AIR-CONDITIONING, HEATING, AND REFRIGERATION TECHNOLOGY INSTITUTE

A Not-for-Profit Organization for
Scientific Research in the Public Interest
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The Air-Conditioning, Heating, and Refrigeration Technology Institute (AHRTI) invites your company to submit a proposal for the following research project:

AHRTI Project No. 9018
Risk Assessment of Open Flame Proximity to Commercial Refrigeration Appliances

The proposed scope of work is outlined in the attached work statement.

Proposal Submission

Proposals are due by 12:00 PM Eastern Time on Wednesday, November 22, 2023.

Proposals should be submitted in electronic form (Adobe PDF or MS Word file format), and be emailed to: xwang@ahrinet.org

Contact for technical questions concerning the scope of work:

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Proposal Evaluation Criteria

Proposals will be evaluated per the criteria and weighting listed below:

Understanding the problem (20%)
Approach to solving the problem (20%)
Probability of (timely) success (10%)
Qualifications and experience of key personnel (25%)
Quality of facilities to perform the work (25%)

AHRTI
WORK STATEMENT

AHRTI WS#_9018___

Title: Risk Assessment of Open Flame Proximity to Commercial Refrigeration Appliances

About AHRTI

The Air-Conditioning, Heating, and Refrigeration Technology Institute (AHRTI) is a not-for-profit organization established to undertake scientific research in the public interest. AHRTI's mission is to foster applied research on technologies to improve products, systems, and controls that benefit the general public in the areas of Heating, Ventilation, Air-Conditioning, Refrigeration (HVACR), and Water Heating.

AHRTI is an entity associated with the Air-Conditioning, Heating, and Refrigeration Institute (AHRI). AHRI is the national trade association representing manufacturers of HVACR and Water Heating equipment within the global industry.

Background: Addendum L of ASHRAE Standard 15-2019, which was incorporated into the 2022 edition, addresses the use of larger charge sizes of flammable refrigerants in commercial refrigeration applications. One of the requirements contained within Addendum L is that all appliances containing flammable refrigerant charge sizes greater than 4xLFL cannot be installed within 20 ft of an open flame. The rationale for this restriction is related to the Annex CC door/drawer opening test procedure found within the IEC and UL 60335-2-89 standards (3rd and 2nd editions, respectively).

In the IEC standard, refrigerant concentrations exceeding 50% LFL are permitted around the perimeter of the appliance for up to 5 minutes, which in theory allows flammable concentrations to persist around the appliance for up to five minutes. Concerns were raised over the relative safety of these criteria. The AHRTI 9015 research project examined this and other aspects of the Annex CC test procedure. Testing from this project demonstrated that appliances "in compliance" with the IEC standard Annex CC test procedure could still have flammable concentrations present around the appliance for tens of seconds, despite the use of circulation air as a mitigation measure.

The UL version of the standard, which was under the development at the time of the AHRTI 9015 project, addressed these concerns in part by implementing lower charge limits and only allowing refrigerant concentrations exceeding 50% LFL to persist for up to 5 minutes in the area immediately in front of where a door or drawer is opened. However, even with these deviations from the IEC standard, concerns remained about using larger charges of flammable refrigerants in commercial kitchens, where a refrigeration appliance could be installed in close proximity to an open flame. As open flames are potentially competent ignition sources for all flammable refrigerants, a 20 ft installation restriction was added to the proposed Addendum L.

Concerns have now been raised over the challenges created by this installation restriction. Automatic commercial ice machines (ACIMs), for example, are commonly used today in commercial kitchens. Many ACIM models will transition to flammable refrigerants, requiring charge sizes greater than 4xLFL. The 20 ft installation restriction effectively eliminates the use of these products in many commercial kitchens, when using flammable Lower Global Warming Potential (LGWP) refrigerants.

Justification and Value: Several concerns have been raised over the Addendum L installation restriction. First, the 20 ft distance was selected as a "safe distance" that would likely prevent a flammable concentration of refrigerant spilling out of the interior of an appliance from reaching an open flame. However, this distance was essentially an engineering judgement based on limited test data and experience.

Second, this restriction applies to all appliances using a flammable refrigerant charge size greater than 4xLFL. The impetus for this requirement however was the door opening test from Annex CC of the IEC 60335-2-89 3rd edition standard, which applies to leaks that are internal to a refrigerated compartment. AHRTI 9015 clearly demonstrated that external leaks from appliances can be successfully mitigated to prevent refrigerant concentrations from exceeding 50% of LFL at any time. Therefore, appliances that do not have internal leaks to enclosed refrigerated compartments may be restricted unnecessarily.

Third, the 20 ft restriction was based in part on results obtained from the AHRTI 9015 study, which looked at leaks into the refrigerated compartments of reach-in coolers. Concerns have been raised that leaking refrigerant could accumulate into the ice bins of ACIMs, producing a door-opening effect when the ice bin is accessed. However, many ACIMs are designed to prevent refrigerant from leaking into the ice storage bins. As such, the 20 ft restriction may not be warranted for many ACIM designs.

Fourth, the 20 ft restriction is not specific as to the horizontal and vertical relationships between the point of refrigerant release and the open flame, nor the effects of gravity and buoyancy during a release. The restriction could be interpreted as a 20 ft radius in all directions from the open flame location (a spherical exclusion zone) regardless of other surfaces, walls, or equipment in the space. The restriction could also be interpreted as the length of a path that a potential refrigerant leak could take to arrive at the flame location, which might traverse along work surfaces, walls, or other equipment in the space with corresponding changes in both horizontal and vertical directions. There is no consideration for a refrigerant release point low in the space that poses less risk of ignition if the open flame is at a higher point in the space, or that a refrigerant release above the location of an open flame may pose a higher risk of ignition due to the dispersion characteristics.

Lastly, testing conducted during the AHRTI 9015 was done in a quiescent environment, following the compliance requirements of the IEC 60335-2-89 3rd edition standard. Commercial kitchens use vent hoods that may help prevent or reduce flammable concentrations from forming. Additionally, appliances were not tested that would meet the more restrictive requirements of the UL 60335-2-89 2nd edition standard. Successfully meeting the requirements of the UL standard

may also reduce or eliminate the potential of a flammable concentration forming, or how far it could travel from the appliance.

Given all of these considerations, there is a need to evaluate existing test data and risk assessments (AHRI Project 8009, AHRTI Projects 9013 and 9015, & NFPA Report FPRF-2017-15) to validate the suitability of the 20 ft installation restriction. Additional testing or modeling may also be required to determine whether ACIMs will accumulate the refrigerant charge in their bins, and what the refrigerant concentrations exiting an appliance meeting the Annex CC compliance requirements of UL 60335-2-89 2nd edition look like.

Objective: The objective of this project is to evaluate the equipment configurations and refrigerant leak scenarios of commercial refrigeration products (ice makers and reach-in coolers/freezers) and conduct a risk assessment for flammable refrigerant applications close to open flame ignition sources.

Scope: This project will have the following major tasks to be accomplished in general. The specific tasks and approaches may be subject to changes upon agreement between the Project Monitoring Subcommittee and the contractor.

Task 1 - Evaluation of refrigeration equipment configurations and refrigerant leak scenarios

The task shall include, but not be limited to the following,

- gather up-to-date information about common design configurations of ice makers and commercial refrigerators; obtain information about potential leak locations from Original Equipment Manufacturers (OEMs),
- collect information about the current equipment installation locations in commercial kitchens and relative distances and heights from open flames; consider whether model building codes allow or prohibit commercial kitchens with multiple floor levels or a split-level configuration
- Collect information on the ventilation scenarios (e.g., general exhaust and hood exhaust in compliance with model building codes) for commercial kitchens and select the representative cases for study (such as with or without exhaust fan running).

Task 2 – Review of existing test results

The test scenarios of previous studies (AHRI Project 8009, AHRTI Projects 9013 and 9015 and NFPA Report FPRF-2017-15) should be reviewed. These tests were for reach-in coolers. The contractor shall first identify those tests that can be used to derive the safe distance between the units and open flames and analyze the test results compared to the current 20 ft proposed requirement. The contractor shall then identify similar leak scenarios to those identified in Task 1. For example, the contractor should assess whether a top-mount condenser leak of a reach-in cooler would be comparable to a leak external to the ice bin of an ice maker etc. Test results of similar or equivalent cases will be focused on and analyzed in terms of refrigerant dispersion patterns and

concentration levels. The contractor should also review the existing risk assessment (AHRI project 8009) for suitability of applying to ice maker applications.

Task 2 deliverables should include a list of existing scenarios and results that can be used to define the safe distance and elevation relative to an open flame for reach-in cooler and ice maker applications and a list of data gaps needed from testing for a fault tree analysis type risk assessment.

Task 3 – Testing

Testing will be conducted using similar set ups and procedures per the AHRTI Project 9015 reach-in cooler tests. The equipment includes:

- commercial refrigerators (reach-in coolers / freezers)
- ice makers with two typical design configurations shown in pictures below:

Testing shall also be conducted to simulate equipment complying with both the Annex CC requirements of IEC 60335-2-89 3rd edition and UL 60335-2-89 2nd edition. Various mitigation mechanisms may be used (e.g., circulation air or safety shut-off valves) to help comply with the requirements of these standards. Refrigerant charge sizes and room dimensions to be tested will be decided by the project monitoring subcommittee.

Measurement requirements:

- an array of fast responding sensors measuring refrigerant concentrations at multiple locations and elevations (T90 less than 3 seconds). The number of sensors must be able to capture the size and range of refrigerant cloud within the space being tested.

Test matrix

The contractor will use similar approach to the AHRTI Project 9015 and build a configurable mockup room with a floor area of 625 ft² (25 ft × 25 ft) that can be re-arranged as needed to recreate

various scenarios. The contractor shall conduct refrigerant release and concentration measurement testing following similar procedure used in the AHRTI project 9015. The key factors impacting the refrigerant dispersion are listed in the table below. The tests will be combinations of each factor so there are a total of 36 combinations. The contractor will also budget four additional tests with different room configurations that will be decided by the project monitoring subcommittee once reviewing the results of the 36 tests.

Equipment	**Refrigerants**	**Refrigerant release quantity**	**Refrigerant release location**	**Refrigerant state**
Ice maker (floor-mount)	Low density (R290 or an equivalent A1 refrigerant)	4×LFL	Internal release	liquid
Ice maker (counter-mount)	High density (an A2L, e.g. R454C or R32, or an equivalent A1 refrigerant)	8×LFL		
Reach-in cooler (3 door)		13×LFL		
		Maximum releasable charge per UL60335-2-89 Ed 2 when the full charge is 4×LFL		
		Maximum releasable charge per UL60335-2-89 Ed 2 when the full charge is 8×LFL		
		Maximum releasable charge per UL60335-2-89 Ed 2 when the full charge is 13×LFL		

<u>Task 4</u> – Risk Assessment

The contractor will conduct a quantified risk assessment for release of A2L and A3 refrigerants in the vicinity of open flames as potential sources of ignition. The open flames shall be typical of those found in commercial kitchens (e.g. natural gas or propane cooking burners, gel or liquid chafing fuel based food warmers, but not candles). Other potential sources of ignition, such as

electrical sparks, are out of scope. The risk assessment shall focus on the probability of an ignition occurring. Severity of the ignition event or decomposition products are out of scope.

To generate required inputs for the risk assessment, the contractor should propose some combination of simulation analysis and empirical testing for evaluation of the refrigerant dispersion characteristics and subsequent probability of creating relevant hazards.

Task 5 – Reporting

The report of the project shall be a compilation of the information generated throughout the project. AHRI reserves the right of withholding any part of this research to be published. Report in detail all data, procedures, and equipment in sufficient detail to enable others to fully understand the procedures and results and to be able to replicate the procedures if needed.

Deliverables

The output from this project shall be a compilation of the information generated throughout the project. The contractor shall provide the following:

- Monthly invoices and letter reports on progress and task results;
- Progress reviews in the contractor's facilities and/or by teleconference, by AHRTI project monitoring committee members, to assess the work-in-progress;
- Draft technical report, executive summary, tabulated data, and recorded video files documenting the procedures, conditions, and findings, for review by and a presentation to an AHRTI project monitoring subcommittee; and
- Final technical report, executive summary and tabulated data resolving review comments provided by AHRTI. Included as part of this deliverable is the source code for any model tools developed, which are expected to be AHRI properties.

Unless otherwise specified by AHRTI, printed material will be delivered on standard 8-1/2 by 11 inch paper. Electronic documents shall be delivered as a consolidated document file that integrates all text, figures, tables, and photographs into a single file in both Microsoft Word and PDF file format.

Unless otherwise specified by AHRTI, the contractor shall deliver the following as scheduled:

Invoices & Letter Reports on Progress	Monthly, within 30 days of reported period
Review Presentation Materials	Within 1 week after review
Technical Papers/Presentations Upon Approval by AHRTI	30-days prior to submission due date

Draft Final Technical Report; Executive Summary and Tabulated Data	60 days prior to contract completion date
Final Technical Report; Executive Summary; and Tabulated Data	30 days after receipt of AHRI comments

Level of Effort

Completion of this project is expected within 9 months of elapsed time at a cost not to exceed $150,000. It is anticipated that the contract for this work will be awarded at a lower price based on selection from competitive proposals. However, price will not be the only factor weighed in the selection process. Prior experience and expertise in the field of study, access to laboratory and/or instruments required for completion of this project, and competitive prices will all be considered in selecting a contractor for this project.

Limitation

Solicitation of this project does not commit AHRTI to award a contract, pay any cost incurred in preparing a proposal, or to procure or contract for services or supplies. AHRTI reserves the right to accept any or all proposals received, or to cancel in part or its entirety a solicitation for this work prior to the signing of a contract agreement, when it is in AHRTI's best interest. AHRTI reserves the right to negotiate with all qualified sources.

PROPOSAL EVALUATION CRITERIA & WEIGHTING FACTORS

Understanding the problem (20%)
Approach to solving the problem (20%)
Probability of (timely) success (10%)
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