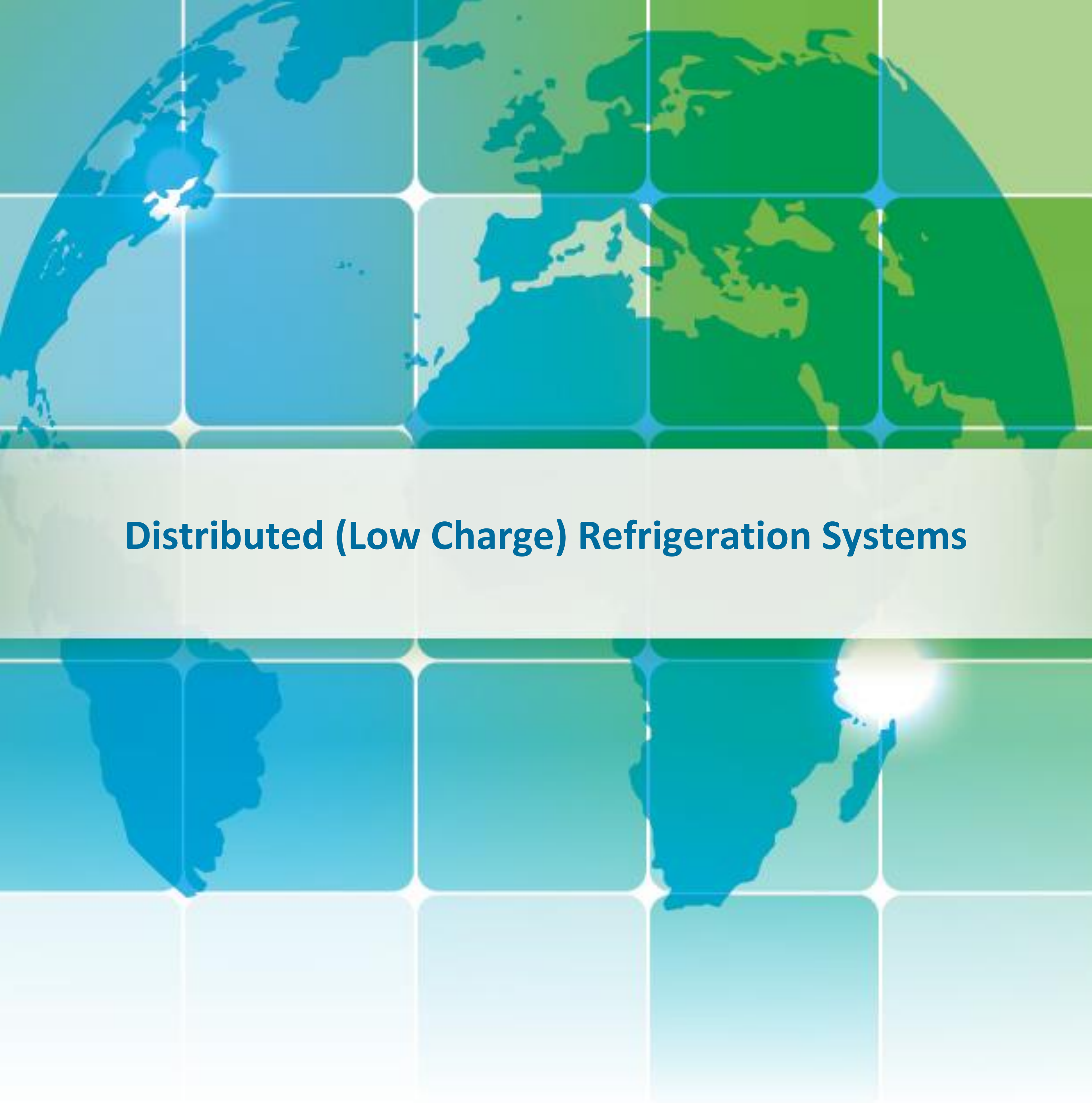

Distributed (Low Charge) Refrigeration Systems

IARW International Association of Refrigerated Warehouses

World Food Logistics Organization
WFLO
The Refrigeration Research & Education Foundation

Construction & Codes Committee

Global Cold Chain Alliance

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OVERVIEW:

1) **Description**: Distributed Refrigeration Systems are growing in popularity and site installations, so understanding this new technology and how to apply it is the purpose of this document. Distributed Systems utilize packaged or skidded subsystems that are spread throughout a facility and located close to the cooling loads, instead of a central system that has a central machinery room serving many cooling loads and is piped to the various rooms throughout a facility. Often these packaged systems are called Low Charge Systems because they can greatly reduce the quantity of ammonia (or other refrigerants) as compared to a central system.

   Distributed Low Charge Systems are also typically factory assembled and tested, which can facilitate faster installations for refrigerated facilities. Each package is typically provided with the evaporator, compressor, vessels and condenser all pre-assembled, wired and ready for quick installation and start-up.

   The driving force behind these packaged low charge systems is the increasing enforcement and burden of government regulations (primarily OSHA and EPA), as well as growing industry codes and standards. These regulations and codes often reference a Threshold Quantity (TQ) related to a systems total refrigerant charge. An example of this is the 10,000 lb. ammonia TQ under OSHA's Process Safety Management (PSM) program and EPA's Risk Management Plan (RMP). Minimizing the total system charge, to stay below a TQ, is now a key objective for many owners and operators, who are evaluating the refrigeration system design for new warehouse and food processing facilities. The Distributed Low Charge Systems represent a new technology and new overall system design that help solve this need.

   The growing use of Distributed Systems is also driven by industry's response to the environmental and safety issues surrounding both synthetic refrigerants (HCFC, HFC's & HFO's) and natural refrigerants (Ammonia, CO2 & hydrocarbons). Navigating these environmental and safety issues to determine what refrigerant a facility should use can be made easier with a low charge Distributed System because there is much less refrigerant to worry about. Choosing the right refrigerant for a particular application is also driven by energy efficiency, system reliability and cost effectiveness.

   The growing adoption of Distributed low charge ammonia systems has led IIAR to publish new guidelines that manufacturers, contractors and end users can use to apply this technology. The IIAR *Low Charge Ammonia Refrigeration Management (ARM-LC) Guidebook* provides a detailed overview of the procedures recommended to implement a management program for low charge ammonia refrigeration systems with appropriate regulatory compliance and is recommended to be used by all stakeholders.

2) **Overview of Technology Solution:** Industrial refrigeration projects range from small to large, and from new "green field" projects to various expansions or retrofit projects of existing facilities, and Distributed Systems can fit many different project types. An important step to implementing this new technology is for the owners design team, and/or design build contractor, to integrate the design attributes of the Distributed System into the early stages of the facility design development process. This can maximize the potential cost savings for using this solution because it can eliminate the cost of a central machinery room from your building budget and potentially lower the field electrical budget, while also minimizing the extra steel

cost impact of roof mounted Distributed units.

Another potential application for this technology is on more complex projects wherein a "Hybrid Design" that uses a combination of the packaged units along with a smaller conventional field erected system, serving different parts of a facility. For example, a warehouse with a lot of blast freezing, or a Freezer/Dock expansion where the freezer expansion uses the packaged units but the dock expansion is able to tie into the facility's existing high temperature system. This is a very effective solution and eliminates the need to expand or add a traditional machinery room.

Distributed Systems are available in different packaged configurations and understanding how they can be applied is important. These packaged configurations can include:

a) Direct Systems - cooling of the air with refrigerant in the evaporator:
   i) Evaporators are located in a Penthouse and close coupled to the rest of the packaged system, or
   ii) Remote Evaporators, which can be ceiling hung in the room, in an air handing unit, process equipment, etc., and are field piped to the packaged unit.

b) Indirect Systems - Cooling of air (or process) with a secondary fluid in the cooling coil. This design is also called a Chiller. The secondary fluid is cooled in the Chiller, or multiple Chillers, and pumped to remote cooling coils (which can be ceiling hung or in a penthouse) or process loads as well. The chilled secondary fluid can feed various types of process loads. The secondary fluid can be various fluids such as water, propylene glycol, calcium chloride, aqueous ammonia, CO_2 volatile brine, etc.

The inherent and major design feature of Distributed Refrigeration Systems is they eliminate all or most of the extensive long piping runs and pipe headers from a central plant system to the various remote evaporators located throughout the facility. This has several benefits related to the significant reduction in refrigerant charge, improved energy efficiency through the elimination of piping losses and easier mechanical integrity, all of which are reviewed in detail the following sections.

DESIGN:

1) Design Considerations:

a) **Packaged Equipment Sizing and Layout:** Applying Distributed Systems is similar to the initial steps of applying any other refrigeration systems. You start with calculating the cooling load for each room or process, then select the equipment that meets the load and facilitates good air distribution or cooling for the process. Below is an overview of the basic steps for a cold storage facility.

The load calculation for each room needs to be developed and calculated taking into consideration conduction, infiltration, product load, people, motor and lighting loads and all miscellaneous sources of heat.

Once the cooling loads are estimated for each room, the Distributed System equipment layout can be determined. This involves deciding how many units are required for each room and how best to locate them. Similar to a penthouse configuration, the key is locating the equipment such that the air can be evenly distributed throughout the facility. Obviously, the more units used per room the more expensive the installation will be. The engineer should evaluate how much air throw is feasible based on the configuration of the building and the product storage.

b) **Air Flow:** Some Distributed Systems utilize evaporators that are located in a roof-mounted penthouse while others utilize evaporators that are ceiling hung below the roof. Determining the proper distribution of air, from the evaporators and throughout a room for either of these configurations is the same undertaking as required for traditional refrigeration systems. As such, providing the necessary throw, velocity, room coverage and temperature requirements must be understood for each application.

c) **Indoor vs. Outdoor Packages:** Distributed Systems can be installed indoors or outdoors. Outdoor Distributed Systems need to be designed and rated for exterior service and/or come with exterior enclosures or paneling to weather-proof and protect the equipment and associated components. Enclosures should be designed with thought and consideration for equipment access needs and also must comply with applicable life safety codes and standards. Alternatively, Distributed Systems can be installed indoors and eliminate the need for exterior enclosures. Indoor Distributed Systems do not need an outdoor enclosure but may need to have other corresponding features integrated with the interior room or building where they reside. This may include ventilation, refrigerant detection, emergency controls, access & agrees means, lighting and material handling.

   i) **Walk-in vs. Reach-in Packages:** If the Distributed System package is installed outdoors it may come with an enclosure that is a “walk in” style unit or a ‘reach-in” style. Both are meant to protect the unit from the weather and exterior elements while also providing the required accessibility for service and maintenance. A walk-in enclosure is designed to allow operators to enter the space while reach-in is not, and operators must have access thru reach-in doors or panels. Walk-in units can be considered an occupied space if properly designed and include the life safety code requirements as mentioned at the end of the above paragraph for indoor units, or else it will be considered a confined space with restrictive entry requirements. In most instances this occupied space is considered a machinery room and therefore must have the necessary items to comply with the applicable codes and include such things as external and internal emergency safety controls, internal ventilation, refrigerant detection and required access to service components.

d) **Redundancy:** Distributed Systems can have built-in redundancy or no redundancy and determining how much redundancy is required or desired is an important part of the design basis. Depending on how each packaged unit fits the required load, how many units are needed for each area, and if any have spare capacity available, can provide definition on how much redundancy or spare capacity is available. Built-in redundancy can often be provided by dual compressors, dual evaporators and/or spare capacity within the package.

e) **System Accessibility:** Since many Distributed Systems are installed near the cooling load they often are required to be installed on the roof. Therefore, access to the roof for maintenance and service of the packaged units is an important consideration. The accessibility to packaged units, and to any of its access or service doors, will need to be considered. Also, if the unit is located near the edge of the roof, consult local codes and OSHA requirements, which may dictate railings or other safety criteria. Considerations for walkways to and around the packages should also be evaluated.

Facilities that have multiple units on the roof, stairs or a stair tower should be provided to access the roof instead of a ladder to facilitate easy and safe maintenance access. This stair structure could also be used as support for a small davit or jib hoist for maintenance purposes, and provide easy rigging of major components from the roof to the ground.

f) **Water-cooled condensing versus Air-cooled condensing:** Distributed packaged units are available in either water-cooled condensing or air-cooled condensing configurations (including adiabatic condensing). Some suppliers of the packaged units offer water-cooled, others offer air-cooled and some offer both. Selecting the appropriate method of refrigerant condensing in the packaged units, which is best suited to your application, is an important step and impacts the overall system design.

The advantage of the water-cooled system is better energy efficiency during peak ambient conditions and a lower ammonia charge. The advantage of air-cooled is it uses no water and does not required an external cooling tower or fluid cooler, nor the associated field piping. Air-cooled units also have the benefit of no water treatment systems.

The project site's design ambient Wet Bulb and Dry Bulb temperatures are needed to size and rate water-cooled packages and air-cooled packages respectively.

i) **Water Cooled:** This configuration uses externally cooled water (or glycol) to absorb the heat of rejection from the packaged unit. The externally cooled water (or glycol) can be furnished from a cooling tower or fluid cooler. The Distributed System package incorporates a heat exchanger (condenser) to transfer the heat of rejection from the compressor discharge gas to the water to condense the refrigerant vapor back to a liquid.

Cooling water supply piping is run from the cooling tower to each water cooled package and then return water piping is run back to the cooling tower. A control valve is then installed at each package to modulate the amount of cooling water needed by the water cooled condenser to maintain the desired refrigerant head pressure.

The return cooling water has sufficient heat to also be used directly or indirectly (through a heat exchanger) for underfloor warming of the warehouse, truck apron snow melt, or other purposes such as coil defrosting or reheat.

ii) **Air-cooled units:** An air cooled condenser is provided and installed on the package (or piped to it) to transfer the heat of rejection from the refrigerant condenser to the atmosphere. The advantage of this configuration is no water is required and it may be easier to install because there no external cooling tower or associated cooling water piping required. The method of compressor oil cooling must also be accounted for in the design of this type of packaged system.

The Air Cooled system may be available with an adiabatic air-precooling option. Adiabatic condensers use small amounts of water dripped over adiabatic pads, or atomized into the air, to saturate the intake air to the condenser and reduce the entering dry bulb temperature. Depending on the ambient conditions, this could facilitate energy savings during peak ambient conditions, especially in hot dry climates. Adiabatic condensers use water but significantly less water than cooling towers associated with water-cooled packages, particularly during peak ambient and peak load conditions.

g) **Refrigerant Selection:** Refrigeration selection for a Distributed System could typically be ammonia, CO2 or Halocarbon. For retrofits and expansions, it may be desired to select the same refrigerant already being utilized at the facility. Distributed Systems may allow the site to stay below a regulated refrigerant TQ, or a new refrigerant might be selected if the expansion brings the facility over the regulated TQ. Potential phase out of certain Halocarbon refrigerants due to environmental regulations should also be considered.

2) **Project Site:**

a) **Impact on Machinery Room:** A Distributed System may allow for the elimination of a central machinery room or can greatly reduce its size. Or in the case of a plant expansion, eliminate the need to expand the existing central machinery room. This is a significant advancement with this new technology because each Distributed System packaged unit typically includes the components found in the central machinery room but on a smaller scale.

b) **Property Optimization:** The elimination of the machinery room, or its reduction in size, can allow an owner to transform that space into revenue generating product storage, production or operations space. Many refrigerated warehouses have a central machinery room along the front of building taking up valuable dock space and dock doors. A Distributed System can eliminate this central machinery room and create additional dock space and more dock doors. For facility footprints that reside on limited property lines, or push up against a property line, right of way or egress, the elimination of the machinery room can also help fit the building within the constraints of the site.

c) **Crane Access:** The jobsite may need to accommodate the use of cranes to set the packaged units on the roof or ground. Some large packaged units can require large cranes to rig and set them so the jobsite logistics will need to take this into account.

d) **Environmental, Safety & Location:** The availability of water is important to understand since the Distributed units are available in either water-cooled or air-cooled designs, and can make a big difference in water usage as outlined in section 1.f) above.

The location of the site relative to it is neighbors may be a driver for Distributed Systems. Is the facility in a rural or urban area? Sites that have close neighbors, schools, churches, business or other public facilities are sensitive receptors to ammonia releases and are great candidates for the low charge Distributed System units. This design significantly helps reduce any potential ammonia release and its offsite consequences and reduces the regularity burden from agencies such as the EPA and OSHA.

3) **Retrofits**: Distributed Systems can be applied on retrofit projects. Items to be considered include: available space (square footage, and height limitations), structural, electrical, and water

capacity or related limitations. An audit of these variables should be conducted and evaluated with the understood requirements to support the Distributed System. For structural, care should be given to the point loads, live loads, and distribution of weight, not just the overall weight of the system. Penthouse units that are typically mounted on the roof may also alternatively be mounted on the ground with ducted air supply and return to and from the refrigerated space. Units providing a chilled secondary fluid (Chillers) such as chilled glycol can easily be applied to retrofits since they are not required to sit on the existing steel or be in close proximity to the cooling load.

4) **Site Utilities:**

   a) **Power and Electrical:** Typically a primary electrical panel is provided with the Distributed System package which houses the power distribution, motor starters or VFD's, safety controls and control system for the entire package. If it does not then these electrical items must be furnished separately. The typical power supply to the Distributed System package is 460 Volt, 3 phase, 60 Hz. Large facilities with many Distributed Systems need to account for electrical diversity to prevent oversizing of main service transformer.

   Since the packages are typically prewired and include the necessary starters and controls they can reduce the on-site electrical work, with each package typically only needing a single electrical feed to power the unit along with a communication cable such as Ethernet or Modbus date link for remote monitoring. Packaged units should also have an earth ground lug for grounding of the complete skid.

   b) **Controls Integration:** A local controller is typically provided with each Distributed System package. If it does not have one then the package control must be provided by others. The Distributed System setpoints, their ranges, operating parameters and package control functions should reside in this local controller. The package controller should also be capable of automatically restarting the unit after a power failure.

   Supervisory Control System: Since the overall refrigeration control system is also distributed, with a controller located within each package, the entire refrigeration system can then be monitored, supervised and/or remotely controlled by a central computer or PLC. This is accomplished by data communication wiring between the packaged units and the Supervisory computer or PLC via Ethernet or Modbus communication cable.

   c) **Water & Sewer:** The availability and cost of water, and disposal of water, is important to understand for the particular project since the Distributed units are available in either water-cooled, air-cooled or adiabatic condensing designs, which can result in large differences in water consumption as outlined in section 1.f) above. Water-cooled units require make up water to the cooling tower or fluid cooler, which then must dispose of bleed water to maintain water quality. Adiabatic units require minimal water and air-cooled require none.

5) **Building Design & Budget Coordination:** It is important to coordinate with the general contractor, architect, structural engineer and electrical engineer during the building design phase. Installing packaged systems will affect these scopes of work and can reduce building cost estimates if accounted for properly. An example of this is the elimination or reduction in

size of the central machinery room. This space can be eliminated from the project design and budgets, or perhaps converted into revenue generating storage space, additional dock doors, operating space or other purposes. Additionally, thought must be given to future building expansions and additional refrigeration needs and possible future distributed systems. A great benefit of Distributed Systems is the units can be easily added in future building construction phases, in lieu of installing extra costly infrastructure in the original building phase for future use.

Outlined below are the major building coordination scopes:

a) **Machinery Room:** A Distributed System may allow for the elimination of a central machinery room or can greatly reduce its size. In the case of a plant expansion they eliminate the need to expand the existing central machinery room. Since central machinery rooms have a long history as the basis of design for refrigerated buildings, the design team, general contractor and subcontractors must make sure to properly account for this costly building space being removed from the scope of work and budget estimate.

b) **Structural:** It is important to coordinate the building structural design with the layout of the packaged units. The package unit supplier needs to provide certified drawings of the package showing the unit weights, dimensions, required supports and attachment details. The building structural engineer can then design the necessary steel supports into the building design.

   The Distributed System package must sit level and most roofs have a slope. To accomplish this a structural frame or roof curb is typically needed that is attached (welded or bolted) to the roof steel and accounts for the slope to allow the package to be level.

   Packaged units that include the evaporator penthouse section may have supply air ducts that penetrate through the roof plane into the refrigerated space below. It is critical that the roof steel is coordinated to not interfere with the ducts. The supplier must provide drawings that shows the unit layout and location of any ducts. Using this layout, the package needs to be coordinated with the building architect or structural engineer to coordinate the location of roof bar joists and/or support steel so they are spaced such that the ducts will pass through them. Obstructions in the return air flow, back into the penthouse, must also be avoided or eliminated,

   The structural engineer will need to account for the weight of the packaged units when laying out roof structural steel. Units may require more localized support in the roof than typical stick-built installations, and this should be accounted for in the design of the building. Any future distributed systems should be accounted for at this time to ensure structure is economically designed to accommodate expanding refrigeration needs and additional distributed units.

c) **Electrical:** The electrical designer and subcontractor will not need to perform as much site electrical work because Distributed units typically come internally prewired with internal power and control wiring, including all necessary motor starters and simply need to be connected by a main power feed. Typically, internal wiring of the machine room, all evaporator motors and control value stations are included in the pre-wired Distributed System packages.

d) **Piping Headers & Insulation**: Typically the Distributed units have the necessary pipe and vessel insulation provided with the package by the manufacturer. The elimination of pipe and vessel insulation from long runs of pipe headers and large vessels can help reduce project budgets as well as reduce this mechanical integrity burden on the owner. Also, elimination of roof piping supports and stands, and reduction of associated roof maintenance can reduce project budgets and operating costs.

e) **Ammonia Diffusion Tanks:** With the significant reduction of ammonia charge, and the distributed nature of the system design, it's possible the ammonia diffusion tank(s) can be eliminated where they may be called for by local codes or the AHJ.

If architects and general contractors take the above factors into account early in the building design, they can maximize project savings. Much of above scope of work is typically not part of the refrigeration contractor's scope or budget. It is therefore necessary for the general contractor or owner to understand that the electrician's budget, insulator's budget and building construction budget can all be reduced to account for the related scopes being included in the packaged system price.

6) **Code Compliance:** Is important that the manufacturer of the packaged systems complies with all the applicable codes that govern refrigeration systems, including ASHRAE, IIAR, ASME, IBC, IMC, IFC, NEC, UL and OSHA. Many of these code requirements have been historically understood and implemented by installing contractors of field erected systems, and less understood or enforced by packaged system providers. An example of this is making sure the necessary maintenance access, working platforms and handrails, ammonia detection, ventilation, safety controls and safety relief systems are provided in conformance with the codes.

7) **Considerations for Items Not Included:** What items are not included with the Distributed System packaged units can vary greatly between suppliers so it is important to identify those items during the project development and cost estimating phase. Listed below are possible examples of items or scope that may not be included with the packaged systems:

   a) Water-cooled units: Cooling water source (cooling tower or fluid cooler), Cooling water pump, Controls for cooling tower (or fluid cooler) and pump, Field piping (and insulation) for the cooling water.
   b) Air-cooled units: Mounting or reconnection of air-cooled condenser on the package, support steel to support condenser.
   c) Condensate piping and any associated heat trace and insulation
   d) Electrical power supply
   e) Grounding of package
   f) Data communication and supervisory computer
   g) Safety showers & eye wash stations
   h) Fire protection or sprinkler system if required

8) **Submittals:** When an order is placed for packaged units the following submittals should be supplied by the packaged system manufacturer:

a) Technical Data Sheets
b) Product Specifications
c) Package General Arrangement Drawings & Details
d) Penthouse Ductwork Drawing
e) Installation Requirements
f) P & ID Drawing
g) Electrical Single Line Drawing
h) Controls Architecture Drawing
i) Communication Points List
j) Recommended Spare Parts
k) Pre-Startup Check List

9) **Permitting:** In most ways, permitting for Distributed Systems will be similar to conventional refrigeration systems. It's important to note that lower refrigerant charges may positively affect any environmental impacts and reduce mitigation through the planning phases and pre-approval of the project. Additionally, these smaller Distributed Systems may be less impactful from a sound and visual standpoint for a community – benefiting the project in reduced measures for sound and visual screening. Permitting will vary by jurisdiction; however, in most cases this can be handled as a deferred submittal for permit. Additional benefits can be a reduction in permit costs, parking requirements, etc. that are associated with additional square footage required with a central plant machine room. Lastly, it is important to get design input from the supplier at the beginning of the project as this information is integral with the corresponding designs associated with Structural, Architectural, Electrical, Plumbing and HVAC disciplines.

10) **Owner Impacts:** A summary listing of the possible owner benefits are:

a) Inherently safer technology
b) Significantly lower regulatory burden
c) Possible Lower energy usage
d) Eliminate Central Machine Room
e) Possible Faster Installation & Customer Use
f) Competitive Cost
g) Reduced Piping and Pipe Insulation/Jacketing
h) Reduce Tax Burden thru accelerated depreciation
i) Units can moved and/or transported
j) Great for phased building construction projects
k) Lower Life Cycle Costs
l) Latest Technology
m) Single Source Refrigeration System Design & Manufacturing

CONSTRUCTION:

1) **Lead Times:** Lead times can vary but generally these can be assumed to be 15-20 weeks for smaller jobs and 20-25 weeks for larger jobs. It's important to note that once equipment is approved it may be difficult to change. Adding units once the building design is done may have significant impacts on structural steel and designs already in motion.

2) **Timing:** Faster Installation of the facilities refrigeration system is possible with Distributed Systems, allowing the owner to move into the facility sooner and have quicker use of the facility to start generating revenue. This is achievable because the packaged units can be manufactured & shipped in parallel with the building construction schedule, not in a series schedule that is indicative with stick built or traditional systems that need to wait for the building to be ready to begin field fabricating the refrigeration system. This accelerated schedule is possible if the packaged units are purchased about the same time the building structural steel fabrication is released. The units can then arrive on site when the building structure is ready to support them. From this point forward there is significantly less on-site labor with the packaged units and the completion schedule can be shortened.

   The packaged units can provide a shorter installation time and can typically be commissioned much sooner than a stick built system. Factory testing of the packaged units can facilitate a quick startup. As a result, the Refrigeration Contractor is no longer the schedule's critical path of the construction project schedule.

3) **Arrival/Offloading:**

   a) Carefully inspect the unit(s) upon arrival to make certain that no damage has occurred during shipment. In order to protect the internal components of the packages system, and prevent corrosion or ingress of air or water, the units should be shipped from the factory with a low pressure nitrogen charge (approximately 10 to 15 psi). Verify the nitrogen charge is intact immediately upon arrival at the jobsite. It is required that this charge be maintained until the unit is installed and ready to be evacuated just prior to charging the refrigerant before startup.

   b) It is up to the refrigeration contractor and general contractor if the packaged units are to be off-loaded and set in a laydown area or immediately set in place. Avoiding double handling is often desired to save on crane and rigging cost and reduce the opportunity for damage. If the units are set in a laydown area it may be important to make sure they are level to avoid damage or deformation.

4) **Rigging/Setting:** The manufacturer of the packaged unit must provide a recommended rigging plan for the installing contractor to follow. The unit may need to be lifted with appropriate spreader bars to avoid damage. Make sure that the lifting chains are not in a position to damage protruding items such as door handles and control panels. If the unit is lifted in multiple sections then manufacturer must provide installation and assembly procedures.

5) **Means/Methods/Access:** Special considerations should be given for equipment delivery, and corresponding hoisting efforts to install packaged equipment. Specifically, it's important to have proper accommodations (site space, adequate crane size, and structure) to allow for installation when equipment arrives. Evaporators, ductwork, and ancillary components can be installed or staged prior to equipment arrival. Also, electrical and plumbing infrastructures can be stubbed to equipment location prior to equipment arrival.

   IIAR's new guideline ARM-LC (Ammonia Refrigerant Management – Low Charge) also recommends that suppliers of the Distributed packages provide the necessary Installation Procedures with the unit(s). This should provide complete documentation to the installing contractor and facilitates easier field work.

6) **Installation:** The supplier of the packaged units needs to provide installation instructions as recommended in IIAR's ARM-LC guideline. Typical installation steps may include:

   a) Determine unit location and orientation
   b) Ensure proper rigging and handling
   c) Rig and set unit on roof support steel, roof curb, or ground support
   d) Tie unit into building insulated roofing system (roofer) (if applicable)
   e) Hang and attach penthouse supply air ductwork (if applicable)
   f) Connect supply and return cooling water (if applicable)
   g) Mount and connect air-cooled condenser (if applicable)
   h) Connect condensate drain(s)
   i) Connect any manufacturer specified piping
   j) Connect or complete relief piping (if applicable)
   k) Connect main 460 volt power
   l) Connect communication data link and supervisory computer (if applicable)
   m) Mount any room temperature sensors
   n) Charge refrigerant and oil
   o) Start-up unit

MAINTENANCE, OPERATIONS & EFFICIENCY:

1) **Access:** See Accessibility in the Design section 1), e) and Walk-in versus Reach-in in section 1), c), i) for relevant information.

2) **Operation:** In most cases, these systems have been pre-tested at the factory and could allow for a more streamline and shorter startup. However, the site startup work should be a cooperative effort between the supplier and the installing contractor and the supplier should provide operator training to the contractor and end-user at the time of startup.
   IIAR's new guideline ARM-LC (Ammonia Refrigerant Management – Low Charge) also recommends that suppliers of the Distributed packages provide the Operating Procedures, Maintenance Procedures and a Hazard Review with the unit(s) provided. This greatly facilitates operator training and effective long term operation as a result complete documentation.

3) **Maintenance Checklist:** Similar to traditional system and as recommended by supplier. However, as mentioned above, the new ARM-LC program recommends that the supplier should provide the Maintenance Procedures and PM checklists. This eliminates the need for the owner, contractor or a third party to develop them as is the case with traditional systems.

   Distributed units may or may not include means to rig large components, such as motors and compressors, with rigging davits or monorails. If provided they can greatly simplify major repairs. If a repairs require a pump out then means and procedures may or may not be provided with the unit(s) and should be evaluated with the purchase.

4) **OEM Parts to Have On-Site:** Similar to traditional systems and as recommended by supplier. Pre-engineered Distributed Systems allow for recommended spare parts to be defined much earlier in the project schedule.

5) **Efficiencies:** Distributed System packaged units can eliminate the energy-consuming piping pressure drops from the long piping runs common with traditional systems (not to mention eliminating the long term cost of maintaining the insulated roof from damage that can be caused by the extensive roof piping systems). Typical piping runs for stick built systems can add up to 3° to 5°F (and higher) equivalent system pressure losses, making the central machine room compressors operate at lower suction temperatures to overcome the losses and can consume more energy as a result.

   Distributed System packages allow the refrigerant suction temperatures to be matched continuously to each individual room temperature, allowing each room to operate as efficient as it can, versus a traditional central plant system that is typically limited to only 2 or 3 "house suction" temperatures, which serve many rooms and many room temperatures.

   Distributed units commonly have variable speed drives included as standard for compressor control, allowing this primary energy user to operate very efficiently. The smaller compressor motors in Distributed Systems, versus central plant motors, allow VFD's to be more common and cost effectively applied. VFD's are also typically provided with the evaporator fans and condenser fans as well.

   All of the above provide the ability for a facility to have a supervisory control system that provides complete energy management at the point of use. Built-in software available in some Distributive Systems, in conjunction with a supervisory control system, can provide very efficient energy management.

6) **Life Span:** Life span may vary depending on system design, commercial vs. industrial, etc. but should be comparable with stick-built systems at 20 to 30 years.

7) **Warranty:** Warranty to be as defined by the supplier. Note the advantage of having a single source supplier of the Distributed units that provides a package warranty that covers all of the multiple internal components. This can simply warranty claims.

APPENDIX

PROS & CONS OF DISTRIBUTED LOW CHARGE REFRIGERATION SYSTEMS VERSUS TRADITIONAL CENTRAL PLANT SYSTEMS		
CATEGORY & SCOPE	**PRO**	**CON**
Design Considerations		
Engineering	Pre-engineering can make design process easier and quicker	Finite number of models and solutions
Facility Layout	Eliminates central machine room and interdependency between central machine room and room being cooled	Some end-users may prefer a central machine room
Cooling coils in refrigerated space	Solution may use penthouse(s) with cooling coils inside the penthouse, which provide several benefits	Penthouse itself adds cost as compared to ceiling hung coils
Redundancy	Can have redundant units or redundant components in units. Each room can be evaluated for redundancy requirements.	Central plant system may be easier to have backup or swing compressors and condensers
Accessibility	May be roof mounted which can free up other building spaces	Access to roof needed & related maintenance access
Structural	Can be qualified early in design development	May have heavier roof structural load
Condensing design	Water-cooled, Air-cooled & Adiabatic all available	Traditional evaporative condensing not available
Refrigerant Selection	Ammonia, C02 and also some Freon systems available	Ammonia and CO2 systems may have higher first cost than Freon systems
Project Site		
Space	Eliminates space required for central machine room and frees up this area for other purposes	Units on roof may be visible on roof
Machinery Room	Saves cost of constructing central machine room. Machine room is also pre-tested.	Must service multiple packaged machine rooms

CATEGORY & SCOPE	PRO	CON
Crane Access	Setting units can occur as soon as building steel ready	Larger crane needed
Environmental	Lower environmental risk and lower off site consequences	None
Retrofits	Packaged systems or chiller packages may be easier or more cost effective then adding or expanding a central plant system	Installing roof top units on existing roof structure may be difficult or cost prohibitive
Site Utilities		
Power & Electrical	Less site electrical design and field scope of work and may be lower electrical cost because units are prewired	Large Distributed Systems with many packages need to account for electrical diversity to prevent oversizing of main service transformer
Controls Integration	Automation built in to packaged units	Customization may be added cost
Water Usage	Packaged units available in water-cooled, air-cooled & adiabatic condensing which can eliminate or greatly reduce water usage	None
Project Coordination		
Scope Coordination	Pre-engineered Distributed units allow for early definition of the refrigeration system design	Requires changes to traditional building design be done earlier such as structural and electrical
Code Compliance	Easier to enforce due to obligation of manufacturer's design to comply	Customization or international compliance may add cost
Items not included	Can be defined early	Scope must be defined for packaged units
Submittals	Typically available sooner	Customization may take longer
Permitting	Pre-engineering & Inherently Safe designs may make permitting easier	Need to make sure packaged units comply with relevant codes

CATEGORY & SCOPE	PRO	CON
Construction & Installation		
Schedule	Can shorten construction schedule	Packaged units may need to be ordered when building steel fabrication is released
Arrival/Offloading	Enclosed packages more protected from weather & elements	Roof top units may need to go right to roof upon arrival to avoid double handling
Rigging & Setting	Rigging plans readily available	Larger cranes required than typical equipment
Installation	Significantly less onsite labor and time to install	Adding unforeseen scope changes may be more difficult to accommodate
Startup & Commissioning	Much quicker and easier due to factory testing	May rely more on manufacturer
Training	Easier & effective due to complete documentation	May rely more on manufacturer
Maintenance, Service & Operation		
Access	Penthouse units will have control valve stations indoors instead of outdoors	May be more trips to the roof
Operation	Can be unattended and remote monitored, training easier.	May have more (but smaller) compressors than central system
Maintenance	Good documentation & procedures provided, training easier	May have more (but smaller) compressors than central system
Mechanical Integrity	Can eliminate large amounts of refrigerant piping, pipe insulation & pipe supports, and provide smaller compressors, motors and vessels	May have more (but smaller) compressors & vessels than central system
Documentation	More provided by manufacturers	May rely more on manufacturer
Impact on building	Less roof piping, pipe support stands, pipe insulation and less roof maintenance	High importance of roof access to units

CATEGORY & SCOPE	PRO	CON
Efficiency	Can have lower energy consumption than central system due to elimination of pipe headers, being able to have a suction level associated with every room temperature and the high use of VFD's.	Needs to be evaluated based on site conditions
Life span	20 to 30 year life span and also better than commercial equipment	Future retrofit options for packaged equipment should be defined
Warranty	Single source system supplier can make warranty claims easier	may vary by supplier