calculated annual savings of $500/year (at $0.10/kWh).[6] This was a best-case replacement where the existing system was very inefficient and they were able to install a very efficient replacement.

The second issue preventing elevator replacements from being cost-effective is that it can be very expensive to upgrade an elevator. Elevators are most often designed systems – not off-the-shelf equipment. Also, a renovation can trigger code requirements that necessitate significantly more construction than simply swapping out the motor and controls. For example, in some jurisdictions, an elevator replacement can trigger the requirement that every landing be made accessible for people in wheelchairs, which includes lowering the elevator call button on each floor by several inches. If an elevator energy upgrade is planned, we recommend checking with an elevator consultant when formulating the work scope. A very rough guide for elevator upgrades is to budget $15,000 per floor per elevator.[7]

The low energy savings and high cost of renovation often result in very long paybacks for elevator upgrade measures. For example, installing a machine room-less elevator in new construction and existing buildings can have a payback as long as 23 years and 60 years, respectively.[8]

Elevators are sometimes replaced because they reach the end of their useful life, or because a building is undergoing substantial other renovations. In those cases, and in all new construction, it is prudent to consider installing a high-efficiency elevator system. Just like there are many factors that affect elevator energy consumption, there are several parts of the elevator system that affect the overall efficiency:

- Hoist mechanism – hydraulic elevators should be avoided as they are the least efficient, and least resilient, type of elevator. Machine room-less elevators may be a good option for replacing hydraulic elevators, although they are more expensive to install.
- Drive motor efficiency – a high-efficiency drive motor should be installed. The table below shows the efficiency of a variety of common drive motor types.

	No regeneration	With regeneration
DC motor with motor-generator set	280	259
Geared AC motor	224	198
Gearless AC motor	134	60
Permanent magnet synchronous motor	119	35

Table 3: Drive motor efficiencies
Units of input required for 100 units of output[9]

- Control type – the controls should be the most efficient possible. Figure 4 shows the possible energy savings for various controls.

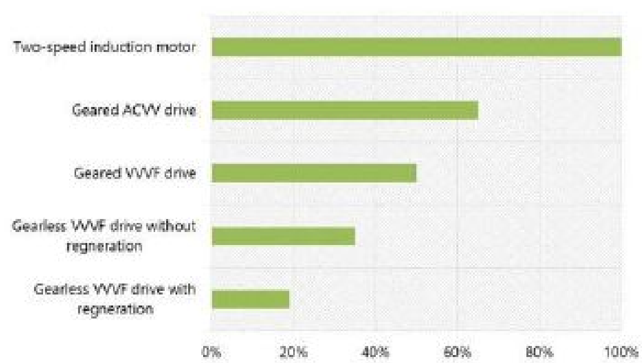

Figure 4: Average energy consumption relative to a two-speed induction motor[10]

- Machine room-less (MRL) elevators – MRL elevators are considered the most efficient available technology. They use several advances to reduce electricity consumption, including extremely efficient motors and new cable materials that allow for smaller pulleys and reduced torque requirements. MRL elevators are able to use much smaller motors: a low-rise MRL elevator might require a 10 HP motor, where the equivalent traction or hydraulic elevator would require a 40 HP or 60 HP motor, respectively. Also, the lack of a machine room eliminates the need for an air conditioner in the machine room and also reduces stack effect and infiltration losses.

- Regeneration – from the table and figure above, it is clear that regeneration can save considerable energy. However, it is expensive to install and therefore should be evaluated for appropriateness for each elevator system individually.

As mentioned above, the standby energy consumed when the cab is stationary can account for well over half of the total energy consumed in many multifamily buildings. Also, reducing standby energy can be significantly less expensive than replacing an entire elevator. We therefore recommend consideration of the following measures in any building with an elevator:

- Motor-generator sets – elevator systems with motor-generator sets have especially high standby power consumption because of the electricity used by the motor-generator set when it is idling. Motor-generator sets should be placed on a timer that turns the MG set off after the cab has been stationary for 5-10 minutes. Sometimes timers exist but are not working; this should be verified on site.

- Cab lights – replace existing lights with high-efficiency fluorescent or LED fixtures. The minimum efficacy should be 35 lumens per watt. Install an occupancy sensor in each cab to turn the lights off when no one is in the elevator.

- Cab ventilation – a fan in the elevator cab is generally not required by code, so it should be disconnected or removed. If building management is uncomfortable removing the fan, connect it to an occupancy sensor so it only runs when there is someone in the cab. Make sure the fan uses a maximum of 0.33 W/cfm.

- Door operators – the elevator cab doors must stay closed when the cab is in motion. Some systems use a stalled motor to hold the doors closed, which means that energy is being consumed all the time.[12] Any system that uses a stalled motor should be retrofit with a mechanism that does not require constant energy.

- Shaft airsealing – elevators act as large air pumps, pushing a considerable volume of conditioned air out of the building each time they move. This loss of conditioned air can be minimized in several ways. For example:

    * Airseal the machine room. If louvers are required by the local fire code, install motorized louvers that remain closed until smoke is detected.
    * Reduce the open area around the elevator cables where the cables pass through the machine room floor to the minimum required by code.
    * Weatherstrip the elevator doors at each floor.

- Elevator machine room cooling – some elevator control systems require that they not get too hot, so many elevator machine rooms have air conditioners. However, elevator machine rooms often have louvers to the outside, which means the air conditioners run all the time in the warmer months. Furthermore, in many machine rooms the air conditioners are set to temperatures that are much lower than required by the equipment. Reduce the amount of energy needed for cooling the machine room by:

    * Airsealing the machine room as described above.
    * Confirming with the elevator control manufacturer the maximum allowable temperature and setting the AC thermostat to just a few degrees below that temperature.
    * If motorized louvers are installed in the machine room wall, use them as an economizer to take advantage of days when the outside temperature is cooler than the temperature in the machine room.

In buildings with hydraulic elevators, the relevant recommendations above should be investigated. Additionally, the following measures should be considered:

- Trip speed – Reduce the speed of the cab as it travels up, and increase the speed of the cab as it travels down. The round-trip travel time does not change. A smaller motor can then be installed, and savings of 20% are possible.[13]

- VVVF drive on the pump motor – Using a VVVF drive on the pump motor can reduce the amount of electricity consumed by the elevator by 30% when the elevator is in motion.[14] Starting current is also reduced. VVVF drives increase the amount of energy used in standby mode, however, so they need to be carefully compared to a single-speed motor, especially in buildings with low elevator usage.

- Hydraulic accumulators – Instead of the potential energy of lowering the cab being dissipated as heat, it can be stored in a bladder type hydraulic accumulator. The accumulator releases the energy back into the system to help raise the cab. Manufacturers claim savings of 70% when the cab is in motion.[15]

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Appendix I: Technical Topic—Indoor Temperature

Technical Topic – Indoor Temperature

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

Indoor Temperature

There are two important steps to take when modeling indoor temperature reduction as an energy efficiency measure:

1) Determine a realistic assumption of the existing average indoor temperature.
2) Determine a realistic assumption of the new average indoor temperature and whether the technology proposed can achieve that temperature.

Assumed existing temperature (before the improvement)

If your model assumes an average indoor temperature of 75 F or higher for a majority of heated areas, then it should be supported by a record of indoor temperatures measured from multiple locations in the building. It is usually not realistic to assume 75 F or higher for the entire building based on only 2 or 3 temperature measurements, even if the building management claims that the building is overheated.

Assumed indoor temperatures resulting from the improvement

The following table illustrates the likely average indoor temperatures in buildings that allow resident controlled temperature, such as installing resident-controlled thermostatic radiator valves (TRVs) or programmable thermostats.

Building Type	Typical Min. Temp.
Master-metered heat	74 F
Tenant-paid heat	72 F

If you recommend an improvement that includes a specific upper-limit to indoor temperatures, such as range-limited thermostats, then the improved indoor temperature should be modeled as no less than the upper limit. Also keep in mind that building managers may increase the upper limits to 72 F or higher for the following reasons: reduce resident complaints, increase marketability, reduce resident turnover, reduce vandalism of range-limiting equipment by residents, reduce usage of electric space heaters by residents.

Summary

1. If residents are provided unlimited apartment-level control over heat, the seasonal average indoor temperature will rarely be below 74 F in buildings with owner-paid utilities or 72 F in buildings with resident-paid utilities.
2. Buildings that are reportedly overheated are typically overheated only in some sections of the building. The overall average temperature for the entire building is typically not found to be more than 76 F in buildings with owner-paid utilities.
3. Replacement of non-programmable thermostats with programmable thermostats will likely generate zero energy savings, especially if utility bills are not paid by the residents.

This information is provided as a summary to the Technical Topics discussion in March 2008

Appendix J: Technical Topic—Calculating the U-Values of a Surface

Technical Topic –
Calculating U-Value
of a Surface

NEW YORK STATE OF OPPORTUNITY. NYSERDA

Summary

Proper characterization of the building envelope is critical to any energy reduction plan that includes changes in insulation. This Tech Tip describes how to calculate the effective U-value of a building assembly and discusses de-rating insulation.

Calculating the Effective U-Value of a Building Assembly

Many people are more familiar with R-values than with U-values because insulation comes labeled with R-value ratings. R-value expresses the resistance to heat transfer. The U-value is the rate of heat transfer per unit area per degree of temperature difference, and is the inverse of the R-value. That is, U=1/R and R=1/U.

If different cross-sections through a building assembly such as a wall, roof, or floor have different R-values, the effective R-value for that surface must be calculated by first calculating the U value of each different cross-section. TREAT and eQuest offer libraries with R-values for different building surfaces. Here is how those R-values can be calculated for a wood frame stucco wall with nominal 2" x 4" framing, 3.5" fiberglass batt insulation.

The R-value at a cross-section through the insulation is higher than the R-value of the insulation itself:

Material	R value[1]
Outside air film[2]	0.17
Stucco	0.08
Gypsum board	0.56
Batt insulation (nominal rating)	11.00
Gypsum board	0.56
Inside air film[2]	0.68
Total R	13.05
U value	0.08

The R-value of a cross-section at the framing is lower than the R-value of the insulation.

Material	R value[1]
Outside air film[2]	0.17
Stucco	0.08
Gypsum board	0.56
3.5" wood (nominal 2" x 4")	4.38
Gypsum board	0.56
Inside air film[2]	0.68
Total R	6.43
U value	0.16

[1] R-values for insulation and building materials can be found in ASHRAE Fundamentals as well as many sources on the Internet.

[2] Different modeling tools handle air films differently. For TREAT, calculate R-values without interior or exterior air films, as they will be added later. For eQuest, omit the exterior air film from your calculation. For other tools, consult your manual.

This information is provided as a summary to the Technical Topics discussion in November 2008

Assume (per ASHRAE 90.1-2004) that the studs, plates, sills and headers are 25% of the total area of a wood-framed wall, while the cavity insulation is 75% of the total area.

The effective U-value of this wall assembly would be calculated as:

Effective U-value = (0.75 x 0.08) + (0.25 x 0.16) = 0.1

The effective R-value for the wall assembly is 1/0.1 = 10, lower than the nominal R-value of the insulation.

ASHRAE Standard 90.1-2004 contains a series of tables that show the effective R-value of different wall, roof, and floor assemblies, including both cavity and continuous insulation. If you are considering a building whose construction is not described in the TREAT or eQuest libraries or the ASHRAE Standard 90.1-2004 tables, you can calculate its R-value using the procedure described previously. ASHRAE Fundamentals contains R-values for many building materials; these values are also widely available on the Internet. In addition, Oak Ridge National Laboratory offers free R-value calculation software at http://www.ornl.gov/sci/roofs+walls/AWT/InteractiveCalculators/index.htm.

Assumptions about the fraction of the total surface area that is insulated (compared to the fraction that consists of framing members) have a large effect on the effective U-value of the surface. According to Oak Ridge National Laboratory (ORNL), framing factors such as studs, wall/wall (corners), wall/roof, wall/floor, wall/door, and wall/window connections can occupy 10% to 40% of the wall area. Appendix A of ASHRAE 90.1-2004 recommends the following assumptions for wood-framed buildings:

Construction type	**Material**	**% of surface area**
Attic roof with wood joists, Standard framing (insulation tapers at perimeter)	Full-depth insulation Half-depth insulation Joists	85% 5% 10%
Attic roof with wood joists, Advanced framing	Full-depth insulation Joists	90% 10%
Single-rafter roof (ceiling and roof attached to the same rafter)	Full-depth insulation Joists	90% 10%
Wood-framed walls, Standard framing (16" on center)	Insulated cavity Studs, plates and sills Headers	75% 21% 4%
Wood-framed walls, Advanced framing (24" on center)	Insulated cavity Studs, plates and sills Headers	78% 18% 4%

This information is provided as a summary to the Technical Topics discussion in November 2008

Metal Wall Studs

The attached table, reproduced from ASHRAE Standard 90.1-2004, Appendix A presents measured R- values for wall insulation installed between steel framing. Metal framing presents a special situation because of metal's high thermal conductivity. To calculate the overall U value for a wall with metal studs, use the R-value from this table and add the R-values of the rest of the wall assembly (e.g. masonry, interior gypsum board, interior and exterior airfilms), using the procedure described previously.

TABLE A9.2B Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

Nominal Depth of Cavity (in.)	Actual Depth of Cavity (in.)	Rated R-Value of Airspace or Insulation	Effective Framing/Cavity R-Value at 16 in. on center	Effective Framing/Cavity at 24 in. on center
		Empty cavity, no insulation		
4	3.5	R-0.91	0.79	0.91
		Insulated Cavity		
4	3.5	R-11	5.5	6.6
4	3.5	R-13	6.0	7.2
4	3.5	R-15	6.4	7.8
6	6.0	R-19	7.1	8.6
6	6.0	R-21	7.4	9.0
8	8.0	R-25	7.8	9.6

The table below excerpts ASHRAE Standard 90.1-2004, Appendix A, Table A9.2A, which provides measured R-values for metal framed roofs. As with metal-framed walls, you should add the R-values of air films and construction materials to this base value.

Effective Insulation/Framing Layer R-Values for Roof and Floor Insulation Installed Between Metal Framing (4 ft on center)

Rated R-value of Insulation	Framing/Cavity R-Value
11.00	10.01
19.00	16.34
38.00	28.12
55	36.85

If your insulation is an intermediate R-value between those provided in the table, it is legitimate to interpolate between the framing/cavity R-values shown in the table.

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