

Purpose:

This document sets forth the Statement of Work (SOW) for services to be provided to UT-Battelle, LLC, the managing and operating contractor for The Oak Ridge National Laboratory (Company), pursuant to a contract with the U.S. Department of Energy (DOE) on a project known as 60,000 - 300,000 Btu/h Automated Air Enthalpy Test Facility.

The Seller shall provide an automated stacked Air Enthalpy type test facility (Facility) for the measurement of performance of commercial rooftop units (RTUs), steep sloped roofs, flat roofs, and floors for residential and commercial buildings. Other heat pumping systems may be tested in the facility in the future; however, it is intended that they will be tested under the capabilities and limitations of the facility that are specified by this statement of work.

To satisfy the requirements of industry and government test standards as well as the Company's additional required test ranges and allow for full correlation between the new test facility and the Seller's test provider, the following items must be supplied in addition to a typical Psychrometric test facility.

Test Conditions:

Sufficient airflow, dehumidification, humidification, cooling, heating, and controls must be included to maintain conditions as per the test standards in the TECHNICAL DESCRIPTION section. These include Cooling and Heating, steady and Cyclic conditions, Defrost Conditions and Low Temperature test conditions as described in the test condition section below. Systems shall require significant over-sizing to meet this requirement.

For the operation of this apparatus, the upper chamber shall be operated over an ambient temperature range of -32 to 66°C (-25 to 150°F) and the lower chamber must simulate a wide range of indoor temperatures from 7 to 66°C (45 to 150°F).

Cyclic Tests:

Support equipment shall be provided to provide proper setup and timing for duct dampers and integrating temperature measurement. This equipment is mandatory for proper sequencing and measurement. This includes DOE dampers, temperature and humidity measurements, and controls for cycling.

Training:

Seller shall provide training to properly explain the setup and measurement techniques associated with DOE testing. Seller shall provide two weeks of onsite training after completion of the test facility and may provide one additional week of training at the Seller's facility.

Correlation:

Seller shall perform a full correlation test in coordination with the Company upon installation of the Facility. One commercial RTU will be selected for this task. The Seller shall choose the correlation unit, to be supplied by the Company, to the Seller. The correlation unit shall also be tested at a commercial testing laboratory to ensure data accuracy. It should be feasible to perform training during this task.

Laboratory Evaluation and Adjustment Plan (LEAP):

The Seller shall perform test evaluations as outlined in Appendix C. of AHRI 210/240-2023 and AHRI 340/360 2022. Evaluations shall include:

- C5.1 Sensible Heat Capacity Evaluation of Code Tester for both indoor and outdoor code testers
- C5.2 Evaluation of Thermal Energy Storage Effect for C_D Testing for the indoor chamber.

- C5.3 Evaluation of External Static Pressure Measurement System
- C5.5 Evaluation of Latent Capacity Measurement

Note: the C5.2 evaluation may require two sets of mixing boxes to meet the requirement.

Where corrections are allowed, corrections shall be determined for any tests that fall outside of the allowable tolerances. If results fall outside of the tolerances for which corrections are allowable, corrective actions shall be taken to bring the measurement equipment or facility into tolerance.

SEER/HSPF, SEER2/HSPF2, EER, IEER, COP, SHR Calculations:

Training and Calculations shall be provided to allow the operators to calculate the SEER/HSPF, SEER2/HSPF2, EER, IEER, COP and SHR values from the test data obtained with the test facility.

Online Service Support:

The Seller shall offer ongoing online support for one year after delivery and setup if issues arise with the Facility. This ensures prompt handling of any issues by the experts.

Technical Description

The Facility shall conform to the instruments and test requirements and provide the conditions specified in the following standards. The Facility shall use either the Outdoor Air Enthalpy or the Refrigerant Enthalpy method as the Standard Test Method secondary check to the performance results as prescribed in ASHRAE 37.

- AHRI 210/240 – 2017 with specific requirements in Section 5, Appendices C, D, E, and F
- AHRI 210/240 - 2023 with specific requirements in Section 5, Appendices C, D, E, and F
- AHRI 340/360 – 2019 with specific requirements in Section 5, Appendices C and E
- AHRI 340/360 – 2022 with specific requirements in Section 5, Appendices C and E
- ASHRAE 37 - 2009 with specific requirements in Sections 5, 6, 7, 8, 9, 10, and 12
- ASHRAE 41.1 – 2020, 41.2 – 2022, 41.3 – 2022, 41.4 – 2015, 41.6 – 2021, 41.7 – 2021, 41.8 – 2016, 41.10 – 2020, and 41.11 – 2020
- DOE Appendix M – 2021 with specific requirements in Sections 2 and 3
- DOE Appendix M1 – 2021 with specific requirements in Sections 2 and 3

In cases of conflict between the AHRI, ASHRAE, and DOE standards, the DOE standards shall take precedence.

Insulated Test Rooms

Approximate test room size will be:

Height: 26 ft. (14 ft. for “top” Outdoor chamber and 12 ft. for “bottom” indoor chamber)

Length: 22 ft.

Width: 22 ft.

Capacities

The Facility must be designed and constructed to accurately test air source air conditioners of cooling and heating capacities from 60,000 to 300,000 BTU/h 95 (5-ton to 25-tons).

Instrumentation

Each chamber shall be configured to handle up to two hundred channels of data. Connection blocks containing pin plug connectors shall be installed in each chamber. One hundred seventy-five channels of data

will be for temperatures (Type T thermocouples) and the remaining twenty-five channels will be for voltages (0-5V).

Accuracy

Standard Cooling and Heating Capacity test accuracy shall be within $\pm 2.5\%$ when compared against identical test conditions performed at the Seller’s test facility.

Test Conditions

The table below includes a list of some of the common test conditions that will be used in the chamber. This is not an exhaustive list and other test conditions may be required by the list of test standards in the TECHNICAL DESCRIPTION section.

STANDARD	TEST NAME		INDOOR °F	OUTDOOR °F
210/240, 340/360	A	DB / WB	80.0 / 67.0	95.0 / 75.0
210/240	B	DB / WB	80.0 / 67.0	82.0 / 65.0
210/240	C and D	DB / WB	80.0 / 57.0 max	82.0 / 58.0
210/240	E	DB / WB	80.0 / 67.0	87.0 / 69.0
210/240	F	DB / WB	80.0 / 67.0	67.0 / 53.5
210/240	G and I	DB / WB	80.0 / 57.0 max	67.0 / 58.0
210/240	Maximum Operation (Cooling)	DB / WB	80.0 / 67.0	115.0
210/240	Extra High Maximum Operation (Cooling)	DB / WB	80.0 / 67.0	125.6
210/240	Insulation Efficiency, Condensate Disposal	DB / WB	80.0 / 75.0	80.0 / 75.0
210/240	Low Temperature (Cooling)	DB / WB	67.0 / 57.0	67.0 / 57.0
210/240	H1, H1C	DB / WB	70.0/ 60.0 max	47.0 / 43.0
210/240	H0	DB / WB	70.0/ 60.0 max	62.0 / 56.5
210/240	H2	DB / WB	70.0/ 60.0 max	35.0 / 33.0
210/240	H3	DB / WB	70.0/ 60.0 max	17.0 / 15.0
210/240	H4	DB / WB	70.0 / 60.0	5.0 / 3.0 max
	ORNL SPECIFIED RANGES*	DB	32.0 to 100.0	-40.0 to 130.0

STANDARD	TEST NAME		INDOOR °F	OUTDOOR °F
340/360	A (full load)	DB / WB	80.0 / 67.0	95.0 / 75.0

340/360	75 Percent Load	DB / WB	80.0 / 67.0	81.5 /
340/360	50 Percent Load	DB / WB	80.0 / 67.0	68.0 /
340/360	25 Percent Load	DB / WB	80.0 / 67.0	65.0 /
340/360	Maximum Operation (Cooling)	DB / WB	80.0 / 67.0	115.0
340/360	Insulation Efficiency, Condensate Disposal	DB / WB	80.0 / 75.0	80.0 / 75.0
340/360	Low Temperature (Cooling)	DB / WB	67.0 / 57.0	67.0 / 57.0
340/360	H1, H1C	DB / WB	70.0/ 60.0 max	47.0 / 43.0
340/360	MAX OPERATING CONDITION HEATING	DB / WB	80.0/ not spec	75.0 / 65.0
340/360	H3	DB / WB	70.0/ 60.0 max	17.0 / 15.0
	ORNL SPECIFIED RANGES*	DB	32.0 to 100.0	-25.0 to 130.0

Note:

These tests should be configured on the data acquisition computer during initial startup and evaluation. The Seller shall configure computer-generated reports per the Company’s report requirements.

*The Unit Under Test (UUT) mode will be favorable for the goal temperatures during the extreme test. This means that the UUT will operate in cooling mode for high ambient extreme temperatures, and in heating mode for low ambient extreme temperatures. Heat will be rejected from the UUT during high extreme temperatures, but not during low extreme temperatures.

Facility Test Rooms

The Facility should be divided into an indoor (bottom or lower level) and outdoor room (top or higher level). The indoor and outdoor rooms shall be pre-engineered, insulated modular structure. The walls, ceiling, and floors shall be of minimum of 4-inch-thick urethane panels with a painted, galvanized steel cladding having an R value of 34. Floor drainage or floor panel seam sealing shall be designed to prevent water from seeping into the seams of the insulated floor to prevent damage from repeated freezing/thawing. A large double door and a small section of openable ceiling shall be provided for the outdoor room allowing easy loading of the Facility. An oversized sliding door shall be located as a separate entrance for the indoor room. Ramps shall be provided to allow for ingress and egress of equipment. Outdoor rated LED lighting shall be attached to the ceiling panels and walls as required to achieve a minimum of 70 (50?) lumen/ft².

Reconditioning Equipment

Cooling shall be accomplished utilizing direct expansion refrigeration systems with air-cooled condensers. Dehumidification shall be provided by a desiccant wheel dehumidification system. Electric duct heaters with SCRs shall control heating. Humidity shall be added with steam injection from an electric boiler system supplied by the Seller. The boiler shall include a drawdown function to drain the used water after a test.

Aspirated Psychrometers and Air Sampling

Seller shall provide two aspirated psychrometers for each room, indoor and outdoor. Seller shall locate

outdoor room psychrometers outside the outdoor chamber and include a heater with automatic controls for heating cold air to a desired temperature above freezing prior to dry bulb and wet bulb measurements. Additional RTDs shall be used to measure the dry bulb temperature of the air at the sampling trees. Additionally, Seller shall provide one RH sensor at each sampler to spot check the humidity of the air at the samplers to help monitor the sampling hoses for leakage. This will be accomplished by comparing the RH measured inside the sampler to the RH measured outside the sampler. The psychrometers shall be connected to the room control system and achieve the room temperature settings. The Seller shall provide 3 air sampling boxes, one for the indoor side return air, one for the indoor side supply air, and one for the outdoor side. A complete set of sampling trees and hoses needed to conduct testing and correlation shall be provided as part of the project. Indoor supply air sampling box shall include a mixing device, thermocouple grid or thermopile, sampling tree connected to an aspirated psychrometer in the insulated enclosure, and a damper. A sample tree, hoses, and an aspirated psychrometer shall be provided by the Seller for measurement of the indoor return air. Outdoor supply air sampling box shall include a mixing device, thermocouple grid, and sampling tree with dry bulb and RH measurement location in an insulated box. Four sample trees with connecting hoses and dry bulb temperature measurement location shall be provided for sampling the outdoor return air. Hoses from the outdoor sampling trees shall connect to the outdoor aspirated psychrometers located outside of the chamber. All aspirated psychrometers shall have local velocity measurement tied to a variable speed fan and controller to automatically measure and maintain the appropriate air velocity through the psychrometer.

Code Testers

Airflow tunnels (code testers) shall be supplied for the indoor and outdoor rooms. The code testers shall be integrated with the automated end-to-end DAS and provide required level of accuracy, ease of use and reliability. The code testers shall be designed and constructed in accordance with ASHRAE 37 by the Seller. These are widely used in the air conditioning industry. The code tester shall be supplied on casters to allow for movement. Code tester shall have sufficient number nozzles and varied sizes to measure airflow in the following range while maintaining allowable nozzle velocities. A small nozzle will be provided specifically for measuring air leakage of the test setup. Code testers shall allow for operation in three different models, manual, maintaining airflow rate, and maintaining UUT external static pressure.

Airflow range:

Indoor: 1000 – 15,000 SCFM

Outdoor: 2000 – 12,000 SCFM

Test Unit Power

The Seller shall supply a test unit power control system. Test unit power shall be monitored and controlled from the console by the system operator. Precision Power Meters shall be provided by the Seller and utilized to measure voltage, current, power (watts) and frequency. Power meters shall include an integration function for providing energy use measurement. The system shall include an independent measured three phase output section and an independent measured single phase output section. Power supplies shall provide target voltage within $\pm 1\%$, frequency within $\pm 1\%$, and less than 3% total harmonic distortion (THD).

Single Phase Test Unit Power Control System:

40kVA (@ 60 Hz) regulated supply 1 phase input, 1 phase output, 2 wire, and 240V 4 wire (including ground) control 50/60 Hz, 100 – 300VAC Single Phase (P-N) +/- 1%. This power supply shall be a split phase power supply: 240 VAC L1-to-L2; 120 VAC L1-to-N; 120 VAC L2-to-N

Three Phase Test Unit Power Control System:

90kVA (@ 60 Hz) regulated supply 3 phase input, 3 phase output, 4 wire,
50/60 Hz, 173 – 540VAC Three Phase (P-P) +/- 1%

Input voltage regulators are supplied by the reputable vendors sourced in United States.

A 20-amp (4 wire) fan circuit and a 60-amp (4 wire) heat circuit shall be supplied to the indoor test room. A 30-amp (4 wire) fan circuit and a 60-amp (4 wire) compressor circuits shall be supplied to the outdoor test room. All circuits shall provide for pass through connection of voltage sense wires for connection within 6 inches of the test unit.

Optional: A 50 hertz generator shall be provided by the Seller. Voltage supply at 50 hertz if required shall be supplied by the Company to a switch from the building's 50 hertz circuit.

Data Acquisition & Control

The Seller shall supply a computerized Data Acquisition/Control System designed specifically for use with the test facility. The system shall include a computer with all necessary I/O hardware, 2 x 24" monitors, printer, software, an analog data sub-system and transducer packages (i.e.: power consumption, signal conditioners/sensors, with inputs such as type-T thermocouples, platinum RTD thermometers, analog voltage, as well as analog output channels for custom control of experiments), control system electronics, test unit power system, and the required documentation, schematics, etc. The precise number and type of channels shall be defined during the engineering phase of the project. LabView is the preferred system for the data acquisition, but other platforms shall be considered. The source code for the data acquisition shall be provided to the Company. Wherever possible, low voltage shall be separated from high voltage in separate cabinets. Control of chamber conditioning system shall include both hardware and software. The chambers must be able to operate safely on the hardware controls in the event of software shutdown (computer freeze, power off, reboot, etc.). It is desirable that the chamber controls be separate from the monitoring computer for reliability purposes.

Computer System

The computer shall be a Windows OS compatible computer. The computer system shall include two (2) industry standard mirroring solid-state drives to provide data and program storage. This prevents down time or data loss due to a failing drive. Network card and support software shall be installed for online support. The Seller shall also supply an uninterruptible power source be used for the computer.

System Software

The operating system shall be Windows based. The Seller shall supply the system with applications software for data acquisition, facility control and report generation. Seller shall install all software on the system drive at the time of facility installation.

Analog Data, Sub-System

This system shall be used as a "data logger" containing a highly efficient and accurate multi-channel analog intelligent front end, which communicates with, and is remotely programmed through the test system computer. Additional inputs not specified in prior sections or for performing standard tests include a minimum of 60 user thermocouple inputs, 20 user voltage inputs, 8 user 4-wire RTD inputs, and 10 user relays shall be provided on patch panels split evenly between the indoor and outdoor rooms.

Power Transducer Packages

The test unit power system shall contain a package consisting of five precision power analyzer(s) capable of providing $\pm 0.5\%$ reading accuracy for both on-cycle and off-cycle operation of the UUT.

Control System Electronics

Seller shall provide all the necessary control electronics (i.e.: regulators, phase controllers, etc.) and their sensors for use in the control loops.

Full Software and Hardware Automation

Software and hardware required to automate all tests. It shall include voltage regulation of single-phase test unit power, three phase test unit power, and setup and control of all temperature conditions. Test setups can be stored and recalled from disk. Test data will be acquired, averaged, and stored to disk files, air flow and capacity calculations for all heating and cooling tests will be included. Refrigerant properties (e.g., superheat, subcooling, and enthalpy) will be calculated with NIST Refprop version 10 or higher. Calculations for the refrigerant enthalpy method will be included. PID control and/or controllers will be interfaced through the computer data acquisition system.

DOE Test Equipment

All necessary damper boxes and interfaces used for performing DOE "D" cyclic tests shall be provided. Optional: The Seller will supply a system to automatically raise and lower the DOE box based on the UUT outlet duct.

Refrigerant Flow

Two mass flow meters will be provided by the Company and shall be approved by the Seller based on the ability to read the signal with the data acquisition system. Meters should provide instantaneous and integrated mass flow outputs. Accuracy of $\pm 1.5\%$ of reading is required for flow range of 500-3500 lb/h.

Refrigerant Pressure Transducers

The Seller shall provide a total of 14 pressure transducers, 6 high (1000 psi) and 6 medium (500 psi) and 2 low (300 psi), to accommodate two compressor or dual DX systems. The transducers shall be approved by the Seller based on the ability to read the signal with the data acquisition system.

Air Pressure Transducers

The Seller shall provide a total of 9 air pressure transducers, 2 inlet static (-2.0 - +2.0" WC), 2 total static (-2.0 - +2.0" WC), 2 before nozzle static, 2 nozzle delta pressure (0-4" WC) and barometric pressure accurate to 0.030" Hg. The transducers shall be approved by the Seller based on the ability to read the signal with the data acquisition system.

Fan Speed Measurement

Two (2) transducers shall be installed for measuring fan speed of UUT, one each in the indoor room and outdoor room.

Low Temperature Outdoor

Equipment necessary to bring outdoor room to -25°F shall be added to meet the Company's requirements.

Safety

Necessary sensors and circuits shall be provided to protect the facility from abnormal failures. These shall include over temperature sensors for the test rooms, and software programming to shut down the facility during abnormal operations and notify the operator of this failure. A software and hardware alarm shall be integrated together to provide audible, visual, and detailed information about the cause of the alarm when practical to do so. Adequate lighting shall be provided in the test rooms and Mechanical Area as required.

The chambers shall be designed for the use of A2L refrigerants at potential concentrations up to 25% of the lower flammability limit. The Seller shall install a flammable refrigerant detection and evacuation system. The system shall be designed to operate independently from the chamber software and include visual and audible alarms, activation of emergency lighting, chamber electrical shutdown with the exception of chamber air handling units, and chamber air evacuation. The system shall also have the capability to be activated by the operator. Facility and equipment shall comply with UL 60335-2-40 3rd edition and ANSI/ASHRAE Standard 15-2019. Electrical outlets and switches shall be located above ¼ of the chamber height. Overpressure panels are also required to ventilate the chambers during a safety situation with the leak of an A2L refrigerant.

All purchased equipment, site-built equipment, and electrical panels must be certified by an OSHA designated Nationally Recognized Test Lab (NRTL). The vendor chosen to supply this facility shall be responsible for hiring a NRTL to do a field evaluation of the chamber after it is installed onsite. In addition, the Authority Having Jurisdiction (AHJ) of the Company will do electrical inspections at periods of 30%, 60%, and 90% of the completion of construction.

Manuals and Documentation

The Seller will provide manuals which describe the operation of the test facility, periodic preventive maintenance procedures, and calibration requirements. The Seller shall also provide a complete set of engineering drawings and schematics for the test facility. The Seller shall also provide manufacturer's documents and manuals for the commercial equipment used.

Training

An engineer from the Seller's facility shall test and commission the Psychrometric facility as constructed and assembled on site to assure proper operation. As a part of this procedure, the Company's technicians and engineers shall be trained to operate the facility.

Calibration

The Seller shall conduct the initial ISO 17025 accredited calibration and furnish calibration records for all instrumentation requiring calibration. Calibration markings shall be affixed to calibrated instruments where practical.

Software Updates

Software updates to maintain regulatory compliance shall be provided free for three (3) years following the project completion date.

Correlation Testing

One (1) correlation unit will be provided by the Company. The commercial rooftop heat pump shall be evaluated and documented at the Seller's laboratory. The heat pump shall be delivered to the Company along with the DAQ equipment supplied by the Seller and will be used as test and calibration standards by the Company. The Seller shall supply a final report and certificate detailing the results of the acceptable correlation tests.

Limited Warranty for Test Facilities and Instrumentation

The Seller shall offer a warranty for its design and instrumentation of the facility to be constructed pursuant to its design documentation and contract. Warranty period shall be valid for 12 months following final acceptance.

The Seller shall provide 1 (one) follow-up visit to the Company's facility after 30 days and within 90 days

after completion of installation.