



**Advanced Automated HVAC Fault
Detection and Diagnostics
Commercialization Program**

**California Energy Commission
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Project 4: Advanced Rooftop Unit

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ARTU Product Definition Report

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Advanced Packaged Rooftop Unit (ARTU) Project

Task 4.3: ARTU Product Definition

Final Report

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Preface

Architectural Energy Corporation (AEC), an energy and environmental research, development, and design consulting firm located in Boulder, Colorado, submits this document to the California Energy Commission. The AEC Project Manager and author of this report is Doug Dougherty.

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0.0 Executive Summary

This project is part of a California Energy Commission program within the “Public Interest Energy Research” program (PIER), known as the “Advanced Automated HVAC Fault Detection and Diagnostics Commercialization Program” (FDD program).

This document presents a list of product features that will define an Advanced Packaged Rooftop Unit (ARTU). Existing rooftop units have documented problems and that by combining the expertise of the members of the project's Technical Advisory Group (TAG) and the research team, and with the funding provided by the California Energy Commission (CEC), we can help solve many of these problems. We further believe that we can identify particular “features” that an ARTU should have, and that incorporating these features in a demonstration rooftop unit would provide value to the manufacturing, contracting, utility and energy communities.

The ARTU project builds on previous research conducted under NBI PIER Element 4, Integrated Design of Small Commercial HVAC Systems (CEC Contract 400-99-012). That program published results of field studies in which more than 200 rooftop units, none of which were more than four years old, exhibited a number of problems with poor economizer operation, improper refrigerant charge, low air flow, high fan power and cycling fans, and other control issues. Such issues often go undetected by building owners and even service personnel.

The program also produced performance guidance for designers and operators on ways to improve the efficiency and operations of small package HVAC units. Many of these improvements could be integrated into a new “advanced” unit that would directly address performance and market impact objectives.

This project will develop and test an Advanced RTU prototype with a 5 ton cooling capacity that addresses the reliability of small commercial building mechanical systems, and the resulting energy impacts and ventilation problems (IEQ) found in these systems that result from unreliable, poorly controlled or out-of-tolerance systems.

Features of the ARTU will demonstrate the four main goals of the project:

1. Improved outdoor air control,
2. Improved economizer reliability,
3. On-board self-diagnostics and troubleshooting capability, and
4. Fault-tolerant design.

Features will be described that address:

- Economizer Improvements
- Fan Improvements
- Unit Efficiency
- Refrigeration Cycle Improvements
- Fan Controls
- Refrigerant Control
- Thermostat Capability
- Sensors
- Installation & Check-out Capability
- Advanced Monitoring
- Advanced Diagnostics

This Product Definition document will be used to guide the assembly of a prototype ARTU. The unit will then be tested to demonstrate the feasibility and effectiveness of the incorporated features. Results of those tests, and any impact they have on the Product Definition of the ARTU specification, will be presented in future reports.

1.0 Introduction

1.1 General Information

Architectural Energy Corporation is administering a program for the California Energy Commission’s “Public Interest Energy Research” program (PIER), known as the “Advanced Automated HVAC Fault Detection and Diagnostics Commercialization Program” (FDD program).

One of the projects within the FDD program is Project 4, “Advanced Packaged Rooftop Unit (ARTU)”. This project will develop and test an Advanced RTU prototype with a 5 ton cooling capacity that addresses the reliability of small commercial building mechanical systems, and the resulting energy impacts and ventilation problems (IEQ) found in these systems that result from unreliable, poorly controlled or out-of-tolerance systems.

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This document presents a list of product features that will define an Advanced Packaged Rooftop Unit (ARTU)”. Existing rooftop units have documented problems and that by combining the expertise of the members of the project’s Technical Advisory Group (TAG) and the research team, and with the funding provided by the California Energy Commission, we can help solve many of these problems. We further believe that we can identify particular “features” that an ARTU should have, and that incorporating these features in a demonstration rooftop unit would provide value to the manufacturing, contracting, utility and energy communities.

2.0 Task 4.3: Identify ARTU Product Features

2.1 Project Goals

Features of the ARTU will demonstrate the four main goals of the project:

1. Improved outdoor air control,
2. Improved economizer reliability,
3. On-board self-diagnostics and troubleshooting capability, and
4. Fault-tolerant design.

The end result will be a unit that not only operates according to prevailing ventilation standards, but that also reduces energy use and maintenance requirements through improved reliability and control.

2.2 Features Background

This document defines the ARTU product and describes the features proposed to be included. The starting point for these definitions is the draft “Preliminary Specification for an Advanced Packaged Rooftop Unit (ARTU),” originally dated July 17, 2003, developed by the Consortium for Energy Efficiency (CEE). This document was chosen because a number of parties in the research community are familiar with it and are anxious to see the work continued. Successful implementation of the various features in an ARTU would have significant impact on the reliability, operating and maintenance costs, and energy usage for air-conditioning equipment in the State of California and, eventually, nationwide.

The CEE “specification” was more a proposed list of provisions or “features” for an advanced rooftop unit than a traditional (i.e., Construction Specification Institute (CSI) format) specification for air handling units. CEE divided their features into three “Tiers,” but the features are now sorted into three “Levels” since the “Tier” terminology conflicts with other meanings in the industry. The term “Level” has the following definitions:

- **LEVEL 1** is a set of features that are all currently available on the market, can be requested today, and are fundamental to improving field efficiency and performance. Although some of these features are not routinely purchased with basic systems

today, features in this level are intended as the foundation requirements of an advanced roof top unit.

- **LEVEL 2** incorporates the features in Level 1, plus additional design features that create a new Advanced Rooftop Unit (ARTU) that can deliver greater field efficiency and performance. These features may not be readily available on the market, but some are a part of a development and testing project underway through California Public Interest Energy Research and manufacturing partners.
- **LEVEL 3** is a set of proposed performance-based measurements for future specification development. In the course of exploring in-field performance problems affecting efficiency, CEE found that there was a lack of performance-based measures and test protocols to address these aspects of performance. As a result, CEE identified a number of measures that would be useful in developing a performance-based specification.

Level 1 features and many of the Level 2 features identified in this project are currently incorporated into “Tier 2” HVAC systems available from most manufacturers. In industry terminology, “Tier 1” equipment meets minimum efficiency and product specifications, and “Tier 2” is Energy Star compliant or equivalent. Industry’s “Tier 3” equipment includes features justified by lowest life-cycle cost and highest annualized efficiency, which includes the balance of this project’s Level 2 features. Level 3 features are not yet available in manufactured equipment and require further technological development.

The intent of this project is to demonstrate that incorporation of Level 1 and Level 2 features can increase the reliability of rooftop units, as well as raise the baseline energy performance for HVAC equipment beyond the current “Tier 1” and “Tier 2” efficiency benchmarks.

2.3 Organization of the Features List

In the remainder of this report, each feature is described and the reasoning behind its inclusion (or rejection) is presented. Level 1 and Level 2 features, taken together, constitute the “Product Definition” of an “advanced” unit in that such a unit incorporates features that are readily available today as well as new beneficial features that will be available “soon” or are presently in development. The end product will be a new rooftop unit incorporating a set of features that hopefully defines a new “standard” unit with

better outside air control, economizer reliability, on-board diagnostics and fault-tolerance than existing units marketed today.

Level 3 features are included in the ARTU Product Definition as targets for future development, since, while they would provide a benefit to the industry, they are considered to be beyond near-term availability. Manufacturers and control systems developers are asked to consider such features when they develop new products and capabilities. Level 3 features that this project has considered are listed after the Level 1 and Level 2 features group.

Features that have been discussed during this task, but that we ultimately decided not to incorporate, are listed after the ARTU Product Definition. They are presented here for completeness since they were discussed by the project team and the TAG.

We wish to emphasize that this document is not a specification for an Advanced Packaged Rooftop Unit, but that part of this project is to develop such a specification that would be met by the features incorporated in the ARTU. We recognize that the HVAC unit manufacturing industry desires a performance specification rather than a prescriptive one. A performance specification will define the performance and reliability goals for an ARTU, but not dictate hardware that must be included to meet those goals. Defining performance goals leaves room for innovation at the unit design and manufacturing level as to how those goals will be met. At this time, this document simply presents various features in several categories that describe our vision of what an ARTU should incorporate.

3.0 ARTU Product Definition

3.1 Level 1 & Level 2 Features

Category 1 = ECONOMIZER

<u>Feature #</u>	<u>Feature</u>
1-01	Factory-installed economizer.
<u>Level:</u>	1

Comments:

In a previous PIER research study, factory installed economizers were found to be more reliable than field installed economizers. Field installed economizers tend to be more prone to problems. With factory installation, quality control checkout procedures at the plant increase the likelihood that the economizer will operate properly.

We realize there are some good reasons for field installation of economizers. For example, units may be easier to ship without the economizer installed. Field installation is often used to allow local inventory of the units and final configuration as needed based on customer requirements. Even if units can ship as one piece, hoods and some sensors (return air) may need to be installed in the field.

California's Title 24 allows both factory and field installations, but with field installations additional field tests are needed that don't have to be done if the economizer is factory installed. Ultimately, if a field-installed economizer is installed to factory tolerances, and is run-tested and commissioned properly, it should be as reliable as a factory economizer. However, manufacturers are encouraged to do as much factory installation as possible, such as pre-wiring, to simplify field installation. This will reduce field errors and increase the percentage of systems with properly operating economizers. When economizers don't work properly, the "cure" is sometimes to disconnect the economizer and close outside air dampers, even though this action creates a code violation and may lead to poor indoor air quality or increased energy usage.

Since Title 24 makes factory installed and field installed economizers equivalent with certain additional testing for field installations, an eventual ARTU specification will allow both. For this project, a factory-installed economizer is the preferred choice.

<u>Feature #</u>	<u>Feature</u>
1-02	Direct drive modulating actuator, gear driven interconnections and permanently lubricated bushings or bearings on outside and return dampers.

Level: 1

Comments:

Economizer mechanical reliability is improved by using direct drive actuators and gear driven interconnections, rather than linkage driven systems that can become loose from wear and fall out of adjustment. Permanently lubricated bushings or bearings and stainless steel construction provide greater resistance to corrosion.

The industry is already trending to direct drive.

The final specification will allow for the possibility that new drive methods will be developed.

<u>Feature #</u>	<u>Feature</u>
1-03	Economizer control type will be differential dry-bulb, differential enthalpy or dewpoint/dry-bulb temperature control.

Level: 1

Comments:

Economizer controllers with single setpoint logic are often set to changeover points that reduce their effectiveness. Differential control logic prevents many of the field problems associated with single point logic. Dewpoint/dry-bulb control is now an allowable option in ASHRAE 90.1.

The control types allowed by ASHRAE 90.1 vary depending on the climate in which the unit is located. Although ASHRAE 90.1 allows fixed dry-bulb and fixed enthalpy control in certain climates, the types listed above for this feature provide better energy savings.

Manufacturers and distributors are encouraged to provide guidance to purchasers of rooftop units as to the ASHRAE climate zone in which the unit is to be installed, preferred control types and example settings for the controller.

<u>Feature #</u>	<u>Feature</u>
1-04	Economizer controller will have the capability to operate under demand controlled ventilation (DCV) control.

Level: 1

Comments:

Both Title 24 and ASHRAE 62.1-2004 now allow DCV control, and many controllers provide this capability as an option. The addition of one or two CO₂ sensors and appropriate controller programming is all that is required to implement demand controlled ventilation.

The requirements set forth in ASHRAE Std. 62.1, latest edition, will be used to govern the controller programming. The locations of the CO₂ sensors may be site specific, depending on the application. The controller must also be capable of protecting the coil from freezing if DCV requirement brings in cold air and the compressor is activated.

A recent study found that DCV has the one of the best paybacks of any RTU-related measure.

<u>Feature #</u>	<u>Feature</u>
1-05	Compressor operation will be locked out when the outside air temperature is lower than that at which the outside air alone can satisfy the cooling load.

Level: 1

Comments:

Satisfying the cooling load with outside air alone is the basic function of an economizer. This feature can be set by locking out compressor operation when the outdoor temperature is lower than the design supply air temperature (typically about 45 to 55°F). This feature helps occupants to detect when economizers are not working properly, because the malfunction will not be masked by the inappropriate operation of refrigeration when cool outside air should meet cooling needs.

This setting will be user-adjustable so that it can be overridden for high-load applications (computer and server rooms, etc.) or applications in humid climates. Adjustment of the lockout temperature setpoint will also allow system set-up to be optimized for each particular application.

<u>Feature #</u>	<u>Feature</u>
1-06	If the discharge air temperature falls below a low limit of 40 to 45°F (field adjustable), the outside air damper will modulate toward closed until the desired discharge air temperature setpoint is met.

Level: 1

Comments:

The cooling coil could freeze or comfort problems could arise if outside air that is too cold hits an active coil. The intent of this feature is to prevent comfort problems caused by low discharge air temperature (DAT) and to prevent freezing the cooling coil.

When the OAT is between about 45 and 55°F, full cooling should be available through the economizer. A low DAT could arise if the outside air is simply too cold to provide economizer cooling without endangering the equipment. It could also arise if the compressor continues to operate even though the OAT has dropped below 55°F.

Setting a discharge air temperature low limit of 40 to 45 °F would allow the economizer to modulate toward closed if the controls fail to turn off the compressor and the outside air temperature has dropped to around 50 to 55°F (assuming about a 10°F drop across the coil). This feature will protect the coil.

This situation should also trigger a fault notification.

<u>Feature #</u>	<u>Feature</u>
1-07	Economizer controller will utilize a deadband between economizer enable/disable operation of no greater than 2°F in a dry-bulb temperature application and 2 Btu/lb in an enthalpy application.

Level: **2**

Comments:

Some existing controllers have a 10°F deadband, which severely limits economizer operation. A large deadband prevents the economizer from re-opening, even as the OA temperature drops below the high temperature lockout value, until the 10°F deadband is achieved. For example if the economizer high temperature lockout is set at 65°F, the economizer will be disabled when outdoor air temperature exceeds 65°F. However, the air temperature must drop to 55°F before the economizer will be re-enabled again. This means that even if the outdoor temperature drops to 60°F, the economizer will be locked out and mechanical cooling would be used to satisfy a cooling load. This is not a very effective economizer control strategy.

Some controllers utilize a 0.5°F deadband. Two degrees is a reasonable deadband to maximize economizer operation and minimize the possibility of short-cycling the compressor.

A minimum economizer runtime or time delay may also be superimposed to keep the operation from becoming unstable and provide further compressor protection.

The two-degree deadband does not include any additional inaccuracy that may result from the A/D conversion.

<u>Feature #</u>	<u>Feature</u>
1-08	Relief dampers will be located to minimize the potential for re-entrainment of exhaust air into outdoor air intakes.

Level: **1**

Comments:

Re-entrainment of exhaust air into outdoor air intakes reduces the effectiveness of the economizer when in economizer mode, and reduces the ability of the unit to provide proper fresh-air ventilation when in non-economizer mode. The intent of this feature is to discourage locating exhaust outlets directly above, below or adjacent to outside air intakes on the same unit.

ASHRAE 62.1-2004 outlines a method for determining the minimum separation between exhaust outlets and outdoor air intakes in Appendix F. Separation distance should comply with section F3 as best as possible.

<u>Feature #</u>	<u>Feature</u>
1-09	Relief dampers, when installed on the unit, shall allow up to 100% relief airflow at a pressure drop not to exceed XX% of the unit internal pressure drop (evaporator coil plus filter pressure drops). (Percentage to be determined.)

Level: 2

Comments:

The intent of this feature is to prevent relief dampers from creating a significant pressure drop when the system is running in full economizer mode, which would increase fan power or potentially over pressurize the building.

The maximum relief damper pressure drop will be defined as a percentage of other system pressure drops. An allowable pressure increase of 10% is suggested. Note that the minimum relief pressure drop requirement is not applicable for systems with powered exhaust. Also note that total relief air volume from an HVAC system may not reach 100% flow since local exhaust and desired building pressurization may limit the amount of air returned to the unit.

Often relief dampers are not included in the unit but are installed in a separate section of return duct or elsewhere in the building. In this case, this feature is not within the control of unit manufacturers but becomes a system design issue.

<u>Feature #</u>	<u>Feature</u>
1-10	Economizer systems (sensors, dampers, actuators and controller) shall be factory warranted for parts and labor by the manufacturer for 2 to 5 years.

Level: 2

Comments:

A typical standard warranty is one year, but most manufacturers sell an optional longer warranty that the customer can purchase. This feature is intended to encourage manufacturers to provide a longer standard warranty, which will have the further effect of encouraging them to resolve additional equipment failure issues, perhaps not covered in this document, that occur repeatedly during the longer warranty period.

<u>Feature #</u>	<u>Feature</u>
1-11	Outside air and return air dampers will have maximum leakage rates conforming to the requirements of ASHRAE 90.1-2004.

Level: 2

Comments:

Economizers, when fully open, often do not provide 100% outside air due to return damper leakage, reducing the economizer cooling benefit. Field surveys have shown that in full economizer mode (100% OA) there may be as much as 20% return air in the mixed air stream due to return damper leakage.

ASHRAE 90.1-2004 already requires ventilation outdoor air dampers be capable of automatically shutting off airflow during pre-occupancy warm-up, cool-down or setback modes. At a minimum, in the Simplified Approach Option for HVAC Systems, blade and jamb seals are required for *outdoor air* dampers used with economizers. Alternatively, in the Mandatory Provisions, section 6.4.3.3.4 prescribes maximum leakage rates (when tested in accordance with AMCA standard 500) for both outdoor air and exhaust air dampers.

For return dampers, the leakage requirement depends on how one approaches compliance with the Standard. If the Prescriptive Path is chosen, the Standard already extends the maximum leakage rates prescribed for outdoor air and exhaust air dampers to return air dampers. However, if either the Simplified Approach or the Energy Cost Budget Method is followed, return damper leakage is ignored altogether. This feature attempts to add a leakage prevention feature to return air dampers.

Category 2 = FANS

<u>Feature #</u>	<u>Feature</u>
2-01	The ARTU will have supply fan power limitations as addressed in ASHRAE 90.1, when tested according to current ARI rating standards.

Level: 1

Comments:

ASHRAE defines Watts / CFM for fan systems, and Energy Star requirements limit overall unit power.

While an external static pressure drop of 0.20 to 0.75 in-wg, depending on unit capacity, matches ARI testing requirements, these values are somewhat lower than conditions often found in the field, especially if ductwork is installed. Poor ductwork design is the main reason for higher static pressures in the field.

It should be noted that ASHRAE 90.1 might be revised to incorporate actual fan brake horsepower at actual job conditions rather than motor nameplate horsepower at ARI conditions when calculating fan power per cfm delivered. The intent of this feature is to test system operation under actual pressure conditions rather than ARI test conditions. If the ASHRAE requirement is changed, this feature will be reviewed.

Although manufacturers rate their equipment in accordance with ARI standards, designers often attach units to ductwork that has more pressure loss than the selected unit was designed for. Improving duct design is not within the scope of this project, but designers are urged to design efficient ductwork and select units that have the proper performance capability to handle the full design external pressure.

Finally, installed systems must be properly commissioned to ensure that the selected unit and ductwork together provide the full design airflow at no more than the design external pressure. Field conditions may dictate that ductwork is installed with additional fittings and in some cases ductwork may be pinched or crushed in order to avoid existing structural members. Lack of fit and interferences are issues that should be addressed during design. These considerations will help ensure that fan power limitation and unit efficiency goals are met.

Category 3 = UNIT EFFICIENCY

<u>Feature #</u>	<u>Feature</u>
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3-01	ARTU will be Energy Star compliant.
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Level: 1

Comments:

Energy Star compliance promotes a baseline minimum efficiency level, and is readily available and accepted.

Category 4 = REFRIGERATION CYCLE

<u>Feature #</u>	<u>Feature</u>
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4-01	A high efficiency hydrofluorocarbon (HFC) refrigerant with no ozone depletion potential, such as R410a, will be used.
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Level: 1

Comments:

R-410a is the refrigerant of choice for small RTUs. It has lower pressures and lower heat transfer coefficients than other choices and the trend is toward this refrigerant in the rooftop unit industry. It also has no ozone depletion potential.

This selection is not meant to dictate the refrigerant that must be used. Other refrigerants may also be acceptable.

<u>Feature #</u>	<u>Feature</u>
4-02	The condenser fan motor will be a high efficiency ECM or PSC type motor.

Level: 2

Comments:

A high efficiency PSC or ECM condenser fan motor will improve overall unit efficiency.

While this could be covered as part of the overall efficiency, an ECM motor could also improve low ambient operating controls and part load performance at very little cost.

Although ECM motors are only presently available in fractional horsepower sizes, this should be acceptable for low-capacity ARTU condenser fan applications. It should be noted that various improvements in compressor operation and condenser fan controls at low ambient conditions may minimize the efficiency improvement associated with ECM condenser fan motors.

This feature does not apply to units with multiple-speed condenser fans or multiple fans.

Category 5 = FAN CONTROL

<u>Feature #</u>	<u>Feature</u>
5-01	Continuous supply fan operation during occupied hours and intermittent operation during unoccupied hours will be the default operating modes.

Level: 1

Comments:

ASHRAE 62 requires this operation in order to provide proper indoor air quality. Studies have shown that when supply fans cycle off with the compressor during occupied hours, the ventilation air delivered to the space averages only 25 - 33% of that required.

Most commercial controls today allow for night shutdown and automatically switch to intermittent fans. Cycling fans during occupied hours is against code although reducing fan speed during ventilation is acceptable.

<u>Feature #</u>	<u>Feature</u>
5-02	During unoccupied hours, supply fan will operate for a short period after compressor turns off.

Level: 1

Comments:

Allowing the supply fan to operate briefly after the compressor turns off will remove residual cooling energy from the cooling coil (or heat from the heating section, if present) and reduce compressor cycle time. This feature is usually included now to remove residual heating energy.

Since the supply fan should run continuously for ventilation in commercial applications, this feature is only activated during unoccupied periods upon a call for cooling if the load cannot be met by the economizer.

Category 6 = REFRIGERATION CONTROL

<u>Feature #</u>	<u>Feature</u>
6-01	The unit will use an adjustable expansion control device such as a thermostatic expansion valve (TXV) or an electronic expansion valve (EXV).
<u>Level:</u>	1

Comments:

In previous field surveys, approximately 45% of the units tested were found to be improperly charged; this problem increases as units age. Unit efficiency degrades quickly as the charge deviates from the factory recommendations. Units equipped with TXVs are more tolerant to charge variations and maintain efficiency over a wide range of charge conditions. Such devices are becoming increasingly more common, especially on larger units.

Our use of a TXV or an EXV is not meant to exclude other technology that may be developed. Although some coil capacity is sacrificed to achieve desired superheat, use of an adjustable expansion control device will ensure that no liquid refrigerant is returned to the compressor.

Category 7 = THERMOSTATS

<u>Feature #</u>	<u>Feature</u>
7-01	A commercial-grade thermostat appropriate for use in commercial buildings will be used. Thermostats will meet the following requirements: ASHRAE 90.1 <ul style="list-style-type: none">• Separate heating and cooling setpoints (“dual” setpoints)

- Capable of a deadband of at least 5 degrees between the heating and cooling setpoints
- The thermostat will prevent:
 - Reheating of previously cooled air (except in humidity control applications)
 - Recooling of previously heated air
 - Mixing or simultaneously supplying air that has been previously mechanically heated and air that has been previously cooled, either by mechanical cooling or by economizer systems.

Other

- Solid state
- Capable of continuous fan operation during occupied hours
- Capable of programming time-of-day schedules (night setback / setup) and multiple day types (weekday, weekend)
- Capable of programming individual holiday schedules
- Capable of temporary occupied override
- Capable of two-stage cooling.

Level: 1

Comments:

Residential thermostats are not appropriate for commercial applications, yet they have been used. Most residential thermostats do not meet the requirement to allow continuous supply fan operation during occupied hours, or have two-stage cooling capability.

Thermostat programming can be an issue. Prior studies have discovered thermostats in use that were not programmed.

Feature #

Feature

7-02

The thermostat or unit controller will incorporate “integrated economizer” control.

Level: 1

Comments:

In a few climate zones, ASHRAE 90.1 already requires that units with capacities above 65,000 Btu/hr have integrated economizers that allows for the economizer and compressor to be used at the same time.

In many applications, the economizer is a three-position type (outside air damper can be closed, at minimum position, or fully open) and the low ambient cutout temperature sensor is located downstream of the cooling coil. The first-stage call for cooling will enable the economizer if the outdoor air temperature is less than return air temperature or high ambient cutout (depending on control strategy implemented). If outdoor air alone cannot satisfy the cooling load, the second-stage call will enable the compressor and the economizer stays at 100% open position. Typically, with the compressor operating, the supply air temperature will drop below the low ambient cutout setpoint, and the economizer will then close back to minimum position. The compressor is then cooling a mixture of return and outdoor air, which is warmer than the outdoor air alone. This increases the load on the compressor and uses more energy and is technically not an integrated economizer control strategy.

As long as the outdoor air temperature is below return air temperature, it is beneficial to use 100% outdoor air when the compressor is operating, thereby achieving a totally integrated control strategy.

The integrated economizer is common in larger systems having variable-capacity or multistage compressors. Some controls incorporate a dedicated cooling stage or have two setpoints for economizers. Additional stages of economizer and compressor operation are also possible.

In a smaller system with a single-stage compressor, allowing an integrated economizer when the outside air is only slightly above the normal supply air temperature and the compressor is activated may result in fairly cold supply air, triggering complaints from occupants. Manufacturers are encouraged to develop ways to incorporate an integrated economizer in small systems and avoid this initial blast of cold air. Implementation of this feature will require some form of damper modulation and/or compressor capacity control in order to prevent possible coil freezing or comfort problems due to excessively cold discharge air temperature.

<u>Feature #</u>	<u>Feature</u>
7-03	Thermostat or controller will be capable of interfacing with an occupancy sensor, switching the unit to intermediate temperature settings when no occupants are present during normally occupied hours.

Level: **2**

Comments:

During normally occupied hours, there may be periods of time in which an area will be temporarily unoccupied. During these times, the ARTU could go to an intermediate setpoint (between occupied and overnight setback/setup settings). Using intermediate setpoints would avoid lengthy cool-down or warm-up periods when the occupants return.

This feature does not build the occupancy sensor into the thermostat, it merely provides terminals to connect to an external occupancy sensor and the control logic to make use of the sensor input.

A number of hotels have units with an occupied / unoccupied mode already. Occupancy sensor capability in thermostats is currently available from at least two manufacturers. In an office setting, the intent would be to adjust heating and cooling setpoints to some intermediate values if motion is not detected within a predetermined time (such as 30 minutes). Using intermediate setpoints will allow the space to recover quickly and prevent humidity control issues once the space becomes occupied again. The setpoints would revert to full unoccupied settings if no occupancy is detected for an extended period of time (say 3 hours), or upon reaching the normal unoccupied time of day.

Category 8 = SENSORS

<u>Feature #</u>	<u>Feature</u>
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8-01	Sensors that are used to detect outdoor air and return air conditions shall have the following accuracy.
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- **Temperature sensors shall have an accuracy of 1°F.**
- **Enthalpy and humidity sensors shall have an accuracy of ±5%.**
- **CO2 sensors shall have an accuracy of ±50 ppm (0 - 2000-ppm range).**

Level: 1

Comments:

Tightening the sensor accuracy will result in better control of outside air and the unit in general. Note this feature addresses only sensor accuracy and is not intended to address or specify the type of economizer changeover control to be used.

The above accuracies are exclusive of any inaccuracy that may be added by the analog to digital conversion. This feature also does not address the issue of sensor placement. Sensors must be appropriately placed to accurately measure average temperatures and avoid solar load.

<u>Feature #</u>	<u>Feature</u>
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8-02	Enthalpy sensors will have solid state electronic humidity sensing elements.
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Level: 1

Comments:

Most enthalpy sensors are already solid state. Some controls have gone to separate temperature and humidity sensors and internally calculate enthalpy.

<u>Feature #</u>	<u>Feature</u>
8-03	Connectors will be designed to prevent reversed polarity connection at the sensor/controller and actuator/controller connections, or, sensors that are not polarity sensitive will be used.

Level: **1**

Comments:

Reversed polarity is a common field installation error that can be overcome with appropriate connectors. Any current-loop-powered sensor has a polarity that must be connected correctly.

Using a factory-installed economizer will reduce the chance of this error occurring. Equipping units with a wiring harness with a polarized connector should meet the intent of this requirement, even if the final connections at the economizer module are not polarized.

Although the polarity issue seems less important for a factory-installed economizer than a field-installed unit, the issue will still be important if the controller has to be replaced. Possibly, the controller could be programmed to notify the installer if it detects incorrect connections.

<u>Feature #</u>	<u>Feature</u>
8-04	If DCV control is to be used, the controller manufacturer will supply a CO2 sensor that is compatible with the controller, and with terminals that can easily be connected.

Level: **2**

Comments:

Sensor will be field mounted based on site-specific requirements. This feature should lessen the chances of potentially obtaining a sensor with an output signal that is incompatible with controller requirements (such as sensor output is 0-5V but the controller is looking for 0-10V), or installing it incorrectly.

Category 9 = INSTALLATION AND CHECKOUT CAPABILITY

<u>Feature #</u>	<u>Feature</u>
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9-01	Units with multiple compressors will have labels on the suction, discharge, and liquid lines indicating the appropriate circuit.
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Level: 1

Comments:

Labels make testing and troubleshooting easier and help reduce mix-ups in the field.

<u>Feature #</u>	<u>Feature</u>
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9-02	A high-pressure refrigerant port will be located on the liquid line. A low-pressure refrigerant port will be located on the suction line.
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Level: 1

Comments:

Improves the ability to troubleshoot refrigerant charge and compressor operation, and to add and recover refrigerant.

The amount of subcooling of the refrigerant leaving the condenser is a key parameter in determining proper system operation, especially for units with automatic expansion control devices. Subcooling is calculated by measuring liquid pressure to determine saturated liquid temperature and then comparing the saturated temperature with the actual measured liquid temperature.

However, subcooling is often estimated in the field by measuring discharge (hot gas) pressure and assuming a pressure drop across the condenser to determine the saturated liquid temperature. This method is less accurate, since actual pressure drop is difficult to estimate.

Units equipped with pressure transducers mounted directly into the suction and liquid lines are exempt from this requirement. See Feature 10-01.

<u>Feature #</u>	<u>Feature</u>
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9-03	When the compressor is located within the condenser fan plenum, pressure ports and adequate refrigerant piping to measure temperature will be accessible from outside of the condenser fan plenum.
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Level: 1

Comments:

Access ports make testing and troubleshooting easier, and improve the ability to measure subcooling and/or superheat.

This will allow easy access for the technician without having to take off a panel. Having a panel open, or not being able to re-install it fully because the refrigerant hoses hang out, adversely impacts airflow across the condenser.

Pressure sensors could be permanently installed and the pressure could be displayed on the controller readout. This lets the service technician avoid installing gauges altogether and eliminates refrigerant loss when those gauges are removed.

<u>Feature #</u>	<u>Feature</u>
9-04	Controls to adjust the minimum outside air position shall be accessible with air plenum panels in place.

Level: 2

Comments:

It is very time consuming to adjust the minimum outside air with a temperature or other measurement method when panels need to be removed and replaced for each adjustment. Consequently, most minimum outside air settings are made by guessing (if at all) and tend to be much higher than good ventilation requires.

Some manufacturers already have methods to make these adjustments without opening the airstream.

Category 10 = ADVANCED MONITORING

<u>Feature #</u>	<u>Feature</u>
10-01	(A) - The following sensors should be permanently installed to monitor system operation and, (B) - The controller should have the capability of displaying the value of each parameter: <ul style="list-style-type: none">• Refrigerant suction pressure• Refrigerant suction temperature• Liquid line pressure• Liquid line temperature• Outside air temperature• Outside air relative humidity

- **Return air temperature**
- **Return air relative humidity**
- **Supply air temperature**
- **Supply air relative humidity.**

Level: **2**

Comments:

These sensors and associated display will provide the service technician with operating data about the system to improve diagnostics and troubleshooting. In addition, the hard-wired pressure sensors will eliminate the need to actually tap into the refrigerant circuit. Permanently installed temperature sensors directly into the refrigerant piping will accurately measure actual refrigerant temperature, thereby minimizing errors associated with pipe surface temperature measurements and undue influence of ambient temperature. For example, the ambient air temperature could influence a surface temperature measurement by as much as 5°F, which can result in incorrect refrigerant charge diagnosis.

Note that advances in alternate system diagnostic techniques may eliminate the necessity for some of the sensors listed above.

The method of displaying the values is not stated, but may be an LCD display, plug-in hand-held device, or other method.

<u>Feature #</u>	<u>Feature</u>
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10-02	The controller will provide system status by indicating the following conditions:
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- **Compressor enabled**
- **Economizer enabled**
- **Free cooling available**
- **Mixed air low limit cycle active**
- **Heating enabled.**

Level: **2**

Comments:

This feature is intended to give the owner and service technicians an easy way to determine the operating mode of the unit.

Most economizer controls today have some type of indicating display, either with illuminated LEDs or an LCD display.

<u>Feature #</u>	<u>Feature</u>
10-03	The unit controller will have the capability to manually initiate each operating mode so that the operation of compressors, economizers, fans, and heating system can be independently tested and verified.

Level: **2**

Comments:

This feature will make troubleshooting easier; and eliminates the need to use jumpers to initiate various operating modes. The controller will include a set of diagnostic tests, to be defined. The intent is to be able to manually cycle through the modes, not provide an automatic self-test capability.

This ability is available on some controls today.

Category 11 = ADVANCED DIAGNOSTICS

<u>Feature #</u>	<u>Feature</u>
11-01	Unit controller will utilize an analog to digital resolution no less than 8 bits.

Level: **2**

Comments:

Eight-bit resolution assures that the analog signal received by the controller from various sensors is converted into enough discrete digital signals for processing to ensure that sensor accuracy is not lost. Eight bits gives 256 discrete steps of digital signal and is readily available.

This feature relates mainly to diagnostic features. Using an analog controller limits the ability to develop diagnostic capability. Providing a digital microprocessor will add cost, but reduce the cost of diagnostics because the processors can be combined.

This feature is not meant to require or enable 256 discrete steps of economizer positioning. Rather, the intent is to achieve an acceptable resolution in sensor measurement. For example, with an eight-bit controller, an outdoor air temperature that varies from 0 to 102°F can be resolved into steps of 0.4 F.

<u>Feature #</u>	<u>Feature</u>
11-02	Controller will be able to detect faulty and failed sensors (short or open circuit). Upon detecting a faulty sensor, the controller will send a fault signal to the thermostat and/or energy management

system. The thermostat and/or energy management system will be capable of receiving and displaying the signal.

Level: 2

Comments:

Occupants and building managers are generally not aware of problems that don't result in comfort complaints. Notification of detected faults at a location at which the owner will notice it will enable the owner to keep the RTU working at peak efficiency and avoid higher operating costs that often go along with degraded unit operation.

This notification, in the form of a "trouble" light, is already done on many systems. It does depend on the thermostat having the ability to display the fault signal.

<u>Feature #</u>	<u>Feature</u>
11-03	Sense a non-operating or improperly operating economizer damper and send a fault signal upon detection.

Level: 2

Comments:

Economizer failure is largely undetected by occupants and even service technicians. Failure modes should include:

- Damper open above minimum position when OAT is above high limit
- Damper not fully open when OAT is above low limit but below return air temperature
- Damper open above minimum position when OAT is below low limit
- Damper open above minimum position when unit is in heating
- Damper open when space served is unoccupied and cooling is not called for.

If the damper is not working properly, a fault signal should be sent.

Although position sensors / feedback potentiometers can be used for this purpose, they are reportedly not very reliable and manufacturers are moving away from their use. Temperature monitoring is a way to sense these faults, but other methods are also possible.

Feature # Feature

11-04 **The unit will have the diagnostic capability to detect when the temperature differential across the evaporator coil is less or greater than a predetermined value (i.e. target temperature drop as determined by Carrier Slide Rule or equivalent calculator).**

Level: **2**

Comments:

Detecting when the temperature differential across the evaporator coil is less than the target temperature drop is useful in diagnosing a capacity problem. Detecting when the temperature differential is greater than the target temperature drop is useful in diagnosing an airflow problem.

This diagnostic is best applied at near-full-load conditions. If a microprocessor controller is utilized, the target temperature can be calculated based on existing conditions and load to improve the system diagnostics.

Some diagnostic strategies may not be compatible with variable air or refrigerant flow systems and alternative strategies may need to be developed.

Feature # Feature

11-05 **The unit will have the diagnostic capability to self-monitor refrigerant charge level, and detect when the refrigerant charge is outside preset limits.**

Level: **2**

Comments:

This feature allows the owner or service person to be notified about charge problems that cause efficiency degradation and to correct the refrigerant charge before the unit loses significant cooling capacity.

Although there has been discussion about making this feature a Level 3 item, there are devices on the market in high-end units that can provide this ability. Overall accuracy of some devices may require improvement in order to fully develop this feature.

Feature # Feature

11-06 **The ARTU controller will be able to diagnose and send a fault signal for the following faults:**

- **Severe faults:**
 - **Failed compressor**
 - **Failed evaporator fan motor**
 - **Failed evaporator fan belt**

- **Failed condenser fan motor**
- **Degradation faults:**
 - **Dirty air filter**
 - **Dirty condenser coil**
 - **Dirty evaporator coil**
 - **Failed relief damper**
 - **Air in refrigeration loop**
 - **Restriction in refrigeration loop**

Level: **2**

Comments:

This feature notifies the occupant that maintenance is required to restore degraded efficiency or repair a catastrophic failure. Many if not all these features are presently available on high-end products.

Degradation faults like air in the refrigerant loop or a restriction are currently detected using suction and liquid temperatures and pressures. Alternative diagnostics may be developed in the future which could minimize the amount of sensors necessary to accurately diagnose system problems.

3.2 Level 3 Features – Future Development

Category 1 = ECONOMIZER

<u>Feature #</u>	<u>Feature</u>
1-12	Economizers shall be tested for XX open/close cycles according to Standard Test YYY.

Level: **3**

Comments:

This feature requires that a research project be performed to develop an economizer test protocol for industry review. Test cycle requirements will be defined at that time.

Category 3 = UNIT EFFICIENCY

<u>Feature #</u>	<u>Feature</u>
3-02	Units in which the supply fan delivers air horizontally to a discharge plenum, from which air is discharged vertically, should incorporate turning vanes or other loss-reduction method in the plenum. This feature will help minimize energy the loss associated with a poor transition from horizontal to vertical air movement.

Level: **3**

Comments:

Many units can be marketed as either horizontal or vertical discharge. The discharge direction is “selectable” in the field by removing either an end panel or a bottom panel from a rectangular discharge plenum at the end of the cabinet. This allows manufacturers to avoid having to stock multiple models that differ only in their discharge direction. However, when such a unit is set up for vertical discharge, the supply air is typically still blown horizontally from the fan into the plenum, where it then changes direction to exit through the bottom opening. There is usually nothing in the discharge plenum to assist the air in making the 90-degree turn into the ductwork. This results in a pressure loss that is higher than necessary and wastes energy. It is here that overall system efficiency is compromised when air is delivered from the fan horizontally but the unit is connected to vertical ductwork. Turning vanes will reduce the energy loss associated with the poor 90-degree transition.

This feature is seen as more of a system design issue than a product issue. Some units are truly designed for vertical supply by rotating the fan housing so that it discharges downward and do not require turning vanes. Manufacturers are urged to eliminate production of units that are not specifically designed for either horizontal or vertical discharge, or to develop low-pressure-drop discharge plenums. Designers are also urged to provide low-pressure-drop transitions when selecting horizontal discharge units but connecting them to vertical ductwork. If this results in exposed outdoor ductwork, an enclosure attached to the end of the unit could be designed to protect the ductwork.

This feature is included as a Level 3 feature to encourage manufacturers to assist designers selecting horizontal discharge units for rooftop applications by offering factory-built transitions sections to turn the air efficiently.

Category 5 = FAN CONTROL

<u>Feature #</u>	<u>Feature</u>
5-03	Equip the unit with a multiple-speed or variable speed supply fan motor interlocked with the outdoor air dampers and compressor to provide ventilation air at reduced fan speed during ventilation-only mode (when compressor has cycled off).

Level: **3**

Comments:

Currently when there is neither a call for heating or cooling, the outside air damper resides at minimum position. Reducing motor speed during these no-load conditions would reduce supply air flow and fan power. However the amount of outdoor ventilation air would also reduce if the outdoor air damper remained at a fixed minimum position (roughly linear with the reduction in supply flow).

Implementing this feature requires that the outside air and return dampers modulate in response to the fan speed. Exercising the dampers in this way, perhaps several times an hour, may create more wear and tear on the dampers and actuators.

Small motors up to one horsepower are likely to be ECM technology; larger motors are likely to be induction motors with VFD technology. Variable speed motors provide soft start capability. While VFDs are reducing in cost, they are still expensive. ECMs also require additional controls. Fan energy savings may not make up these additional costs. More study is needed on this issue. Most of the manufacturers are moving to ECM units for SEER 13 units up to 5 tons.

Some manufacturers felt that demand control ventilation sounds like a better solution, although it is not clear how the energy savings would compare. The CO₂ sensor costs keep dropping, making DCV control more feasible.

In practice, the minimum fan speed may be decided by the need to avoid "dumping" air at the diffusers.

Category 6 = REFRIGERATION CONTROL

<u>Feature #</u>	<u>Feature</u>
6-02	The ARTU will be capable of modulating cooling output.

Level: **3**

Comments:

This feature addresses part-load operation, which can account for the majority of the cooling operating hours, and mitigates the effect of system oversizing and the issues associated with full economizer integration.

Variable operation can include multiple compressors, multi-stages, variable speed compressors, or some other form of modulation.

Category 9 = INSTALLATION AND CHECKOUT CAPABILITY

<u>Feature #</u>	<u>Feature</u>
9-05	Literature supplied with the unit shall thoroughly explain proper application, installation, operation and maintenance of the following components and systems: <ul style="list-style-type: none">• Economizer setup and operating control logic, including setting minimum outdoor airflow.• DCV setup and operating control logic• Proper sensor installation and location (temperature, RH, CO₂)• Sensor calibration procedures and recommended check out schedule

Level: **3**

Comments:

Often, manufacturer’s literature does not include information about setting up dry-bulb differential changeover control or setting minimum outside air volume using either flow plates or a temperature measurement method. Proper minimum outside air setting is very important to the energy use of these systems. More direction on installation or location of outside air and return air sensors should be included.

For DCV control and CO₂ sensor setup, clear instructions for connection and set up of multiple sensor types and instructions about the need for slow, small increment adjustments need to be provided. Regarding CO₂ control settings, ASHRAE Standard 62 language focuses on “lower than” 700 ppm above background concentration. This sometimes leads to settings that are too low and minimum OA volumes that are too high. Resetting OSA minimums to immediately achieve this level rather than making small changes and allowing enough time for dilution to occur can be an issue.

Alternatively, more training for installers and supervision of work may be needed.

While improved literature is recommended, it is not a physical “feature” of a rooftop unit that can be addressed in this project, and therefore is not incorporated as such. It is included in Level 3 as a target for future improvements.

Category 10 = ADVANCED MONITORING

Feature # Feature

10-04 **At the controller, capability to override sensor inputs to allow verification of the sequence of operation shall be provided.**

Level: **3**

Comments:

Lack of the ability to override a sensor makes unit troubleshooting difficult and somewhat weather dependent. Current troubleshooting techniques (cold spray, hair dryers) are not quantitative.

The abilities to drive the controls to commission the system, and to evaluate ongoing diagnostics after receiving a trouble code, are what are desired with this feature. For a service technician to have the ability to override a sensor electronically and observe the response of the unit would be useful in these situations.

To avoid the possibility of leaving the unit in a test condition, the overrides can't be permanent. The override setting must automatically go back to normal operation after some brief time period. Care must be taken to ensure that an overridden sensor input value does not compromise system operation or occupant comfort.

This feature is Level 3 because advisers felt that other test and diagnostic features would be easier to implement. Also, the potential ability to put a unit in an unsafe state must be prevented.

Feature # Feature

10-05 **The controller should be capable of:**

- **Interfacing with central DDC system**
- **Interfacing with hand-held devices (i.e. PDA; laptop, tablet PC, etc)**
- **Data collection and storage**
- **Totaling compressor runtime; supply fan runtime; economizer runtime.**

Level: **3**

Comments:

The controller will have the capability to diagnose system problems based on the monitored data, and report the data and problems to a central system or hand-held device. Some high-end products already have these abilities.

Other features require diagnosing and reporting faults as they occur, and it is felt that collecting and storing historical data and having the ability to interface with other devices could be optional features.

4.0 Additional Features – Not Incorporated

Category 1 = ECONOMIZER

<u>Feature #</u>	<u>Feature</u>
1-13	Relief air dampers will be provided in lieu of powered exhaust.

Level: Not Incorporated.

Comments:

Building pressurization problems can occur during economizer operation if the relief air outlet or return system is too restrictive. Without adequate relief, the economizer doesn't work to its full potential since backpressure on the supply fan reduces the airflow. Providing barometric relief dampers instead of powered exhaust was considered as a feature, since the exhaust fan energy partially negates the energy savings from economizer operation. Also, powered exhaust adds cost to the unit.

However, powered exhaust is almost required at higher tonnages to overcome return side pressure drops. The use of relief dampers and power exhaust should be based on the application. Powered exhaust efficiency can be improved with variable speed fans or multiple stages.

<u>Feature #</u>	<u>Feature</u>
1-14	Provide barometric relief dampers and a variable speed exhaust or relief fan that operates at a speed proportional to outside air damper position.

Level: Not Incorporated.

Comments:

Control of the fan should be based on building pressure, not OA damper position.

Feature # Feature

1-15 **Direct relief air into the intake of the condenser coil.**

Level: Not Incorporated.

Comments:

There would be a COP improvement if relief air could be directed into the intake of the condenser coil. However, this feature is only beneficial when the relief air temperature is less than the OA temperature, in which case the outside air damper should be at minimum position and the airflow volume of relief air would be minimal. In addition, additional control damper(s) and positioning control logic may be required to direct relief air into the condenser coil only when it is beneficial. Therefore this feature is likely to be too expensive and complicated for the amount of benefit gained.

Feature # Feature

1-16 **Economizers shall have design, materials and construction that provide a mean time before failure (MTBF) of 15 years.**

Level: Not Incorporated.

Comments:

A fifteen-year MTBF was proposed as a future performance item. Note that ASHRAE lists the design service life of packaged equipment at 15 years.

Defining an MTBF is typically done in electronics and aviation. Our advisors were unsure as to how practical it would be to define an MTBF for rooftop unit hardware and didn't think the industry would understand the MTBF. A typical fifteen-year design life is better understood. An extended warranty also addresses the issue.

Category 2 = FANS

Feature # Feature

2-02 **Premium efficiency supply fan motor.**

Level: Not Incorporated.

Comments:

Supply fan motors will run continuously during occupied hours. Premium efficiency motors are already available as an option in many units.

However, manufacturers don't see a lot of requests for premium motors in the 3 to 5 ton range. At small sizes, there is not much efficiency gain in relation to the cost to install the premium motor – maybe only ½% - and the payback could be very long.

ASHRAE 90.1, Section 6 specifies efficiency, but allows a wide range of methods of how to reach it. Manufacturers feel it would be better to specify the whole fan system efficiency and let them decide if they want to incorporate a premium efficiency motor to get that system efficiency.

Manufacturers also feel a much quicker payback could come from well-designed ductwork that reduces external pressure drop.

<u>Feature #</u>	<u>Feature</u>
2-03	The ARTU will have a direct drive supply fan.

Level: Not Incorporated.

Comments:

Direct drive avoids loose and broken belt problems, and avoids a small efficiency loss associated with belt-drive systems.

This feature is overridden by the need to be able to balance the air system. On small systems with direct drive ECMS, the balancing can be accomplished, but on larger system belt drives are needed to balance air. Direct drive fans are typically only used on lower tier products.

<u>Feature #</u>	<u>Feature</u>
2-04	In lieu of direct drive, a tooth type belt drive equipped with an automatic tensioning system may be used.

Level: Not Incorporated.

Comments:

Toothed belts have reduced losses relative to standard v-belts. Service problems with v-belt tension exacerbate the problem. Automatic tensioning systems reduces belt losses from slippage.

Manufacturers feel a better alternative would be long-life belts. They note that drive losses are built in to the ARI ratings and they are not especially large.

Category 3 = UNIT EFFICIENCY

<u>Feature #</u>	<u>Feature</u>
3-03	The ARTU shall deliver a rated efficiency in accordance with CEE "Tier 2" efficiency standards. Alternatives: Select current ASHRAE or Title-24 efficiency, or better if readily available.

Level: Not Incorporated.

Comments:

CEE's "High-Efficiency Commercial Air Conditioning and Heat Pumps Initiative (HECAC)" efficiency specifications may be found at www.cee1.org.

The three references listed do not fully agree on efficiency values. Energy Star is well accepted, so that should be the reference.

<u>Feature #</u>	<u>Feature</u>
3-04	Cabinet leakage will not exceed 2% of design flow rate at 0.5 in-w.g. pressure difference.

Level: Not Incorporated.

Comments:

Cabinet leakage is important to increasing overall unit efficiency.

This feature was ultimately not incorporated for several reasons. State-of-the-art cabinet leakage rates have not been surveyed. For ARI or AMCA standards, 5% cabinet leakage is assumed and this amount of air loss must be included in the heat balance.

Two-percent leakage is more aggressive than standards. While this could be a worthy goal, there is at present no standard test procedure for determining cabinet leakage. Also, in the experience of the project team, units are already built with tight cabinets but shipping damage that is not repaired and poor maintenance practices (e.g., removing but not replacing all the panel screws) are larger sources of leakage.

Project advisors also felt that duct leakage, which can be considerably higher than 10%, is a bigger issue.

Category 4 = REFRIGERATION CYCLE

Feature # Feature

4-03 **High-efficiency evaporator.**

Level: Not Incorporated.

Comments:

An evaporator with increased heat transfer surface area and improved fin design will increase unit efficiency.

However, advisors again suggested that the Energy Star goal be set, and component decisions such as this one be left to the manufacturers. Let the manufacturers be creative on how to meet the goal best. For example, smaller units use less efficient motors and would use bigger condensers, etc, to meet goals such as Energy Star. At larger tonnages, more efficient compressors become available.

Feature # Feature

4-04 **High-efficiency condenser.**

Level: Not Incorporated.

Comments:

A condenser with increased heat transfer surface area and improved fin design will increase unit efficiency.

Again this is a function of the overall unit efficiency. It is true to a point, but if the condensing temperature gets too low head pressure control will be initiated earlier, resulting in about the same or lower part load efficiency.

Feature # Feature

4-05 **Liquid-to-suction heat exchanger.**

Level: Not Incorporated.

Comments:

Heat recovery between the liquid and suction refrigerant lines pre-cools the liquid entering the evaporator and preheats the gas entering the compressor, reducing the amount of work the compressor has to do.

Advisors state that on low-lift comfort cooling units there is very little benefit from liquid-suction exchangers. Some units with refrigerant economizers are on the market that have more benefit than liquid-suction exchangers.

<u>Feature #</u>	<u>Feature</u>
4-06	Refrigerant receiver.

Level: Not Incorporated.

Comments:

A Refrigerant receiver may eliminate the adverse effects of potential charge fluctuations.

Advisors state that Refrigerant receivers will result in a loss in subcooling and actually a reduction in performance. Receivers are not needed with TXV systems and actually can cause problems, especially on heat pumps.

Category 5 = FAN CONTROL

<u>Feature #</u>	<u>Feature</u>
5-04	In ventilation-only mode, supply fan specific power will not exceed XX watts per CFM of outside air.

Level: Not Incorporated.

Comments:

Energy Star and ASHRAE requirements are sufficient to cover this feature, and allow manufacturers flexibility in meeting overall efficiency goals.

Category 6 = REFRIGERATION CONTROL

<u>Feature #</u>	<u>Feature</u>
6-03	The refrigerant metering device shall be capable of maintaining the unit efficiency within +/- 6% of the nominal efficiency over a range of +/- 20% of factory recommended charge.

Level: Not Incorporated.

Comments:

A refrigerant metering device is an adopted ARTU feature. This performance range is that seen in previous PIER studies. However, if a TXV, EXV or other device is installed and the tolerance above is not met, there will be very little that can be done. Market forces will cause the type of device selected to be driven towards the more tolerant devices.

Manufacturers noted that the efficiency level is partially dependent on the charge level to start with. The initial “test balance” is allowed to vary 3 – 4%. Note that monitoring the charge level and reporting a problem is also an adopted ARTU feature; therefore, this feature may not be needed.

Category 7 = THERMOSTATS

<u>Feature #</u>	<u>Feature</u>
7-04	The thermostat will be capable of programming the heating, cooling and fan schedules independently.

Level: Not Incorporated.

Comments:

This wording was considered confusing by our advisers. The intent was to require a commercial-grade thermostat that is capable of allowing continuous supply fan operation during occupied hours, as required by standards. Wording to that effect is incorporated in other features that are adopted.

Thermostats already have separate heating and cooling programming for setpoints, although the schedule for each mode is usually the same. This is not seen as a deficiency of existing thermostats.

<u>Feature #</u>	<u>Feature</u>
7-05	As an alternative to occupancy sensor interface, thermostat will have a manual unoccupied mode that the user can initiate if the area will be temporarily unoccupied during a normally occupied period.

Level: Not Incorporated.

Comments:

A conscientious user would be able to place the system in a temporarily unoccupied mode with out undue inconvenience.

Note that while a manual unoccupied override, in which the occupant is able to temporarily turn on the system during a normally unoccupied period, is available on many thermostats today, we are not aware of any systems that provide the opposite capability: the ability to manually command the system to unoccupied settings during a normally occupied period. Certainly a user can turn the system off, but this would not enable any setback settings.

Team members feel the occupancy sensor interface is a preferred method of achieving the same result. An occupancy sensor might take a little longer to activate unoccupied

settings, but would do so automatically and would not depend on the “conscientiousness” of the occupants.

<u>Feature #</u>	<u>Feature</u>
7-06	Controls will be capable of operating the unit for night flushing.

Level: Not Incorporated.

Comments:

A sequence could be programmed to allow flushing the space with outside air before occupied hours begin, to pre-cool the space if needed. Compressor cooling would be locked out during this operation. This technique saves energy by delaying the time at which internal and envelope gains push the space temperature above the cooling setpoint and mechanical cooling is needed.

Setting the start of the occupied time period a little ahead of the actual beginning of occupancy can already enable an approximation of night flushing. The difference with a specific control sequence is that fan energy would be saved if night flushing were not needed.

This feature is listed as not incorporated since it is seen only as an energy savings feature and is not addressed by the increased reliability and diagnostic capability goals of this project. In addition, some codes require a “pre-occupancy purge” to bring fresh air into the space before occupancy begins, regardless of the need for precooling or warm-up of the space. Such purging will accomplish some degree of flushing if conditions are correct.

Category 8 = SENSORS

<u>Feature #</u>	<u>Feature</u>
8-05	Sensors shall be designed to provide a MTBF of 15 years.

Level: Not Incorporated.

Comments:

Similar to the feature for a 15-year MTBF for economizer components, advisers felt this terminology is confusing and inappropriate for rooftop unit technology.

Category 10 = ADVANCED MONITORING

<u>Feature #</u>	<u>Feature</u>
10-06	The unit shall provide the capability of reading the value of all control sensors to assist in troubleshooting and calibration.

Level: Not Incorporated.

Comments:

This feature is already covered in a more specific feature that asks for the capability of displaying various sensor readings.

Category 11 = ADVANCED DIAGNOSTICS

<u>Feature #</u>	<u>Feature</u>
11-07	Provide a readout of the outside air percentage based on air temperature measurements.

Level: Not Incorporated.

Comments:

At first glance, this feature would seem to be very desirable. It could be a big help in original setup and adjustment of the outside air minimum and in troubleshooting the unit.

However, the temperature split method gives very poor results when the temperature differentials are 10F or less. An “unavailable” indicator would have to be displayed when the outside air temperature is too close to the return air temperature to produce a reliable calculation, which could be many hours per year. While the controller may calculate the OA percentage and make it available to a technician, a readout of the value at the thermostat, for example, might be misleading to the occupants.

Installing airflow measurement stations would be an alternative to the temperature method, but at least two measuring stations would be required and this adds cost to the unit.

Other diagnostic features are seen as more reliable in determining economizer problems.

- End -