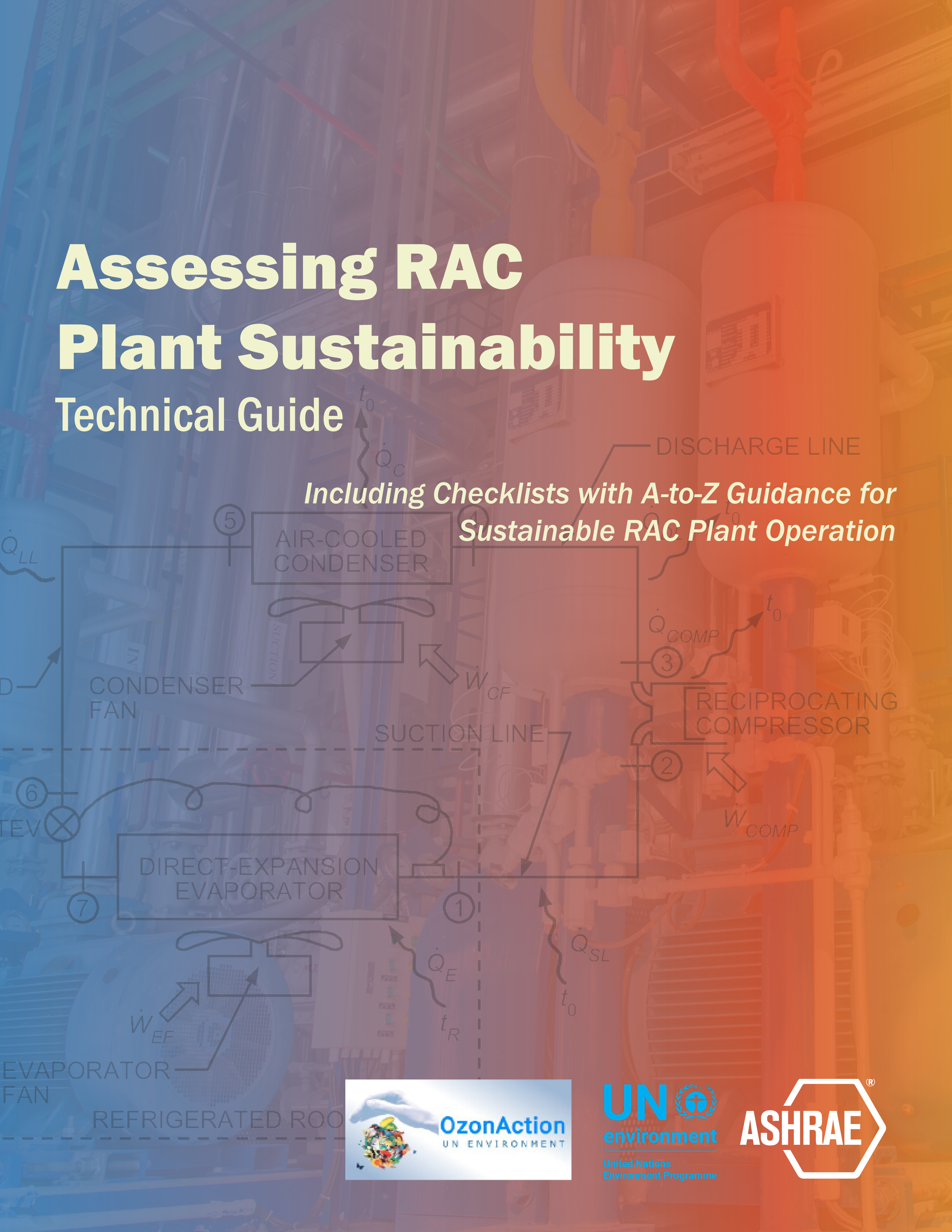
Assessing RAC Plant Sustainability

Technical Guide

Including Checklists with A-to-Z Guidance for Sustainable RAC Plant Operation



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CONTENTS

OVERVIEW

Assessing RAC Plant Sustainability is a technical guide that provides valuable insights and best practices for the sustainable and efficient operation of refrigeration and air-conditioning (RAC) plants. This summary provides an overview of the document's key points and areas of focus.

This guide enables technicians and managers to assess sustainability practices and implement improvements where needed. It is structured to provide succinct guidance in an easy-to-follow format.

Dimensions of Practice Guidance Sheets: The guide covers the key dimensions of practice related to RAC plant sustainability in Guidance Sheets. These guidance sheets address each dimension of practice, providing detailed information, recommendations, and additional resources.

1. Safe Storage and Proper Handling of Refrigerants
2. Periodic Leak Checking and Proper Documentation
3. Preventive Maintenance of Equipment
4. Preventive Maintenance of Automatic Controls
5. Energy-Efficient Operation
6. Proper Commissioning and Recommissioning Practices
7. Proper Disposal of Equipment and Refrigerant
8. Competencies of Operating and Service Personnel

An annex covers requirements for tools and servicing.

Mindset: An important element of the guide is establishing a set of attitudes that will help operators and managers achieve a facility that operates sustainably. The needed mindset is identified at the beginning of each guidance sheet.

Operation & Maintenance (O&M) Best Practice Checklists: O&M best practice checklists for each dimension of practice serve as practical tools for technicians to assess and implement the recommended practices in their day-to-day operations.

Measures of Success: How does a technician or plant manager know if the changes are leading to improvement? Each checklist identifies measures of success, which puts the focus of the activity on outcomes.

Preventive Maintenance: A section on preventive maintenance emphasizes the significance of regular inspections and upkeep of RAC equipment.

Tools and Servicing: The guide reinforces the importance of using proper tools and equipment during the installation, maintenance, repair, and decommissioning of equipment. It highlights the significance of efficiency, speed, and performance in achieving the desired outcomes.

Additional Resources: The guide provides additional resources for each dimension of practice that can further enhance the understanding and implementation of sustainable practices. These resources offer a comprehensive collection of reference materials. Some resources listed are available at no cost, for instance, from UNEP.

Local Laws and Regulations: The guide acknowledges that regional or local labor and environmental laws or regulations may mandate specific tools and equipment usage. It is the responsibility of the client and/or contractor to adhere to these rules and regulations.

In conclusion, *Assessing RAC Plant Sustainability* serves as a resource for technicians, plant managers, and other professionals involved in the operation and maintenance of RAC plants. By following the guidance and best practices outlined in this document, users can ensure the efficient, safe, and environmentally friendly operation of RAC equipment. The inclusion of checklists and additional resources makes it an invaluable tool for promoting sustainability in the RAC sector.

Assessing RAC Plant Sustainability was developed by ASHRAE under a partnership agreement with the United Nations Environment Programme (UNEP) OzonAction.

Founded in 1894, ASHRAE is a global society of professionals organized to advance the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields in the service of humanity. Its members are dedicated to promoting a healthy and sustainable built environment for all through strategic partnerships with organizations in the HVAC&R community and across related industries.

UN Environment Programme is an Implementing Agency of the Multilateral Fund of the Montreal Protocol on Substances that Deplete the Ozone Layer. OzonAction strengthens the capacity of governments—particularly the operational focal points known as National Ozone Units—and industry in developing countries to elaborate and enforce the policies required to implement the Protocol and to make informed decisions about alternative technologies. Its overall goal is to enable those countries to meet and sustain their compliance obligations under the treaty.

BACKGROUND

At the 2017 ASHRAE Winter Conference, the UN Environment Programme (UNEP) and ASHRAE launched their Biennium Joint Work Plan of 2017–2018, “Working Beyond High-GWP Refrigerants.” One of the plan’s main elements was to develop an assessment program for the sustainable operation and maintenance of refrigeration and air-conditioning (RAC) plants.

There are several national programs for certifying field technicians—many of which focus on refrigerant management. UNEP and the Air-Conditioning, Heating, Refrigeration Institute (AHRI) currently have a joint initiative to offer a globally accepted qualification program that sets minimum requirements for the management of refrigerants through the supply chain network and its relevant operations. Known as the Refrigerant Driving License (RDL), www.RDLprogram.org, it is intended to be an industry-driven refrigeration management program. The RDL does not intend to overrule any existing relevant governmental certification scheme. Still, it can offer a structured framework for developing countries without a similar certification program.

The value of qualification programs is critical as low global warming potential (GWP) alternatives become available to the market. Many of these solutions have flammability concerns, and compliance with safe-handling practices is necessary to eliminate risks to humans and property. Environmental regulations also mandate increased tracking and reporting of refrigerant inventory and system leakage.

While the value of the RDL cannot be understated, it is important to understand its limitations. It focuses on the practices of the service technician. In many situations, a knowledge gap exists in how to operate and maintain refrigeration and air-conditioning plants/systems, especially medium- and large-scale ones, in a sustainable, efficient, and safe manner.

Assessing RAC Plant Sustainability fills this gap by being an international reference for the safe and sustainable operation and maintenance of air-conditioning and refrigeration plants, with a special focus on developing markets, and that compliance to these practices can be verified through a point-based qualification or verification scheme.

To develop the guide, ASHRAE assembled a committee of experts in the field to formulate a work plan targeting the subject areas to be covered. They wrote a scoping document that identified the dimensions of practice that need to be addressed, the mindsets needed to execute successful sustainability plans, and checklists of what actions should be taken. An ASHRAE Multidisciplinary Task Group (MTG) involved additional experts to select authors for the guide and to review their progress.

USER TARGETS

Assessing RAC Plant Sustainability enables refrigeration and air-conditioning (RAC) installations to achieve efficient, sustainable performance. The guide's value is critical as low-GWP alternatives become available to the market. Many of these solutions have flammability concerns, and compliance with safe-handling practices is necessary to eliminate risks to humans and property. Regulations also mandate increased tracking and reporting of refrigerant inventory and system leakage.

The primary target group for the guide are service technicians and plant operating managers. Content has been developed to communicate effectively with them and present guidance in the form of checklists that can be easily implemented and referred to in the workplace.

For the guide to achieve its desired impact, however, RAC plant owners should also refer to the guide to learn:

- ways of achieving reductions in refrigerant emissions as well as reductions in energy use,
- methods for documenting refrigerant compliance, and
- how to reduce operating costs, improve uptime, and lower service/maintenance expenses.

Governments can benefit from the guide because it can be a model for establishing requirements and compliance paths for refrigerant emission reductions and reduced energy consumption. Sections of the guide can also provide the basis for safety and sustainability regulations.

RAC equipment suppliers can serve as a distribution channel for the guide, making information available that promotes efficient RAC plant design. Better performing equipment rooms are characterized by more efficient equipment, and this guide can help owners select the competencies that lead to the best performing projects among a wide diversity of options.

The value of *Assessing RAC Plant Sustainability* lies in the potential to close knowledge gaps among operators, managers, owners, and policymakers in how to operate and maintain RAC plants and systems in a sustainable, efficient, and safe manner.

ACKNOWLEDGMENTS

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Operation & Maintenance Guidance Sheet

1

Safe Storage and Proper Handling of Refrigerants

Mindset: Refrigerant is an asset and not a consumable.

INTRODUCTION

A refrigerant is a chemical used for heat transfer in a refrigeration system. Refrigerants absorb heat at a low temperature and low pressure and transfer heat at a higher temperature and a higher pressure. The heat transfer process usually involves state changes in the fluid. Refrigerants are an asset and not a consumable.

Although it is a key substance used in the refrigeration and air-conditioning industry, refrigerants can be harmful to humans and the environment. Technicians can prevent injuries and costly mistakes by consistently following defined procedures and using common sense when handling refrigerants.

Technicians must take extreme care to avoid direct ingestion of refrigerant vapors. Refrigerants are heavier than air and will replace air in a confined space. This situation can lead to possible asphyxiation for anyone working in the space. Oxygen starvation is the leading cause of death in accidents involving a refrigerant. If a spill occurs, they must put on a self-contained breathing apparatus or evacuate the area until it has been properly ventilated.

Refrigerants are shipped and stored in pressurized cylinders. Careless cylinder handling can result in sudden refrigerant releases, which can cause frostbite, skin damage, or blindness. To avoid these circumstances, workers should wear safety glasses with side shields or a full-face shield, safety shoes, a hard hat, long pants, gloves, and a long-sleeved shirt.

Disposable cylinders are constructed of common steel, which can oxidize and become weakened by rust. As a result, cylinder walls and seams can no longer tolerate pressure or contain gases. Refillable cylinders must be retested and recertified every five years, and the test date must be stamped on the cylinder shoulder. Retesting by visual inspection alone is not permitted. Technicians should discard rusted containers and never use them for recovery or refilling. To prevent cylinder corrosion, technicians should store containers in dry locations.

Further information on proper leaking checking can be found in O&M Guidance Sheet 2, “Periodic Leak Checking and Proper Documentation.”

ADDITIONAL INFORMATION AND RESOURCES

- ANSI/ASHRAE 15-2022 has Section 7 on leak detection and ventilation of machine rooms and Section 10 on general requirements and storage and handling of refrigerants.
- ANSI/ASHRAE 34-2022 has lists of refrigerants and their safety classifications.
- ASHRAE Guideline 6-2015 has additional information on refrigerant properties and definitions of terms associated with refrigerants.
- Material safety data sheets (MSDSs) provide information on shipping, storage, and handling of specific refrigerants/secondary fluids (SFs or secondary refrigerants like glycol, brine, or even CO_2).
- Refer to ASHRAE Standards 34 and 15; ISO 817 and ISO 5149 Parts 1, 2, 3, and 4; EN 378; and IEC 60335-2-40 and IEC 60335-2-89.

The above list is not exclusive to all possible references on this topic.

O&M Best Practice Checklist

1

Safe Storage and Proper Handling of Refrigerants

OBJECTIVE

Minimize the environmental impact of refrigerants, protect workers, and ensure efficient equipment operation.

MEASURE OF SUCCESS

- ✓ No environmental incidents, safety incidents, or refrigerant leakage during storage and handling of refrigerants and secondary fluids.

Topic	Actions	Notes
A. Refrigerant Storage	*Proper personal protective equipment (PPE), inspected and certified packaging and storage equipment, as well as other environmental considerations, are necessary to prevent careless handling and harmful refrigerant releases to the environment.*	
	☐ Storage safety signs are posted in accordance with GHS symbols (Globally Harmonized System of Classification and Labelling of Chemicals).	
	☐ Fire suppressants are located near refrigerant storage.	
	☐ Refrigerant leak detectors are installed and operating.	
	☐ Storage room ventilation is functional and provides adequate air exchange.	
	☐ Storage location is secure and inaccessible to unauthorized personnel.	
	☐ Separate storage is used for oxygen, nitrogen, and acetylene tanks.	

Topic	Actions	Notes
B. Packaging Guidelines	*A wide range of packaging equipment can be used to package and store various types of refrigerants from bulk storage containers into small packages. Packaging equipment guidelines are as follows:*	
	☐ Ensure that refrigerant packaging equipment has the proper safety classification, is in a properly classified location, and has adequate ventilation.	
	☐ Ensure all materials (e.g., gaskets, O-rings, hoses, etc.) used in packaging equipment are compatible with the specific refrigerant.	
	☐ Do not use thread-locking agents incompatible with the specific refrigerant in packaging equipment and/or cylinder valve attachment. Ensure that equipment packagers and cylinder manufacturers do not use thread-locking agents that cause product degradation.	
	☐ Inspect refrigerant charging lines to ensure they have been thoroughly prepared and cleaned and do not introduce contaminants into cylinders.	
	☐ Use a handheld leak detector to confirm refrigerant charging lines are leak-free and can properly pull the desired vacuum level during operation.	
	☐ Ensure refrigerant charging equipment or the operator properly closes the valve or installs safety seals (i.e., shrink sleeves) after properly filling and closing valves.	
	☐ Do not repackage refrigerant into cylinders with leaking valves or where the valve has been left open.	
	☐ Ensure cylinders used for packaging various types of refrigerants are clean and properly prepared for packing the refrigerant.	
	☐ Do not fill refrigerant into the cylinders with excessive amounts of air or moisture.	
	☐ Cylinders have proper relief valve (RV) design and pressure rating for refrigerant being packaged.	
	☐ Do not overfill cylinders. Do not refill disposable cylinders.	

Topic	Actions	Notes
	☐ A safety seal (i.e., shrink sleeve) or cylinder dust cap is installed on the full cylinders.	
	☐ Cylinders are stored upright and firmly secured to prevent falling or being knocked over.	
	☐ Store cylinder at no greater than 52°C (125°F). Temperature should be below 50°C (122°F) for cylinders with less than 80% fill capacity and 60% fill capacity if above 50°C.	
	☐ Separate full cylinders from empty cylinders.	
	☐ Cylinders are properly labeled with refrigerant type and marked if it has been used and recovered.	
	☐ Store cylinders in a cool, well-ventilated place away from direct sunlight.	
	☐ Do not store cylinders in areas where salt or other corrosive materials are present.	
	☐ Do not store cylinders near combustible materials.	
	☐ Store cylinders in accordance with local or national requirements.	
	☐ Elevate cylinders away from possible flood areas.	
C. Storage Lines	*Refrigerant bought in bulk must be transferred to a bulk storage tank before being used in the packaging or manufacturing process. Good storage practices ensure that incoming refrigerant will maintain its quality throughout the product packaging, transferring, or manufacturing process.*	
	☐ Inspect, verify, and log bulk refrigerant inventory at delivery.	
	☐ Ensure storage tanks and transfer lines are clean before working with refrigerant.	
	☐ Storage tanks and lines are dry before transferring refrigerant into them. Purge the tank and lines with dry nitrogen (99.99% purity).	
	☐ Storage tanks and lines are evacuated to at least 5000 µm or less vacuum prior to filling with refrigerant.	

Topic	Actions	Notes
D. Environmental Considerations	*Care must be taken to ensure the safe use and storage of refrigerants. Accidental release of refrigerant into the environment can be* prevented *by following these actions.*	
	☐ Do not repackage refrigerant into cylinders with a leaking valve or where the valve has been left open. Minute levels of rust or dirt within the package can negatively impact product quality. Therefore, properly cleaning compromised cylinders will be critical to ensure quality products after replacing leaking valves.	
	☐ Refillable cylinders are retested and recertified every five years, and the test date is stamped on the cylinder shoulder.	

Operation & Maintenance Guidance Sheet

2

Periodic Leak Checking and Proper Documentation

Mindset: No leak is acceptable. The goal should be zero.

General Information

Refrigerant air-conditioning (RAC) systems are designed to operate adequately with a fixed charge of refrigerant. If it has been determined that a system has insufficient refrigerant, the system must be checked for leaks, then repaired and recharged.

Refrigerant leaks are caused by material failures, which are normally attributed to one or more of the following factors:

- **Vibration:** Vibration is a significant factor in material failure and is responsible for the "work hardening" of copper, misalignment of seals, loosening of securing bolts to flanges, etc.
- **Pressure changes:** Refrigeration systems depend on the changes in pressure for their operation. The rate of pressure change has different effects on the various components in the system, resulting in material stress and differential expansion and contraction.
- **Temperature changes:** Refrigeration systems frequently consist of different materials of differing thicknesses. Rapid temperature changes result in material stress and differential expansion and contraction.
- **Frictional wear:** There are many cases of frictional wear causing material failure, varying from poorly fixed pipework to shaft seals.
- **Incorrect material selection:** In some cases, inappropriate materials are selected (for example, certain types of flexible hoses have a known leakage rate), and materials that are known to fail under

conditions of vibration and transient pressure and temperature changes are used.

- **Poor quality control:** Unless the materials used in the refrigeration system are of a high and consistent standard, changes in vibration, pressure, and temperature will cause failure.
- **Poor connections:** Poorly made connections, either brazed joints, screwed connections, or not replacing caps on valves, can allow refrigerant to escape.
- **Corrosion:** Exposure to a variety of chemicals or weathering can result in a variety of different corrosion modes, which decays the construction material, resulting in the eventual creation of holes.
- **Accidental damage:** Accidental mechanical impacts to refrigerant-containing parts can happen under many circumstances; therefore, it is appropriate to ensure that all system parts are protected against external impacts.

Building designers, installers, and service and maintenance technicians should be aware of these potential hazards and always check to see if any are occurring or leading to leakage whenever possible.

Technicians have an important role in preventing refrigerant emissions as well as making the operation of RAC systems as energy efficient as possible. This can only be achieved by adopting good service practices. A technician should be proficient in the following servicing operations:

- Leak detection, purging, and evacuation
- Charging refrigerants
- Identifying the servicing-specific tubing tools and techniques of sizing, unrolling, cutting, bending, flaring, swaging, piercing, pinching, and welding
- Identifying the proper use of servicing instruments, such as manifold gages, charging scales, and thermometers

Technicians should be trained to understand the main causes of operational problems and how to avoid them by adopting good practices and being aware of the main precautions to take when servicing installations and systems.

The methods and techniques used when working on systems, primarily during servicing exercises, are important. This includes consideration of system cleanliness (moisture, acid, noncondensables) and the means for overcoming operational problems, such as proper evacuation methods and system purging. Avoiding such issues first demands appropriate procedures associated with tightness testing (“leak testing”) and refrigerant charging.

ADDITIONAL INFORMATION AND RESOURCES

- ACRIB: The UK Umbrella Body for the Refrigeration, Air Conditioning and Heat Pump Industry Associations and Institutions. *Technical Guidance*. https://acrib.org.uk/help-and-advice/technical-guidance.
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O&M Best Practice Checklist

2

Periodic Leak Checking and Proper Documentation

OBJECTIVE

Identify target leak rates for various types of RAC equipment.

MEASURE OF SUCCESS

✓ Systems are well maintained by proactively checking for, repairing, and documenting leaks while driving toward zero-leak systems.

Topic	Actions	Notes
E. Direct Systems	*The following actions are required to be performed.*	
	☐ Perform regular leak checks as follows: • Self-contained: yearly • Field erected < 20 HP: Semiannually • Field erected > 20 HP: Quarterly • All systems: Leak alarm actuated	
	☐ Properly document leak checks in the daily maintenance log, including the date, specific location, repair method, and amount of refrigerant replaced.	
	☐ Leaks were properly repaired, and the refrigerant used documented.	
	☐ Report leaks as required by regulations.	
	☐ Install leak detection sensors in appropriate locations.	
	☐ Follow protocols for leak detection of flammable and/or toxic refrigerants.	

Topic	Actions	Notes
F. Indirect Systems	*Covering centralized systems typically use air-cooled or water-cooled chillers, heat recovery chillers, heat pumps, absorption chillers, or other types of equipment. Each of the following checks is to be recorded in the daily log.*	
	☐ Meet all requirements for direct systems.	
Monthly		
	☐ Check anticorrosion additive monthly.	
	☐ Check sacrificial anodes for wear monthly.	
Every Three Months		
	☐ Analyze lithium bromide (LiBr) solution for steel or copper deposits every three months.	
	☐ Check heat recovery heat exchanger for corrosion every three months.	
Every Five Years		
	☐ Check heat exchanger tubes for leaks every five years using eddy current test.	

ANSI/ASHRAE Standard 147 gives complete guidance on leak rates and repair techniques.

Operation & Maintenance Guidance Sheet

3

Preventive Maintenance of Equipment

Mindset: Proactive vs. Reactive.

General Information

To maximize equipment service life, the equipment must receive proactive planned maintenance via one of the following three preventive maintenance (PM) methods:

- **Scheduled PM.** Scheduled PM aims to catch and fix problems before they happen. Using PM work orders, the process is carried out through regularly scheduled inspections, usually occurring multiple times per year. The primary benefit of scheduled PM is that it can eliminate unplanned maintenance from unscheduled equipment failure, avoiding problems before they occur.
- **Predictive PM.** More proactive than the PM work order system, predictive PM is an advanced alternative to scheduled PM, usually using computer-aided monitoring. In lieu of inspections and scheduled PM, machines and systems are carefully observed for changes that could indicate upcoming failure via automation (e.g., vibration monitor and alarm). A PM work order is then scheduled to correct the mechanical and/or electrical problem.
- **Unscheduled PM.** Unscheduled PM is initiated when a problem is discovered via equipment failure or possibly by observing equipment not operating as it should. A PM work order will be scheduled and issued to correct the mechanical and/or electrical problem.

There are other PM designations, such as condition-based, predetermined maintenance, etc., but these three categories define planned, predictive, and unscheduled maintenance.

This guidance sheet addresses preventive/planned maintenance, whether scheduled via a work order system or unscheduled emergency work order response. Predictive maintenance is addressed further in Guidance Sheet 4, “Preventive Maintenance of Automatic Controls.”

While there is a maintenance standard for commercial refrigeration equipment (ANSI/ACCA 14-2021, *Quality Maintenance of Commercial Refrigeration Systems),* most maintenance recommendations and/or requirements come from equipment manufacturers. These requirements can be very conservative, placing the responsibility on building owners to determine the labor hours that will be financially committed annually to maintaining their equipment. There are companies who are in the business of providing PM work orders, with each having its own computerized maintenance management software (CMMS) system.

This guidance sheet is intended to mirror organizations like the *Whole Building Design Guide* philosophy that the development of a maintenance program is often predicated on the organization’s operations and maintenance capabilities. The goals of a comprehensive maintenance program are to

- reduce capital repairs;
- reduce unscheduled shutdowns and repairs;
- extend equipment life, thereby extending facility life and assisting in the budgeting of replacement as equipment nears the end of useful life;
- realize life-cycle cost savings;
- provide safe, functional systems and facilities that meet the design intent; and
- provide comprehensive documentation of repair history, leak checking, proper disposal activities (fluids and equipment), and compliance with local safety reporting requirements.

OBJECTIVE

The objective is that PM work will be performed by individuals trained to maintain the equipment and that this work be completed safely. In creating the suggested PM work orders within this guidance sheet, each work order begins with the following:

- Reminding the technician to prepare to start the PM work safely,
- Performing the PM work tasks in a safe environment,
- Completing each work order safely, and
- Documenting the results on the work order form.

Each work order should have an equipment name assigned to it, along with its location inside or outside the building. There should be special instructions included that highlight the following:

- Instructions on how to access the equipment manufacturer's operation and maintenance (O&M) manual, equipment startup and shutdown documents, and any emergency plan instructions pertaining to the equipment.
- Safety instructions, e.g., lockout-tagout instructions, safety glasses, etc.
- Tools required to access and service the equipment, e.g., ¼-inch Allen wrench, etc.
- Required materials, lubricants, etc. (e.g., correct filter replacement size)
- Work orders will have the suggested tasks to be performed along with the required frequency of the particular task, e.g., monthly, quarterly, etc.

The suggested PM work orders found in this guidance sheet are standardized checklists for a maintenance technician to use to complete the work and should be edited for the specific piece of equipment on site. For example, one piece of equipment may be located on the floor and be visible and easily accessible, while a similar piece of equipment may be concealed above a ceiling, requiring a ladder of a specific height. Other work orders may require two technicians to perform the work, which should be added to the PM work order document.

When the PM work is completed, the technician performing the service work must sign and date the PM work order and return it to their supervisor and/or customer, either stating the work has been completed or completed to a point. If the PM work is incomplete, a notation citing that "a part(s) and/or certain material request" has been submitted, with the remaining PM work to be completed once the part or material has been received.

BEST PRACTICES

The technician should be provided with the expectation of performance based on the original design of the equipment.

It also has been proven time and time again that standardized PM work orders are a quality-control tool whether it is to improve a business, complete a task, or problem-solve. Actual PM work orders are located at the conclusion of this guidance sheet. The final PM work orders the technician will create should include recommended practices based on the region the equipment is located and should be edited for the specific piece of equipment by the technician on site.

These work orders will be continuously improved based on feedback, for example, from the maintenance technician.

In addition to identifying standards and required competencies to perform the PM, these work orders will need to be edited by the end-user to include the needed tools and supplies required for the PM work, in addition to making the O&M manual associated with the piece of equipment readily available.

The goals of PM are:

- Understanding refrigerants are an asset and not a consumable.
- Protecting the environment, worker, and community safety in compliance with local requirements.
- Educating maintenance technicians on pertinent components that require service, repair, and/or replacement by using PM work orders and continuously improving these documents.
- Maximizing the useful service life of equipment by using PM work orders that set recommended equipment maintenance timelines to enhance both equipment and system efficiency.

PM Work Orders

The PM work orders included in this guidance sheet are intended to be in an easy-to-use format with support documentation that has heavily illustrated guidance and minimum text. Each equipment-specific work order will be generic, requiring editing by the technician to accommodate location and application-specific guidance.

These work orders cover PM activities for direct equipment and indirect equipment.

Direct Equipment (systems in direct contact with the conditioned space):

- Air-cooled split system:
  - condenser unit and evaporator coil air-handler with/without electric heating coil
  - condenser unit and evaporator coil air-handler with/without gas heating coil
  - condenser unit and evaporator coil air-handler with oil heat unit
- Air-cooled packaged system:
  - condenser unit and evaporator coil air-handler with/without electric heating coil
  - condenser unit and evaporator coil air-handler with/without gas heating coiling
  - condenser unit and evaporator coil air-handler with oil heat unit
- Air-cooled split heat pump system
  - condenser unit and evaporator coil air-handler and heating coil
- Air-cooled packaged heat pump system
  - condenser unit and evaporator coil air-handler and heating coil
- Water-cooled split system
  - condenser unit and evaporator coil air-handler with/without heating coil
- Water-cooled packaged system
  - condenser unit and evaporator coil air-handler with/without heating coil
- Outdoor air-handler system
  - condenser unit and evaporator coil with/without energy recovery unit, electric heat, or gas heat coil(s)

- Outdoor air-handler heat pump system
    - condenser unit and heating-cooling coil with/without energy recovery unit
- Dedicated outdoor air systems (DOASs)
    - condenser unit and evaporator coil with/without energy recovery unit, electric heat, or gas heat coil(s)

Note: Covers single-unit residential splits, mini-splits, through-the-window AC units, spot coolers, supermarket distributed systems, and direct-fired boilers.

Indirect Equipment (systems cool a secondary fluid, e.g., building chilled-water loop, process cooling loop, etc.):

- Air-cooled chillers
- Water-cooled chillers
- Heat recovery chillers
- Absorption chiller
- Heat pumps

VRF AIR-CONDITIONING UNIT PREVENTIVE MAINTENANCE

This section describes equipment preventive maintenance as an example of preventive maintenance. It is essential all equipment receive proactive planned maintenance.

A variable refrigerant flow (VRF) system is an air-conditioning system designed for a building with multiple indoor units connected to a single outdoor condensing unit, either with a comfort cooling, heat pump, or heat recovery system. It is a larger version of a multi-split-type unit wherein two or more indoor units are in different rooms and use a single- or dual-condensing unit.

Modern VRF systems provide some major advantages, such as zoning, individual temperature control, minimized ductwork, excluding the need for secondary fluids (chilled-water or hot-water distribution), and associated costs. Reduced energy costs can also be realized when using digital or inverter-driven compressors that more closely match the load.

This all-electric technology consists of a single outdoor condensing unit, multiple indoor units serving various zones, refrigerant piping with branch selectors, and associated controls. Periodic maintenance with this kind of unit is essential to keep it effective and efficient.

Before carrying out any maintenance (for VRF systems or not), always disconnect the power supply by taking the plug out from the socket or turning off the circuit breaker. Where the power source is inside and the unit is outside and/or not in view of the electrical panel serving the AC unit, lockout-tagout procedures must be applied.

VRF PM Preparation

Tools and Materials. The following tools and materials are required for VRF PM.

- Screwdrivers
- Pliers
- Wrenches
- Pressure washer
- Vacuum cleaner
- Pail/drum

- Rugs and neutral soap
- Non-acidic coil cleaner
- Thermometer
- Gage manifold
- Multi-tester
- Clamp ammeter

Scheduling and Human Resources. The following tables includes the scope, frequency, and condition of the area to be cleaned and the human resources required to complete the PM.

Scheduling

Scope	Frequency	Condition
Filter cleaning	Weekly	Area exposed to dirt
Filter cleaning	Monthly	Clean area such as an office
General cleaning	Semiannually	Operation less than eight hours
General cleaning	Quarterly	Operation more than eight hours
Retightening	Semiannually	Regular routine

Suggested Human Resources

VRF Type	Staff Hours Required
Wall	1
Ceiling mounted	1.5
Cassette	2
Ducted	3

Preventive Maintenance Tasks

Checking Parameter. Check the current performance parameters of the VRF system prior to starting any VRF PM.

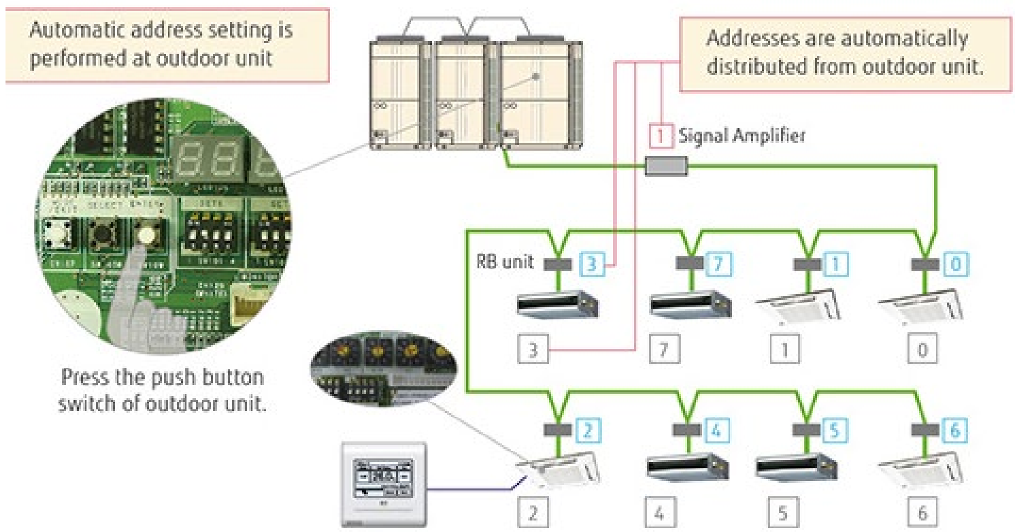
The information on the equipment's Start-Up Data Sheet (SUDS) for a VRF system can be used to compare the current actual parameter reading. SUDSs serve as the data parameter reference of the VRF system.

There are two ways to check VRF performance: manually or using the check button.

Manual Flow Check

1. **Outdoor** = current → voltage → air-cooled condensing unit (ACCU) air → outdoor temperature (°C) → indoor temperature (°C)

   Indoor = pipe temperature (°C) → fan coil unit (FCU) air indoor temperature (°C) → FCU air outlet temperature (°C) → Remote control
2. **Check Button.** The check button is generally located on the control board and can be used to verify operating parameters of the unit. Consult the original equipment manufacturer's (OEM) manual for specific check button instructions and factory-operating parameters.



Sequence	System Operation Parameters	Remarks
1^{st}	This outdoor unit address	0, 1, 2, 3, 4, 5
2^{nd}	This unit outdoor capacity	8 HP, 10 HP, 12 HP, 14 HP...
3^{rd}		

Test Settings

Parameter	Settings
Mode	Cool
Thermostat	17°C (63°F)
Fan speed	High

3. **Communicate.** Communicate with the controller via a direct wired connected or Bluetooth device connected via a smart phone, tablet, or laptop.

General Cleaning

Filter Cleaning

Follow the procedure indicated in the OEM's manual when removing the filter of a wall-mounted, ceiling-mounted, cassette type, or a ceiling concealed and ducted system. General guidance is:

1. Clean the filter with water. If the filter is soiled with oil, it can be washed with warm water (not exceeding 45°C (113°F). The inlet side should face down and away from the water stream.
2. Leave the filter to dry in a cool and dry place.
3. Re-install the filter once fully dried.
4. If using vacuum cleaner, the inlet side should face the vacuum.

Heat Exchanger

As previously stated, the first step for any VRF PM is to check the operating parameters indoors and outdoors. The second step is always to be safe and turn off the circuit breakers of the system.

Outdoor Unit Heat Exchanger

1. Remove the fan grill and the fan motor from the outdoor unit.
2. Using a pressure washer, spray through the fins from the inside out to remove any build up dirt or debris from between them. Be sure to test a small section of the coil with the pressure washer to ensure that the fins are not bent or negatively affected by the pressure of the washer.
3. If the fins are particularly dirty, use a commercially available (nonacidic) coil cleaner. Be sure to test a small section of the coil with the pressure washer to ensure that the fins are not bent or negatively affected by the pressure of the washer.

Indoor Unit Heat Exchanger

1. Secure the fan motor and electric components of the unit.
2. Using a pressure washer, spray through the fins from the inside out to remove any build up dirt or debris from between them.
3. If the fins are particularly dirty, use a commercially available coil cleaner spray.

4. Clean the indoor unit using a cloth with water (not exceeding 45°C [113°F]) and neutral soap.
5. Reconnect all components, return grill and panel of the unit.
6. Clean the evaporator drain line. Disconnect drain line. Using nitrogen gas tank or pressurized air—do not exceed 4 atm (60 psig)—flush the drain line to remove the clogs and test the drain line after.
7. Make sure that the units are properly dried after the cleaning.
8. Turn on the breaker of the indoor units. Make sure that all indoor units are online.
9. Turn on the breaker of the outdoor units. It will take 10 to 15 minutes to re-address and read the indoor units.
10. Gather the operating data of the system (manual or check button). It can be compared to the data gathered prior to the general cleaning. Check if parameter is improved.

Note: Use a startup data sheet (SUDS) form as a reference of a good parameter.

If you plan to *not* use your air conditioner for an extended period, do the following:

1. Clean the filter(s).
2. Turn on the fan function until the unit dries out completely.
3. Remove the batteries from the remote control.
4. Turn off the unit and disconnect the power.

Preseason Inspection

After long periods of nonuse or before a period of frequent use, the following actions should be completed:

1. Check for damaged wires.
2. Clean the filter(s).
3. Replace the batteries in the remote control.
4. Check for leaks.
5. Inspect all air inlets and outlets of the indoor and outdoor units to ensure nothing is blocking them.
6. Turn on the breaker and switch on the units using the remote control.
7. After the unit has reached temperature, record data on a start-up data sheet (SUDS).

ADDITIONAL INFORMATION AND RESOURCES

In addition to material safety data sheets (MSDSs), which provide information on shipping, storage, and handling of specific refrigerants/secondary fluids

(SFs), the UNEP Refrigerant Driving License, and any relevant OEM literature, the following references provide additional information on preventive maintenance for RAC equipment.

ACCA. 2021. ANSI/ACCA 14-2021, *Quality Maintenance of Commercial Refrigeration Systems*. Alexandria, VA: Air Conditioning Contractors of America Association.

UNEP AHRI, Refrigerant Driving License. www.RDLprogram.org.

ASHRAE. 2015. ASHRAE Guideline 6-2015, *Refrigerant Information Recommended for Product Development and Standards*. Peachtree Corners, GA: ASHRAE.

ASHRAE. 2018. *ASHRAE Guide for Sustainable Refrigerated Facilities and Refrigeration Systems*. Peachtree Corners, GA: ASHRAE.

ASHRAE. 2019. ANSI/ASHRAE Standard 147-2019, *Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems*. Peachtree Corners, GA: ASHRAE.

ASHRAE. 2022. ANSI/ASHRAE Standard 15-2022, *Safety Standard for Refrigeration Systems*. Peachtree Corners, GA: ASHRAE.

ASHRAE. 2022. ANSI/ASHRAE Standard 34-2022, *Designation and Safety Classification of Refrigerants*. Peachtree Corners, GA: ASHRAE.

ISO. 2014. ISO 817:2014, *Refrigerants—Designation and Safety Classification*. Geneva: International Organization for Standardization.

ISO. 2014. ISO 5148-1: 2014, *Refrigerating Systems and Heat Pumps—Safety and Environmental Requirements—Part 1: Definitions, Classification and Selection Criteria*. Geneva: International Organization for Standardization.

ISO. 2014. ISO 5148-2: 2014, *Refrigerating Systems and Heat Pumps—Safety and Environmental Requirements— Part 2: Design, Construction, Testing, Marking and Documentation*. Geneva: International Organization for Standardization.

ISO. 2014. ISO 5148-3: 2014, *Refrigerating Systems and Heat Pumps—Safety and Environmental Requirements—Part 3: Installation Site*. Geneva: International Organization for Standardization.

ISO. 2014. ISO 5148-4: 2014, *Refrigerating Systems and Heat Pumps—Safety and Environmental Requirements—Part 4: Operation, Maintenance, Repair and Recovery.* Geneva: International Organization for Standardization.

UNEP Division of Technology, Industry and Economics (DTIE), OzonAction Branch, 2015. Good Servicing Practices: Phasing out HCFCs in the Refrigeration and Air-Conditioning Servicing Sector: https://www.unep.org/ozonaction/resources/publication/good-servicing-practices-phasing-out-hcfcs-refrigeration-and-air-conditioning

UNEP. 2022. UNEP Evaluation Manual. https://www.unep.org/resources/other-evaluation-reportsdocuments/unep-evaluation-manual

O&M Best Practice Appendix

3

Preventive Maintenance of Equipment: Sample PM Work Orders

This appendix to Guidance Sheet 3 provides eight sample equipment-specific PM work orders. They require editing by the technician to accommodate location- and application-specific guidance.

The suggested PM work orders include:

1. Air-Cooled Chiller Unit
2. Water-Cooled Chiller Unit
3. Cooling Tower
4. Chiller System Water Pump
5. Fan Coil Unit (VRF)
    a. Fan Coil Unit (CHW)
    b. Fan Coil Unit (DX)
6. Outdoor VRF Unit

The sample PM work orders are intended to be in an easy-to-use format with support documentation that has heavily illustrated guidance and minimum text.

The PM work orders should be continuously improved based on feedback and experience.

In addition to identifying standards and required competencies to perform the PM, these work orders will need to be edited by the end-user to include the necessary tools and supplies required for the PM work, in addition to making the O&M manual associated with the piece of equipment readily available.

Editable PM work orders can be found in the Assessing RAC Plant Sustainability Toolkit on the ASHRAE UNEP Portal.

Date Issued: __/__/20__ Technician Initial: ___________	Air-Cooled Chiller Unit Suggested PM Work Order			Unit Tag	ACCU-#
	OWNER:				
		YEAR INSTALLED:			
	LOCATION: On Roof	MANUFACTURER:			
	ROOM NAME: Not Applicable	SERIAL No.:			
	ROOM No.: Not Applicable	SIZE:			
	MODEL No.:	REFRIGERANT: Insert Tonnage			
	VOLTAGE: __/__/__				
Equipment Photo	System Details				
	☐ Two Pipe	☐ VFD	☐ Belt Drive		
	☐ Four Pipe	☐ Two-Speed Motor	☐ Direct Drive		
	☐ Roof Mounted	☐ Multistage Control	☐ Winter Low Ambient Control		
	☐ Side Wall Mounted	☐	☐		
	☐ Grade Mounted	☐	☐		
	☐	☐ With Pumps P-#, P-#, P-#			

Special Instructions		Technician Notes
1.) Turn off electrical power at unit disconnect.	☐	
2.) Bring all special tools required for access, PPE, and ladder.	☐	
3.) Bring required lubricants, oils, and cleaners.	☐	
4.) Bring correct belts.	☐	
5.) Bring Operating Log Readings Checklist.	☐	Electronic app
6.) PM work order does not include servicing associated pumps.	☐	Procure associated chilled water and condenser water pump PM work orders.
7.) Lockout-tagout procedures.	☐	
8.) Bring operations and maintenance manual.	☐	Electronic app
9.) Notify service desk operator that the technician will be on the roof.	☐	

Tasks	Frequency					
	MIN:HRS	W	M	Q	S	A
1.) With panel disconnected from power source, clean control panel compartment with a vacuum.	0:05					X
2.) Inspect wiring/components for loose connections and tighten.	0:05					X
3.) Check set point of controls using Operating Log Reading Checklist app.	0:10					X
4.) Check source of the signal and its amplification on electronic controls.	0:05					X
5.) Run systems diagnostic test.	0:15					X

6.)	Check water gages and thermometer and input into Log Reading Checklist.	0:10					X
7.)	Clean chilled-water bundles.	2:30					
8.)	Replace refrigerant filter every two years and tag with replacement date.	0:15					
9.)	Cycle actuators and lubricate linkage while watching operation.	0:05					X
10.)	Check for refrigerant leaks and water leaks.	0:05					X
11.)	Add the refrigerant charge needed and log pounds added.	0:10					X
12.)	Clean and rake condenser coils.	0:10					X
13.)	Clean area around equipment and remove bees' nests.	0:05					X
14.)	Check for corrosion.	0:05					X
15.)	Check for excessive vibration.	0:05					X
16.)	Check packing gland for leaks; adjust as required.	0:10					X
17.)	Inspect insulation condition.	0:00					X
18.)		0:00					X
19.)		0:00					X
20.)		0:00					X
21.)		0:00					X
22.)	Fill out maintenance work order as work is completed.	0:05					X
23.)	Report deficiencies.	0:05					X
	Total Labor Hours/Period:	4:40					4:40
	Total Labor Hours/Year:	4:40					4:40

Notes
1.) Complete work order before leaving the equipment.
2.) Photograph any issues or concerns.
3.) Turn outdoor disconnect back on.

Date Issued: __/__/20__ Technician Initial: ________	Water-Cooled Chiller Unit Suggested PM Work Order	Unit Tag	WCCU-#

Equipment Photo	OWNER:	
	BUILDING:	YEAR INSTALLED:
	LOCATION:	MANUFACTURER:
	ROOM NAME:	SERIAL No.:
	ROOM No.:	SIZE:
	MODEL No.:	REFRIGERANT:
	VOLTAGE: __/__/__	

System Details:		
☐ Two Pipe	☐ VFD	☐ Direct Drive
☐ Four Pipe	☐ Inlet Vane Control	☐ Open Drive
☐ Roof Mounted	☐ Multistage Control	☐
☐ Equipment Room	☐ With Cooling Tower CT-#	☐
☐ Grade Mounted	☐ With Plate and Frame Heat Exchanger HE-#	☐
☐	☐ With Pumps P-#, P-#, P-#	☐

Special Instructions		Technician Notes
1.) Turn off electrical power at unit disconnect.	☐	
2.) Bring all special tools required for access, PPE, and ladder.	☐	
3.) Bring required lubricants, oils, and cleaners.	☐	
4.) PM work order does not include servicing CT-# and HE-#.	☐	
5.) PM work order does not include servicing associated pumps.	☐	
6.) Bring Operating Log Readings Checklist.	☐	Electronic app
7.) Lockout-tagout procedures.	☐	
8.) Bring Operations and Maintenance manual.	☐	Electronic app
9.)	☐	

Tasks	Frequency					
	MIN:HRS	W	M	Q	S	A
1.) With panel disconnected from power source, clean control panel compartment with a vacuum.	0:05					X
2.) Inspect wiring/components for loose connections and tighten.	0:05					X
3.) Check set point of controls using Operating Log Reading Checklist app.	0:10					X
4.) Check signal source and its amplification on electronic controls.	0:05					X
5.) Run systems diagnostic test.	0:20					X

6.) Check water gages and thermometer and input into the Log Reading Checklist.	0:10					X
7.) Clean chilled-water and condenser water bundles.	2:30					
8.) Cycle actuators and lubricate linkage while watching operation.	0:05					X
9.) Check for refrigerant and water leaks.	0:15					X
10.) Add refrigerant charge as needed and log "pounds added."	0:30					X
11.) Test refrigeration relief valve(s).	0:10					X
12.) Clean area around equipment.	0:05					X
13.) Check for corrosion.	0:05					X
14.) Check for excessive vibration.	0:05					X
15.) Check packing gland for leaks; adjust as required.	0:10					X
16.) Test refrigeration emergency exhaust system.	0:15					X
17.) Inspect insulation condition.	0:00					X
18.)	0:00					X
19.)	0:00					X
20.)	0:00					X
21.) Fill out maintenance work order as work is completed.	0:05					X
22.) Report deficiencies.	0:05					X
Total Labor Hours/Period:	5:15					5:15
Total Labor Hours/Year:	5:15					5:15

Notes
1.) Complete work order before leaving the equipment.
2.) Photograph any issues or concerns.
3.) Turn outdoor disconnect back on.

Date Issued: __/__/20__ Technician Initial: ________	Cooling Tower Suggested PM Work Order	Unit Tag	CT-#

Equipment Photo			
	OWNER:		
	BUILDING:	YEAR INSTALLED:	
	LOCATION: On Roof	MANUFACTURER:	
	ROOM NAME: Not Applicable	SERIAL No.:	
	ROOM No. Not Applicable	SIZE:	
	MODEL No.	HORSEPOWER:	
	VOLTAGE: __/__/__		

System Details

☐ Two Pipe	☐ VFD	☐ Direct Drive Fan(s)
☐ Two-Speed Motor	☐ Centrifugal Fan(s)	☐
☐ Roof Mounted	☐ Single-Speed Control	☐ Axial Fan(s)
☐ At Grade	☐ With Water-Cooled Chiller WCCU-#	☐ Sump Heater
☐	☐ With Plate and Frame Heat Exchanger HE-#	☐
☐	☐ With Pumps P-#, P-#, P-#	☐

Special Instructions			Technician Notes
1.)	Turn off electrical power at unit disconnect.	☐	
2.)	Bring all special tools required for access, PPE, and ladder	☐	
3.)	Bring required lubricants, oils, cleaners, and correct belts.	☐	
4.)	PM work order doesn't include servicing WCCU-# or P-#, P-#, ...	☐	
5.)	Bring Operating Log Readings Checklist.	☐	Electronic app
6.)	Lockout-tagout procedures.	☐	
7.)	Bring operations and maintenance manual.	☐	
8.)		☐	
9.)	Notify service desk operator that the technician will be on the roof.	☐	

Tasks		Frequency					
		MIN:HRS	W	M	Q	S	A
1.)	With panel disconnected from power source, clean control panel compartment with a vacuum.	0:05		X			
2.)	Inspect wiring/components for loose connections and tighten.	0:05		X			
3.)	Check set point of controls using Operating Log Reading Checklist app.	0:10		X			
4.)	Check source of the signal and its amplification on electronic controls.	0:05		X			
5.)	Run systems diagnostic test.	0:15		X			

6.) Check water gages and thermometer and input into Log Reading Checklist.	0:05		X			
7.) Clean tower sump and strainer.	0:15		X			
8.) Clean area around equipment and remove bees' nests.	0:15		X			
9.) Check for corrosion.	0:05		X			
10.) Check for excessive vibration.	0:05		X			
11.) Check packing gland for leaks; adjust as required.	0:10		X			
12.) Inspect insulation condition.	0:10		X			
13.)	0:00					
14.)	0:00					
15.)	0:00					
16.)	0:00					
17.)	0:00					
18.)	0:00					
19.)	0:00					
20.)	0:00					
21.)	0:00					
22.) Fill out maintenance work order as work is completed.	0:05					
23.) Report deficiencies.	0:05					
Total Labor Hours/Period:	1:55		1:55			
Total Labor Hours/Year:	0:00					

Notes
1.) Complete work order before leaving the equipment.
2.) Photograph any issues or concerns.
3.) Turn outdoor disconnect back on.
4.) Total Labor Hours/Year will be dependent on the number of months the cooling tower is scheduled to operate.

Date Issued: __/__/20__ Technician Initial: ________	Chiller System Water Pump Suggested PM Work Order	Unit Tag	P-#

Equipment Photo			
OWNER:			
BUILDING:		YEAR INSTALLED:	
LOCATION:	Insert Floor	MANUFACTURER:	
ROOM NAME:	Not Applicable	SERIAL No.:	
ROOM No.:	Not Applicable	HORSEPOWER:	
MODEL No.:		SYSTEM:	☐ Chilled Water
VOLTAGE:	__/__/__		☐ Condenser Water

System Details		
☐ Chilled-Water System	☐	☐ Primary
☐ Condenser Water System	☐	☐ Secondary
☐ Penthouse	☐ With Cooling Tower CT-#	☐ Tertiary
☐ Equipment Room	☐ With Chiller #	☐ Single Speed
☐	☐ With Plate and Frame Heat Exchanger HE-#	☐ Two Speed
☐	☐ With Pumps P-#, P-#, P-#, ...	☐ VFD

Special Instructions			Technician Notes
1.)	Turn off electrical power at unit disconnect.	☐	
2.)	Bring all special tools required for access, PPE, and ladder.	☐	
3.)	Bring required lubricants, oils, and cleaners	☐	
4.)	PM work order does not include servicing chiller.	☐	
5.)	PM work order does not include servicing associated pumps.	☐	
6.)	Bring Operating Log Readings Checklist.	☐	Electronic app
7.)	Lockout-tagout procedures.	☐	
8.)	Bring operations and maintenance manual.	☐	Electronic app
9.)		☐	

Tasks		Frequency					
		MIN:HRS	W	M	Q	S	A
1.)	With panel disconnected from power source, clean control and/or VFD panel compartment with a vacuum.	0:05					X
2.)	Inspect wiring/components for loose connections and tighten.	0:05					X
3.)	Check water gages and thermometer and input into Log Reading Checklist.	0:05					X
4.)	Check source of the signal and its amplification on electronic controls.	0:05					X
5.)	Clean area around equipment.	0:05					X

6.) Check for corrosion.	0:05					X
7.) Check packing gland for leaks; adjust as required.	0:05					
8.) Check for excessive vibration.	0:05					X
9.) Start and stop motor from local switch.	0:05					X
10.) Inspect insulation condition.	0:05					X
11.) Remove and clean strainer screen.	0:20					X
12.) Inspect pump for shaft alignment and adjust as required.	0:10					X
13.) Check net positive suction pressure (closed pump system only).	0:10					
14.)	0:00					
15.)	0:00					
16.)	0:00					
17.)	0:00					
18.)	0:00					
19.)	0:00					
20.)	0:00					
21.) Fill out maintenance work order as work is completed.	0:05					X
22.) Report deficiencies.	0:05					X
Total Labor Hours/Period:	1:40					1:40
Total Labor Hours/Year:	1:40					1:40

Notes
1.) Complete work order before leaving the equipment.
2.) Photograph any issues or concerns.

Date Issued: __/__/20__ Technician Initial: ________	Fan Coil Unit (VRF) Suggested PM Work Order	Unit Tag	FCU-#

Equipment Photo		
	OWNER:	
	BUILDING:	YEAR INSTALLED:
	FLOOR:	MANUFACTURER:
	ROOM NAME:	SERIAL No:
	ROOM No.	SIZE:
	MODEL No.	HORSEPOWER:
	VOLTAGE: __/__/__	

System Details

☐ Two Pipe	☐ Concealed Vertically	☐ W/ Outdoor Air Damper
☐ Three Pipe	☐ Three-Speed Control	☐ Direct Drive
☐ Floor Mounted	☐ Ceiling Discharge One-Way	☐ W/ Outdoor Air Damper
☐ Wall Mounted	☐ Ceiling Discharge Two-Way	☐
☐ Ceiling Hung	☐ Ceiling Discharge Four-Way	☐
☐ Concealed Horizontally	☐ Ceiling Discharge One-Way	☐

Special Instructions		Technician Notes
1.) Turn off electrical power at unit disconnect.	☐	
2.) Bring all special tools required for access.	☐	.
3.) Bring required lubricants, oils, and cleaners.	☐	Refer to O&M manual.
4.) Bring associated air filter replacement.	☐	Insert filter size into master PM work order or note: “washable filter.”
5.) PM work order includes servicing associated condensate pump.	☐	
6.) Bring operating log reader app and checklist.	☐	
7.) Lock-out tag out procedures.	☐	
8.) Bring operations and maintenance manual.	☐	
9.)	☐	

Tasks	Frequency					
	MIN:HRS	W	M	Q	S	A
1.) With panel disconnected from power source, clean control panel compartment with a vacuum.	0:05				X	X
2.) Inspect wiring/components for loose connections and tighten.	0:05				X	X
3.) Check set point of controls and test over operating range.	0:05				X	X
4.) Run microprocessor controls for proper operation (heat, cool, fan, off).	0:05				X	X
5.) Check source of the signal and its amplification on electronic controls.	0:05				X	X

6.)	Clean area around equipment and wipe coil surface.	0:05				X	X
7.)	Bacteria cleaning inside unit.	0:10				X	X
8.)	Tighten arm on motor output shaft.	0:10				X	X
9.)	Lubricate and cycle outdoor actuator while watching for proper operation.	0:05				X	X
10.)	Replace or wash air filter.	0:05				X	X
11.)	Inspect insulation condition.	0:05				X	X
12.)	Check flares for refrigerant leaks.	0:05				X	X
13.)	Check coils and piping for leaks, damage, and corrosion.	0:05				X	X
14.)	Clean coil drip pan and drain line clogging with solvent.	0:05				X	X
15.)		0:00				X	X
16.)		0:00				X	X
17.)		0:00				X	X
18.)		0:00				X	X
19.)		0:00				X	X
20.)		0:00				X	X
21.)		0:00				X	X
22.)	Fill out maintenance checklist and report deficiencies.	0:05				X	X
	Total Labor Hours/Period:	1:25				1:25	1:25
	Total Labor Hours/Year:	2:50				1:25	1:25

Notes
1.) Complete work order before leaving the equipment.
2.) Photograph any issues or concerns.

Date Issued: __/__/20__ Technician Initial: ________	Fan Coil Unit (CHW) Suggested PM Work Order	Unit Tag	FCU-#

Equipment Photo		
	OWNER:	
	BUILDING:	YEAR INSTALLED:
	FLOOR:	MANUFACTURER:
	ROOM NAME:	SERIAL No:
	ROOM No.:	SIZE:
	MODEL No.:	HORSEPOWER:
	VOLTAGE:	

System Details

☐ Two Pipe	☐ Concealed Vertically	☐ Belt Drive
☐ Four Pipe	☐ Two-Speed Control	☐ Direct Drive
☐ Floor Mounted	☐ Three-Speed Control	☐ W/ Outdoor Air Damper
☐ Wall Mounted	☐ Variable Frequency Drive (VFD)	☐
☐ Ceiling Hung	☐ With Heating Coil	☐
☐ Concealed Horizontally	☐ With 1-kW Supplemental Heater	☐

Special Instructions		Technician Notes
1.) Turn off electrical power at unit disconnect.	☐	
2.) Bring all special tools required for access.	☐	Bring ladder for ceiling hung and concealed horizontally above ceiling.
3.) Bring required lubricants, oils, and cleaners.	☐	
4.) Bring associated air filter replacement.	☐	Insert filter size
5.) PM work order includes servicing associated condensate pump.	☐	
6.) Bring operating log readings checklist.	☐	
7.) Lockout-tagout procedures.	☐	
8.) Bring operations and maintenance manual.	☐	
9.)	☐	

Tasks	Frequency					
	MIN:HRS	W	M	Q	S	A
1.) With panel disconnected from power source, clean control panel compartment with a vacuum.	0:05				X	X
2.) Inspect wiring/components for loose connections and tighten.	0:05				X	X
3.) Check set point of controls.	0:05				X	X
4.) Check unit over its range of control.	0:05				X	X
5.) Check source of the signal and its amplification on electronic controls.	0:05				X	X
6.) Clean area around equipment.	0:05				X	X
7.) Run microprocessor controls for proper operation (heat, cool, fan, off).	0:10				X	X
8.) Check controls for proper operation (heat, cool, fan, off).	0:10				X	X

9.) Check air venting.	0:05				X	X
10.) Tighten arm on motor output shaft.	0:05				X	X
11.) Cycle actuator while watching for proper operation.	0:05				X	X
12.) Lubricate actuator linkage and damper blade pivot points.	0:05				X	X
13.) Lubricate valve actuator stem and valve stem, where possible.	0:05				X	X
14.) Check belt for wear, tension, and alignment; adjust as required.	0:05				X	X
15.) Replace air filter.	0:10				X	X
16.) Drain and flush and clean strainer.	0:05				X	X
17.) Check coils and piping for leaks, damage, and corrosion.	0:05				X	X
18.) Inspect insulation condition.	0:05				X	X
19.) Clean coil drip pan and drain line with solvent.	0:05				X	X
20.) Check packing gland for leaks; adjust as required.	0:05				X	X
21.) Check packing gland for leaks; adjust as required.	0:05				X	X
22.) Fill out maintenance checklist and report deficiencies.	0:05				X	X
Total Labor Hours/Period:	2:05				2:05	4:10
Total Labor Hours/Year:	6:15				2:05	4:10

Notes

1.) Complete work order before leaving the equipment.

2.) Photograph any issues or concerns.

Date Issued: __/__/20__ Technician Initial: ________	Fan Coil Unit (DX) Suggested PM Work Order	Unit Tag	FCU-#

Equipment Photo		
	OWNER:	
	BUILDING:	YEAR INSTALLED:
	FLOOR:	MANUFACTURER:
	ROOM NAME:	SERIAL No.:
	ROOM No.:	SIZE:
	MODEL No.:	HORSEPOWER:
	VOLTAGE:	

System Details

☐ Two Pipe	☐ Concealed Vertically	☐ Belt Drive
☐ Four Pipe	☐ Two-Speed Control	☐ Direct Drive
☐ Floor Mounted	☐ Three-Speed Control	☐ W/ Outdoor Air Damper
☐ Wall Mounted	☐ VFD	☐ Heat Pump
☐ Ceiling Hung	☐ With Heating Coil	☐
☐ Concealed Horizontally	☐ With 1-kW Supplemental Heater	☐

Special Instructions		Technician Notes
1.) Turn off electrical power at unit disconnect.	☐	
2.) Bring all special tools required for access.	☐	Bring ladder for ceiling hung and concealed horizontally above ceiling.
3.) Bring required lubricants, oils, and cleaners.	☐	
4.) Bring associated air filter replacement.	☐	Insert filter size.
5.) PM work order includes servicing associated condensate pump.	☐	
6.) Bring operating log readings checklist.	☐	
7.) Lockout-tagout procedures.	☐	
8.) Bring operations and maintenance manual.	☐	
9.)	☐	

Tasks	Frequency					
	MIN:HRS	W	M	Q	S	A
1.) With panel disconnected from power source, clean control panel compartment with a vacuum.	0:05					X
2.) Inspect wiring/components for loose connections and tighten them.	0:05					X
3.) Check set point of controls.	0:10					X
4.) Check unit over its range of control.	0:10					X
5.) Check source of the signal and its amplification on electronic controls.	0:05					X
6.) Clean area around equipment.	0:05					X
7.) Run systems diagnostic test.	0:10					X
8.) Check pressure gauge.	0:05					X
9.) Check thermometers.	0:05					X
10.) Run microprocessor check, if available, or check controls and unit for proper operation.	0:10					X

11.) Tighten arm on motor output shaft.	0:05					X
12.) Cycle actuator while watching for proper operation.	0:05					X
13.) Lubricate actuator linkage and damper blade pivot points.	0:05					X
14.) Check belt for wear, tension, and alignment; adjust as required.	0:05					X
15.) Replace air filters.	0:10					X
16.) Drain and flush and clean strainer.	0:05					X
17.) Start and stop fan with local switch.	0:05					X
18.) Check coils and piping for leaks, damage, and corrosion.	0:05					X
19.) Clean coil drip pan and drain line with solvent.	0:05					X
20.) Lubricate valve actuator stem and valve stem, where possible.	0:05					X
21.) Check packing gland for leaks; adjust as required.	0:05					X
22.) Fill out maintenance checklist and report deficiencies.	0:05					X
Total Labor Hours/Period:	2:15					2:15
Total Labor Hours/Year:	2:15					2:15

Notes

Date Issued: __/__/20__ Technician Initial: ________	Outdoor VRF Unit Suggested PM Work Order	Unit Tag	VRFCU-#

Equipment Photo

OWNER:			
BUILDING:		**YEAR INSTALLED:**	
LOCATION:	Roof	**MANUFACTURER:**	
ROOM NAME:	Not Applicable	**SERIAL No:**	
ROOM No.:	Not Applicable	**SIZE:**	
MODEL No.:		**SIZE:**	Insert Tons
VOLTAGE:	__/__/__		

System Details				
☐	Two Pipe	☐	Total of # Units	☐
☐	Three Pipe	☐	Heat Pump Unit	☐
☐	Roof-mounted	☐	Heat Recovery Unit	☐
☐	Wall-Mounted	☐	Low Ambient Control Kit	☐
☐	Ceiling Hung	☐	Pan Heater	☐
☐	Mounted At-Grade	☐		☐

Special Instructions		Technician Notes
1.) Turn off electrical power at unit disconnect.	☐	
2.) Bring all special tools required for access, PPE, and ladder.	☐	
3.) Bring required lubricants, oils, and cleaners.	☐	Refer to O&M manual.
4.) Bring operating log reader app and checklist.	☐	
5.) Lockout-tag out procedures.	☐	
6.) Bring O&M manual.	☐	
7.)	☐	
8.)	☐	
9.) Notify the service desk operator that the technician will be on the roof.	☐	

Tasks	Frequency					
	MIN:HRS	W	M	Q	S	A
1.) With panel disconnected from power source, clean control panel compartment with a vacuum.	0:05				X	X
2.) Inspect wiring/components for loose connections and tighten.	0:05				X	X
3.) Check set point of controls and test over operating range.	0:05				X	X
4.) Run microprocessor controls for proper operation (sequence by sequence).	0:05				X	X
5.) Check source of the signal and its amplification on electronic controls.	0:05				X	X
6.) Clean area around equipment and remove bees' nests.	0:05				X	X
7.) Check coils and piping for leaks, damage, and corrosion.	0:10				X	X

8.) Check flares for refrigerant leaks.	0:10				X	X
9.) Lubricate and cycle outdoor actuator while watching for proper operation.	0:05				X	X
10.) Inspect condition of insulation.	0:05				X	X
11.)	0:05				X	X
12.)	0:00				X	X
13.)	0:00				X	X
14.)	0:00				X	X
15.)	0:00				X	X
16.)	0:00				X	X
17.)	0:00				X	X
18.)	0:00				X	X
19.)	0:00				X	X
20.)	0:00				X	X
21.)	0:00				X	X
22.) Fill out maintenance checklist and report deficiencies.	0:05				X	X
Total Labor Hours/Period:	1:10				1:10	1:10
Total Labor Hours/Year:	2:20				1:10	1:10

Notes
1.) Complete work order before leaving the equipment.
2.) Photograph any issues or concerns.

O&M Best Practice Checklist

3

Preventive Maintenance of Equipment

OBJECTIVE

The goals of preventive maintenance are:

- Understanding refrigerants are an asset and not a consumable.
- Protecting the environment, worker, and community safety in compliance with local requirements.
- Educating maintenance technicians on pertinent components that require service, repair, and/or replacement by using PM work orders and continuously improving these documents.
- Maximizing the useful service life of equipment by using PM work orders that set recommended equipment maintenance timelines to enhance both equipment and system efficiency.

MEASURES OF SUCCESS

✓ Increased equipment uptime

✓ Maintained energy efficiency

✓ Elimination of unplanned outages

✓ Overall O&M cost reductions

✓ Reduction in refrigerant loss

✓ Assembly of comprehensive log of system performance, refrigerant loss, maintenance operations, etc., over time.

Topic	Actions	Notes
G. Direct Equipment	*The following maintenance tasks are required to be performed and properly documented.*	
	☐ Perform weekly leak checks.	
	☐ Properly document leaks in daily maintenance log.	
	☐ Properly repair leaks and document refrigerant used.	
	☐ Report leaks as required by regulations.	
	☐ Install leak detection sensors installed in appropriate locations.	
	☐ Follow protocols for the detection of flammable and/or toxic refrigerant leaks.	
H. Indirect Equipment	*The following maintenance tasks are to be performed in addition to those tasks listed above for Direct Systems.*	
	☐ Meet all requirements for direct systems.	
	☐ Check heat exchanger tubes for leaks every five years.	
	☐ Check anticorrosion additive monthly.	
	☐ Check sacrificial anodes for wear monthly.	
	☐ Analyze LiBr solution for steel or copper deposits every three months.	
	☐ Check heat recovery heat exchanger for corrosion every three months.	
I. VRF	*Periodic maintenance of VRF systems is essential for keeping them effective and efficient. Follow all OEM instructions and safety requirements while performing maintenance tasks.*	
	☐ Inspect and clean filter weekly.	
	☐ Perform general heat exchanger cleaning quarterly and semiannually.	
	☐ Inspect and tighten wires, bolts, etc., semiannually.	
	☐ Check parameter against startup data sheet and note variances.	
	☐ Manually check flow annually.	

Operation & Maintenance Guidance Sheet

4

Preventive Maintenance of Automatic Controls

Mindset: Be best prepared and be safe.

GENERAL INFORMATION

Maintenance personnel and facility operators should implement preventive maintenance (PM) of refrigeration control systems to create regularly scheduled inspections, usually occurring multiple times per year. The primary benefit of preventive maintenance is that it can be simple and can help to minimize unplanned maintenance and premature failures.

The PM of automatic control systems should be proactive, not reactive PM (i.e., run to fail), to maximize equipment service life. This includes performing PM on standalone controls found in unitary equipment and centralized building automation systems (BASs). A proper PM procedure for control systems aims to identify and repair control problems before they fail or drift out of calibration. Reduced system performance and increased energy consumption can occur if routine maintenance, constant monitoring, and continuous commissioning do not occur. Proactive PM utilizes practices that can help predict potential problems, including point-specific trending, handheld field diagnostic tools, and automatic fault detection (AFD).

ACRONYMS

AFD automatic fault detection (handheld devices)

BAS building automation system

PM preventive maintenance

OBJECTIVES AND GOALS

The objectives of this guidance sheet are to:

- Create PM checklists for refrigeration and HVAC BAS controls to catch and fix problems before they happen.
- Implement continuous testing, commissioning, and monitoring of control systems.
- Identify control problems prior to equipment failure, continuous commissioning of the BAS, predictive maintenance, BAS computer alarm or safety signal, or observation of nonoperating equipment.

The goals of BAS-PM are:

- Understanding refrigerants are an asset and not a consumable.
- Protecting the environment, worker, and community safety in compliance with local requirements.
- Educating maintenance technicians on pertinent components that require service, repair, and/or replacement by using PM work orders and continuously improving these documents.
- Maximizing the useful service life of equipment by using PM work orders that set recommended equipment maintenance timelines to enhance both equipment and system efficiency.

The goals of a comprehensive PM program include the following:

- Reduce capital repairs.
- Reduce unscheduled shutdowns and repairs.
- Extend equipment life, thereby extending facility life.
- Realize life-cycle cost savings.
- Provide safe, functional systems and facilities that meet the design intent.
- Lower system downtime and better performance.
- Fewer safety incidents and/or refrigerant releases
- Management of the equipment service needs on-site promptly.
- Periodic leak checking and proper documentation (including record keeping, documentation of repairs, compliance with local reporting requirements, etc.).
- Documentation of PM activities reported through a log or CMMS work order system.

BEST PRACTICES

Best practice equates to “best prepared and be safe” to perform the BAS-PM work. It has been proven repeatedly that standardized checklists are a quality control tool, whether used to improve a business, complete a task, or problem-solve a problematic piece of equipment and/or system.

This guidance sheet inventories sustainable PM practices for refrigeration and related HVAC controls. The final checklists will include recommended practices and enhanced procedures based on the region the equipment is located, as well as continuous improvement based on feedback, e.g., from the maintenance technician. In addition, these checklist attributes shall be formatted as follows:

- Print format for the technician to have on the job site.
- Poster format for plant display.
- Print format for the plant reference library.
- Online format usable on tablets and phones.
- Offline format usable on tablets and phones.

Competencies of operating and servicing personnel shall be a prerequisite by ensuring that maintenance personnel will receive the necessary training and continuous education to fulfill the tasks at hand.

Certification of technicians via available programs focused on automatic controls, building automation, refrigeration management, and equipment-specific maintenance training on-site and/or at the manufacturer’s factory will ensure each technician is prepared to perform the work at hand. UNEP and the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) have developed a globally recognized and accepted qualification program, the Refrigerant Driving License (RDL). The RDL offers a globally accepted qualification which will be an industry-driven program for the management of refrigerants for maintenance technicians to become certified. This RDL will not overrule any existing governmental certification scheme, but it can offer a structured framework for developing countries without a similar certification program.

In addition to standardization and competency in performing the work, these checklists need to be edited by the end-user to include the necessary tools and supplies required for BAS-PM work, along with making available the O&M manual associated with the piece of equipment.

Addressed in this guide is the prerequisite that equipment rooms have the required leak detection systems to be alarmed based on refrigerant toxicity or flammability. In addition, these machinery rooms must be verified to have ventilation to ensure adequate air exchange and space temperature for maintenance personnel to work safely in this environment. The continuous commissioning monitoring of the refrigeration systems must be part of the BAS-PM process.

Good practice via quality-controlled BAS-PM work orders mean complying with local laws and procedures and ensuring these laws and procedures take precedence. The ability to monitor, measure, and report PM work performance will also be part of this quality control and maximizing the useful service life of the equipment.

WORK ORDERS

Each BAS-PM work order should have an equipment name assigned to it along with its location inside or outside the building. There should be special instructions included, highlighting the following:

- Access to the equipment manufacturer's operation and maintenance (O&M) manual, equipment startup and shutdown documents, and any emergency plan instructions pertaining to this piece of equipment.
- Safety instructions, e.g., lockout-tagout instructions, safety glasses, etc.
- Required tools to access and service the piece of equipment, (e.g., ¼-inch Allen wrench, etc.)
- Required materials, lubricants, etc. For example, correct filter replacement size.
- Work orders will have the suggested tasks to be performed along with the servicing frequency; monthly, quarterly, etc.

The suggested BAS-PM work orders found in this guidance sheet are standardized checklists for a maintenance technician to draw upon to complete the work and should be edited for the specific piece of equipment on site. For example, certain equipment may be located on the floor and be visible and easily accessible while similar equipment may be concealed above a ceiling requiring a ladder of a specific height to access. Other work orders may require two technicians to perform the work, and this would be added into the BAS-PM work order document.

When the PM work order is completed, the technician assigned to service the equipment must sign and date the document and return it to the PM supervisor. The work order should state that work has been completed or completed to a point and that a "part(s) and/or certain material" request has been submitted with the remaining PM work order; work will be scheduled to be completed once the part or material has been received.

ADDITIONAL INFORMATION AND RESOURCES

In addition to material safety data sheets (MSDSs), which provide information on shipping, storage, and handling of specific refrigerants and SFs (secondary fluids), the UNEP Refrigerant Driving License, and any relevant OEM literature, the following references provide additional information on preventive maintenance for RAC equipment.

The reference documents to consider when generating data for BAS-PM include:

1. ASHRAE RP 1634: Guide for Sustainable Refrigerated Facilities and Refrigeration Systems.
2. ASHRAE Standard 114-1986—Energy Management Control Systems Instrumentation
3. ASHRAE Standard 135.1-2019—Method of Test for Conformance to BACnet Standard 180-2018 -- Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems
4. ASHRAE Standard 195-2013—Method of Test for Rating Air Terminal Unit Controls
5. ASHRAE Guideline-1.4-2019—Preparing Systems Manuals for Facilities
6. ASHRAE Guideline-11-2018—Field Testing of HVAC Controls Components
7. ASHRAE Guideline 22-2012—Instrumentation for Monitoring Central Chilled-Water Plant Efficiency
8. ASHRAE Guideline-36-2018—High Performance Sequences of Operation for HVAC Systems
9. ASHRAE Guideline-4-2019—Preparation of Operation and Maintenance documentation for HVAC-R systems
10. ASHRAE Guideline 6-2015 has additional information on refrigerant properties and definitions of terms associated with refrigerants.
11. CIBSE-Understanding Controls
12. Whole Building Design Guide https://www.wbdg.org/facilities-operations-maintenance

13. ANSI/ACCA 14 Quality Maintenance of Commercial Refrigeration Systems and ACCA 4 Quality Maintenance of Residential HVAC Systems

ANSI/ASHRAE/UNEP Reference Documents

1. Section 7 of ANSI/ASHRAE 15-2022 covers leak detection and ventilation of machine rooms and Section 10 covers storage and handling of refrigerants.
2. ANSI/ASHRAE 34-2022 has lists of refrigerants and their safety classification.
3. Material Safety Data Sheets (MSDSs) provide information on shipping, storage, and handling of specific refrigerants/secondary fluids (SFs).
4. Refer to ASHRAE Standards 147, 34, and 15; ISO 817 and ISO 5149 Parts 1, 2, 3, and 4; and EN 378.
5. UNEP Refrigerant Driving License, www.RDLprogram.org.

O&M Best Practice Checklist

4

Preventive Maintenance of Automatic Controls

OBJECTIVES

The goals of a comprehensive preventative maintenance (PM) program include the following:

- Reducing capital repairs
- Reducing unscheduled shutdowns and repairs
- Extending equipment life, thereby extending facility life
- Realizing life-cycle cost savings
- Providing safe, functional systems and facilities that meet the design intent
- Lowering system downtime and better performance
- Fewer safety incidents and/or refrigerant releases
- Managing the equipment service needed on-site in a timely manner
- Periodically leak checking and maintaining proper documentation (including recordkeeping, repair documentation, demonstrating compliance with local reporting requirements, etc.)
- Documenting PM activities reported through a log or CMMS work order system

MEASURES OF SUCCESS

✓ Increased equipment uptime
✓ Maintained energy efficiency
✓ Elimination of unplanned outages
✓ Overall O&M cost reductions
✓ Reduction in refrigerant loss
✓ Comprehensive log of system performance, refrigerant loss, maintenance operations, etc., over time.

Topic	Actions	Notes
G. PM for Automatic Controls: Direct Systems	The following maintenance tasks are required to be *performed and properly documented.*	
	☐ Perform weekly leak checks of all temperature sensors.	
	☐ Document in daily maintenance log.	
	☐ Check refrigerant pressure transducers when used to measure pressures remotely.	
	☐ Install leak detection sensors in appropriate locations.	
H. PM for Automatic Controls: Indirect Systems	The following maintenance tasks are to be performed in *addition to those tasks listed above for direct systems.*	
	☐ Meet all direct systems requirements above.	
	☐ Check anticorrosion sensors, if needed.	
I. PM for Automatic Controls: VRF Systems	*Periodic maintenance of VRF systems is essential to keep them effective and efficient. Follow all OEM instructions and safety requirements while performing maintenance tasks.*	
	☐ Inspect and clean filter weekly.	
	☐ Perform general cleaning of temperature sensors heat exchanger quarterly and semiannually.	
	☐ Inspect and tighten wires to sensors as needed semiannually.	
	☐ Check parameters against the SUDS and note variances.	
	☐ Manually check temperatures and flow annually and compare to control readings on the BAS front end.	

Operation & Maintenance Guidance Sheet

5

Energy-Efficient Operation

Mindset: An efficient plan is an economical and sustainable plant.

GENERAL INFORMATION

Energy is the main input for the operation of any vapor-compression-based or absorption-based air-conditioning and refrigeration (RAC) system. Due to their low-temperature operation, energy consumption is high, resulting in higher energy costs. In the case of water-cooled systems, the cost of water consumption is also a factor to be considered apart from the maintenance cost of the whole system.

RAC systems have vast applications in the multiunit residential, commercial, and industrial sectors. Systems are selected based on capacities, required plant size, performance requirements, availability of cooling water, and environmental issues.

This guidance sheet deals with two basic types of cooling systems: indirect and direct.

INDIRECT SYSTEMS

Indirect systems are central cooling and heating systems used in medium- and large-sized plants for various applications. They include:

- systems consisting of air-cooled or water-cooled vapor-compression chillers with or without heat recovery units
- brine and glycol chillers for commercial/industrial applications.
- absorption chillers: Water chillers based on lithium bromide water (LiBr) solution for comfort air conditioning and process cooling
- heat pumps for chilling and heating

DIRECT SYSTEMS

Direct systems are systems where refrigerant directly flows through the evaporators for cooling spaces/processes. They are used for small- and medium-sized applications, such as

- split AC and heat pumps
- packaged AC units
- packaged thermal AC units (PTACs)
- variable refrigerant flow (VRF) units

Multizone VRF Systems for AC

Multizone VRF units incorporate either inverter-driven compressors or digital compressors, which produce the cooling capacity as needed. The controls help to maintain the evaporating temperature as high as possible, thus saving energy required by the compressor.

COMMERCIAL/INDUSTRIAL REFRIGERATION SYSTEMS

This guidance sheet also addresses commercial and industrial refrigeration systems, including

- centralized chilled-water systems for process applications
- low-temperature centralized brine/glycol cooling systems for commercial and industrial applications
- heat pumps for chilling and heating applications
- absorption chillers using LiBr solution for cooling water for AC and process cooling. Temperatures normally as low as 1°C (33.8°F)
- direct expansion (DX)/flooded/pumped circulation systems for chilling and freezing storage plants

OBJECTIVES FOR ENERGY-EFFICIENT OPERATION

- Identify parameters impact the energy consumption of the various RAC systems.
- Study the methods to evaluate the actual energy performance of systems vis-à-vis the design basis.
- Identify factors that need to be checked/attended to improve the system’s energy efficiency.

- Understand the utility of instrumentation, controls, and automation to ensure energy-efficient operation.
- Identify methods to achieve a reduction in water consumption and maintenance costs.

BEST PRACTICES FOR ENERGY-EFFICIENT OPERATION

To achieve the energy-efficient operation of RAC systems, the operation manager and staff must understand some basic factors related to the system design and its components.

The energy efficiency of ACR systems broadly depends on the following factors.

Factors Related to Basic Design of the Systems

This involves the system type, refrigerant used, selected evaporating and condensing temperatures, superheat, and liquid subcooling.

- Condenser type: for example, air-cooled, water-cooled, or evaporative.
- Evaporators type: liquid chillers, air coolers, for example, AH units, fan-coil units, air coolers for cold storage (coolers and freezers), etc.
- Liquid feed type: DX, flooded, pumped circulation.
- Automation type for capacity control, temperature, and relative humidity control.

Factors Related to Energy Efficiency and Power Consumption of Various Equipment/Components

- **Compressors**

  Compressors work like the heart of the refrigeration system. Compressors consume a significant part of the total energy consumption of the system.

  Most ACR systems must cater to partial load conditions for a major part of operating hours. Most compressors have built-in capacity control systems/variable frequency drives (VFDs) that help reduce the energy required during partial loads. However, the part-load energy efficiency is quite important in terms of the system's overall energy performance. The compressor's power consumption depends on the evaporating and condensing temperatures. Belt drives (for belt-driven units) and VFDs cause some small losses.

Compressor energy consumption also depends on the type, design, and refrigerant used.

- **Air-Cooled Condensers: Related Parameters**
    - Condensing pressure depends on ambient air temperature and airflow
    - For airflow: design versus measured flow
    - Temperature difference (TD) between inlet and exit air
    - Fan motor power consumption: design versus actual measured during operation
- **Water-Cooled Condensers: Related Parameters**
    - Condensing pressure depends on water inlet/outlet temperature and flow
    - Design water flow versus measured flow
    - Water temperature difference between inlet and outlet of condenser: Design versus actual
    - Water pressure drop across the condenser: Design versus actual
    - Power required for water pumps: Design versus measured during operation
- **Cooling Towers for Water-Cooled Systems: Related Parameters**
    - Airflow: Design versus actual
    - Water inlet and outlet temperature: Design versus actual
    - Motor power consumption: Design versus actual
    - Inspection of scaling/impurities in sump, nozzle sprays, and strainers
    - Water quality tests
- **Evaporative Condensers: Related Parameters**
    - Offers a combined function of condensers and cooling towers and gives better energy efficiency and water-saving advantages

- Airflow: Design versus actual
- Water flow: Design versus actual
- Fan motor power consumption: Design versus actual
- Pump motor power consumption: Design versus actual
- Scaling inspections and water quality tests

- **Evaporators for Indirect Systems: Related Parameters**
- **Evaporators for Water/Brine Chillers**
  - Water flow/brine flow through the chiller: Design versus actual
  - Pressure drop across chillers: Design versus actual
  - Temperature difference (inlet–outlet temperature) across the chillers
  - Pump power consumption: Design versus measured
- **Evaporators for Direct Systems: Related Parameters**
- **AHUs/Indoor AC units/Cold Storage Air-Cooling Units**
  - Airflow: Design versus measured
  - Air inlet and outlet temperature and relative humidity
  - External static pressure at the fan outlet
  - Fan power consumption: Design versus measured
- **Absorption Chillers**

These chillers use heat as the main energy input. Only small liquid pumps, which consume about 3% of the total energy, need electrical power. The units can also work on steam from boilers, waste steam from processes, direct-fired fuels, solar energy, etc.

The working medium is a solution of lithium bromide and water, where water acts as a refrigerant. These units can give cooling up to 0°C.

The coefficient of performance (COP) for a single-effect chiller is about 0.7. Double- and triple-effect chillers give a higher COP.

For lower temperature applications, an ammonia-water combination can be used for applications up to –30°C.

Maintenance Practices

Apart from following proper operational practices, using available automation systems, regular maintenance, and yearly overhauling are essential to ensure energy-efficient operation.

The frequency of regular maintenance must be followed as per the system contractor's recommendations.

- Appendix 1 gives a sample checklist for the maintenance of a chilled-water system.
- Appendix 2 gives an example of annual plant maintenance checklist.
- Appendix 3 gives an example checklist for absorption chiller maintenance.
- Appendix 4 includes an additional checklist giving suggested points for energy saving in chillers.
- Appendix 5 includes a list of instruments and controls.
- Record keeping: The operating team shall maintain a proper record of various operational parameters regularly. A record must also be kept for all repairs and maintenance activities and the annual maintenance schedule.

Training

Training must be emphasized for the operating team to stress the need for regular and timely inspection and maintenance. Various aspects of energy efficiency need to be highlighted in the training program.

INDUSTRIAL AND COMMERCIAL REFRIGERATION SYSTEMS

Industrial refrigeration systems have extensive application areas, for example:

- Chilled brine/glycol systems for various industrial applications
- Direct systems for cold stores—both chilled and frozen food stores and other applications

Refrigeration systems must meet cooling requirements generally, in the range of 10°C to –40°C (50°F to –40°F). Depending on the required temperature range, an integrated system with the following combinations is selected:

- Single-stage compressors for temperatures up to –15°C to –20°C (–5°F to –4°F), depending on the refrigerant.
- A combination of single- and two-stage compound compressors for medium and low temperatures, generally up to –40°C (–40°F) or lower.
- A combination of low-stage and high-stage compressors to meet the medium and low temperature requirements.

In the case of a low- and high-stage compressor combination, the energy consumption depends more on the intermediate pressure between the two compressors. Higher intermediate pressure is beneficial for energy saving. However, the selection of compressors and intermediate pressure depends on the refrigeration load at the low and medium temperature levels.

Cascade Systems

In the case of very low temperature applications, cascade systems are sometimes used. They incorporate a low-stage and high-stage system, where the condenser of the low-stage system acts as an evaporator for the high-stage system. Two different refrigerants are used for the low- and high-stage circuits. The system's overall energy efficiency depends on the refrigerant selected, intermediate pressure, and performance of various components.

Large industrial systems use reciprocating compressors, screw compressors, or a combination. The best way to achieve energy savings for part loads is by auto unloading cylinders or using VFDs. For screw compressors with slide valve unloading, there will be an efficiency penalty on part load. In the case of a combination of reciprocating and screws, it is best to use reciprocating for the system capacity control and screws for fixed capacity to achieve better energy efficiency.

Commercial Refrigeration

Most modern small and medium systems are compressor rack systems comprised of a bank of semi-hermetic or hermetic compressors mounted on a common base and connected to common suction and discharge headers. This enables the capacity control of the compressor to match the required evaporator load by using different combinations of compressors in operation. VFD on one/two compressors can help finetune capacity and achieve energy saving.

Typical Example of Load Variation in Coolers and Freezers

Cooling loads vary from 30% to 100% in coolers. Nearly 70% of the load occurs for about 1400 hours per year. A load between 85% to 95% occurs for less than 500 hours. Among various options of evaporator pressure control and variable from speed control, the option of fixed evaporation pressure and variable-speed fan speed control is an easier and reasonable one. The best result, however, with both parameters, is variable.

For freezers, about 80% of the load occurs for about 1800 hours per year. The best COP is obtained with variable evaporating pressure and variable fan speed combinations.

MONITORING ENERGY PERFORMANCE OF THE SYSTEMS

It is important to measure and trace the performance of HVAC&R equipment to ensure that it is performing as intended. Dashboards and trending graphs can provide an immediate visual representation of energy use and efficiency to highlight problems and items that need to be addressed.

Systems with Air-Cooled Chillers

	Design	Data and Actual Measurement	Remarks
General Observations			
Refrigerant			
Visual Condition of Condenser Coil: Clean/Needs Cleaning			
Visual Condition of Chiller and Piping Insulation			
Compressor/Motor Vibrations/Noise			
Visual Condition of Adiabatic for Condenser Air Pad (if installed) Cooling			
Measurement of Operating Parameters			
Evaporating pressure, kg/cm^2 (psig)			
Condensing pressure, kg/cm^2 (psig)			
Heat Exchanger Inlet/Outlet Temperatures, °C (°F)			
Evaporator Air Inlet/Outlet Temperature, °C (°F)			
Evaporator Liquid Flow, l/s (gpm)			
Pressure at Evaporator Liquid Inlet and Outlet, kg/cm^2 (psig)			
Pressure Drop through Evaporator, kg/cm^2 (psig)			
Condenser Air Inlet/Outlet Temperature (TD), °C (°F)			
Condenser airflow, m^3/h (cfm)			
Refrigerant Temperature at Condenser Inlet/Outlet, °C (°F)			
Degree of Superheat at Inlet, °C (°F)			
Degree of Subcooling at Outlet, °C (°F)			

Power Consumption Readings			
Design Data			
Type of System: Direct/Indirect			
Design Temperature, °C (°F)			
Cooling Capacity: kW (Btu/h)			
Type of Compressor			
Refrigerant Used			
Type of Condenser: Air/Water Cooled			
Type of Evaporator: Water Brine Chiller AHU/FCU/Other			
Compressor Power Consumption			
At Full Load, kW (Btu/h)			
At Partial Load, ... (%) .... kW (Btu/h)			
Condenser Fan Power, kW (Btu/h)			
No. of Fans × Power of Each in kW = total kW (Btu/h)			
VFDs, kW (Btu/h)			
Belt Drive Loss, kW (Btu/h)			
Total Power Consumption, kW (Btu/h)			

Systems with Water-Cooled Chillers

	Design	Data and Actual Measurement	Remarks
General Observations			
Refrigerant			
Visual Condition of Chiller and Piping Insulation			
Compressor/Motor Vibrations/Noise			
Measurement of Operating Parameters			
Evaporating Pressure, kg/cm^2 (psig)			
Condensing Pressure, kg/cm^2 (psig)			
Heat Exchanger Inlet/Outlet Temperatures, °C (°F)			
Evaporator Liquid Flow, l/s (gpm)			
Pressure at Evaporator Liquid Inlet and Outlet, kg/cm^2 (psig)			
Pressure Drop through Evaporator, kg/cm^2 (psig)			
Water Temperature at Condenser Inlet/Outlet (TD), °C (°F)			
Water Flow through Condenser, l/s (gpm)			
Water Pressure at Condenser Inlet and Outlet, kg/cm^2 (psig)			
Pressure Drop through Condenser, kg/cm^2 (psig)			
Condenser Water Pump Cischarge Pressure, kg/cm^2 (psig)			
Refrigerant Temperature at Condenser Inlet/Outlet, °C (°F)			
Degree of Superheat at Inlet, °C (°F)			

Degree of Subcooling at Outlet, °C (°F)			
Power Consumption Readings			
Compressor Power Consumption			
At Full Load, kW (Btu/h)			
At Partial Load, ... (%) .... kW (Btu/h)			
Chilled-Water Pumps, kW (Btu/h)			
Condenser Water Pump, kW (Btu/h)			
Cooling Tower Fans, kW (Btu/h)			
Total Power Consumption, kW (Btu/h)			

Air-Handling Units/Fan Coil Units for Water-Cooled Systems

	Design	Data and Actual Measurement	Remarks
General Observations			
Visual Condition of AHU Insulation			
Noise and vibration of the AHU/FCU			
Condition of filter			
Condition of cooling coil			
Measurement of Operating Parameters			
Air Inlet/Outlet Temperature (TD), °C (°F)			
Water Temperature at Coil Inlet/Outlet (TD), °C (°F)			
Water Flow, l/s (gpm)			
Water Pressure Drop Through Coil, kg/cm^2 (psi)			
Power Consumption Readings			
AHU/FCU Motor Power Consumption			
At Full Load, kW (Btu/h)			

At Partial Load, ... (%) .... kW (Btu/h)			
VFDs, KW (Btu/h)			

AHUs /FCUs for Direct Expansion AC Systems

	Design	Data and Actual Measurement	Remarks
General Observations			
Visual Condition of Insulation on AHU			
Noise and Vibration of the AHU/FCU			
Filter Condition Check			
Coil Condition Check			
Measurement of Operating Parameters			
Evaporating Pressure, kg/cm^2 (psig)			
Air Inlet/Outlet Temperature, Dry-Bulb (DB), °C (°F)			
Air Inlet/Outlet Temperature, Wet-Bulb (WB), °C (°F)			
Power Consumption Readings			
AHU/FCU motor power consumption			
At full load, kW (Btu/h)			
At partial load, ... (%) .... kW (Btu/h)			
VFDs KW (Btu/h)			

VRF Systems

	Design	Data and Actual Measurement	Remarks
Outdoor Unit			
Main Power Source Voltage	±10% of Rated Voltage		
Operation Circuit Voltage	±10% of Rated Voltage		
Fan Noise and Vibration	None		
Fan Operating Current, amp			
Outlet/Inlet Air Temperature (TD), °C (°F)	Temperature Difference of 9°C to 11°C (48°F to 52°F)		
Suction Pressure, kg/cm^2 (psig)	3 to 6.5 kg/cm^2 (psig)		
Discharge Pressure (Liquid Pressure), kg/cm^2 (psig)	10 to 18 kg/cm^2 (psig)		
Compressor Operating Current, amp			
Invertor Compressor Frequency			
Suction Pipe Temperature, °C (°F)	3°C to 15°C (37.4°F to 59°F)		
Discharge Pipe Temperature, °C (°F)	95°C to 105°C (203°F to 221°F)		
Crankcase Heater	Should be Warm		
Indoor Unit			
Power Source Voltage	±10% of Rated Voltage		
Room Temperature, °C (°F)			
Supply Air Temperature, °C (°F)			
Fan Rotation Direction	Positive Direction		
Fan Noise and Vibration	None		

Refrigeration Systems

	Design	Data and Actual Measurement	Remarks
Compressor Suction Pressure, kg/cm^2 (psig)			
Compressor Discharge Pressure, kg/cm^2 (psig)			
Compressor Oil Pressure, kg/cm^2 (psig)			
Compressor Motor Current, amp			
Condenser Fan Motor Current, amp			
Air Cooling Unit Fan Motor Current, amp			
Room Temperature, °C (°F)			
AHU Airflow, m^3/h (cfm)			

Refrigeration Capacity, Power Consumption, and COP Calculations

Typical for full-load operation

Air-Cooled Chillers

Refrigeration Capacity of Full Load

$$\text{cooling capacity} = \dot{m} \times Cp \times TD = \text{Btu/h} \qquad \text{(I-P)}$$

$$\text{cooling capacity} = \dot{m} \times Cp \times TD = \text{kW} \qquad \text{(SI)}$$

where

water flow rate through chiller $\dot{m}$, lb/h (kg/s)

specific heat capacity of water *Cp* at constant pressure, Btu/lb°F (kJ/ kg K)

temperature difference (water inlet–water outlet) TD, °F (°C)

Power Consumption

compressor motor (including belt losses, if applicable), kW

condenser fan motors, kW

chilled-water pumps, kW

$\sum$kW total power consumption = compressor motor power + condenser fan motors power + chilled-water pumps power

$$\text{total power consumption} = 3413 \text{ X } \textstyle\sum \text{kW} \qquad \text{(I-P)}$$

$$\text{total power consumption} = \textstyle\sum \text{kW} \qquad \text{(SI)}$$

Air-Cooled Chiller COP

$$\text{COP} = \frac{\dot{\text{m}}\ X\ Cp\ x\ TD}{\mathbf{3413\ x} \sum \mathbf{kW}} = \text{(dimensionless number)} \qquad \text{(I-P)}$$

$$\text{COP} = \frac{\dot{\text{m}}\ X\ Cp\ x\ TD}{\sum \mathbf{kW}} = \text{(dimensionless number)} \qquad \text{(SI)}$$

Percentage of design load as observed during measurement =

$$\frac{Cooling\ capacity\ as\ per\ measurement}{designed\ capacity}$$

Water-Cooled Chillers

Refrigeration Capacity on Full Load

$$\text{cooling capacity} = \dot{\text{m}} \times Cp \times TD = \text{(Btu/h)} \qquad \text{(I-P)}$$

$$\text{cooling capacity} = \dot{\text{m}} \times Cp \times TD = \text{kW} \qquad \text{(SI)}$$

where

water flow rate through chiller, $\dot{m}$ = lb/h (kg/s)

specific heat capacity of water Cp at constant pressure = Btu/ lb.°F (kJ/ kg K)

temperature difference (water inlet–water outlet) TD = °F (°C)

Power Consumption

compressor motor (including belt losses, if applicable) = kW

chilled-water pumps = kW

condenser water pumps = kW

cooling tower fan motors = kW

$\sum$kW total power consumption = compressor motor power + cooling tower fan motors + condenser water pumps + chilled-water pumps power

$$\text{total power consumption} = 3413 \times \sum \text{kW} \qquad \text{(I-P)}$$

$$\text{total power consumption} = \sum \text{kW} \qquad \text{(SI)}$$

Water-Cooled Chiller COP

$$\text{COP} = \frac{\dot{\text{m}} \times Cp \times TD}{\mathbf{3413} \times \sum \mathbf{kW}} \text{(dimensionless number)} \qquad \text{(I-P)}$$

$$\text{COP} = \frac{\dot{\text{m}} \times Cp \times TD}{\sum \mathbf{kW}} \text{ (dimensionless number)} \qquad \text{(SI)}$$

Air-Handling Equipment

Refrigeration Capacity and Power Consumption

fan motor power = kW

reheater in operation (if applicable) = kW

Total power consumption = fan motor power + reheater in operation (if applicable)

Total Chilled-Water System COP

total system power consumption = power consumed by chiller system + power consumed by air-handling equipment.

$$\text{system COP} = \frac{\dot{\text{m}} \times Cp \times TD}{3413 \times [\sum \text{kW chiller system} + \sum \text{kW air-handling equipment}]} = \text{(dimensionless number)} \qquad \text{(I-P)}$$

$$\text{system COP} = \frac{\dot{\text{m}} \times Cp \times TD}{\sum \text{kW chiller system} + \sum \text{kW air-handling equipment}} = \text{(dimensionless number)} \qquad \text{(SI)}$$

VRF Systems

Cooling Capacity

$$\text{room cooling capacity} = \dot{\text{m}} \times (\text{h2}-\text{h1}) = \text{Btu/h} \qquad \text{(I-P)}$$

$$\text{room cooling capacity} = \dot{\text{m}} \times (\text{h2}-\text{h1}) = \text{kW} \qquad \text{(SI)}$$

where

$\dot{m}$ = airflow in lb/h (kg/s)

h2 = Enthalpy of air at outlet of evaporator in Btu/lb (kJ/kg)

h1 = Enthalpy of air at inlet of evaporator in Btu/lb (kJ/kg)

Power Consumed

$$\text{Condensing Unit and AHU/FCU} = \sum \text{kW}$$

1. Compressors
2. Condenser fan motors
3. AHU/FCU

COP for VRF Systems

$$\text{system COP} = \frac{\text{room cooling capacity Btu/h}}{3413 \times \sum \text{kW}} = \text{(dimensionless number)} \qquad \text{(I-P)}$$

$$\text{system COP} = \frac{\text{room cooling capacity kW}}{\sum \text{kW}} = \text{(dimensionless number)} \qquad \text{(SI)}$$

COP: An Important Indicator of the System Performance

COP indicates the energy efficiency of the systems. The higher the COP, the better the energy performance. If the COP of the running system is lower than the design or initial COP, the reason for loss of efficiency needs to be assessed and corrective measures should be taken to improve the performance.

Maintenance Practices Appendices

5

Energy-Efficient Operation

APPENDIX 1
SAMPLE CHECKLIST FOR THE PROPER MAINTENANCE OF A CHILLED-WATER SYSTEM

- Periodically sample, analyze, monitor, and trend key variables in refrigeration system fluids as indicators of fluid (system) health, e.g., water treatment (hardness, pH), compressor lube oil (elemental analysis, viscosity, wear debris, moisture, acid number, etc.), refrigerant condition (water content, high boiling residue, noncondensable, volatile impurities, acid number, etc.), and secondary fluid condition (freeze point, pH, reserve alkalinity, inhibitor levels, degree of contamination, etc.).
- Collect, review, and compare machine-operating data against design prior to annual overhaul to identify performance issues to be investigated/resolved during maintenance outage (water-side pressure drops versus flow, heat exchanger approach temperatures, compressor discharge temperature, condenser/evaporator pressure, oil pressure/temperature, etc.
- On machines equipped with a hot gas bypass valve, prior to maintenance shutdown, verify valve is not leaking hot gas to the evaporator by monitoring downstream temperature (thermocouple under insulation).
- Clean heat transfer surfaces (airside coils, waterside tubes) annually.

- Conduct a visual inspection of condenser/evaporator tubes before and after brushing.
- Visual inspection of chiller water-box division baffles and gaskets prior to cleaning for evidence of bypassing due to corrosion, gasket deterioration, or baffle-to-tube sheet cracked welds.
- Monitor/replace filter-drier cores to keep refrigerant dry.
- Benchmark compressor/motor vibration signature and trend condition over time.
- Eddy-current test condenser and evaporator tubes on aging equipment periodically, especially condensers using surface water.
- Maintain refrigeration insulation system and vapor barrier hermetic integrity to avoid corrosion under insulation and potential for refrigerant loss.
- Monitor for evidence of condensation and/or ice on refrigerant or secondary coolant piping distribution systems indicating inadequate or compromised insulation systems and replace as needed.
- Minimize ambient moisture ingress to equipment open for maintenance by limiting open connections, installing temporary covers (polyethylene film or gasketed covers) at end of the shift.
- Conduct a thorough evacuation and dehydration of the equipment after maintenance per OEM recommendations prior to charging with refrigerant.
- Transfer refrigerant from equipment to secure storage tanks for extended idle periods to avoid potential for refrigerant loss. Avoid using high pressure water blasting to clean tubes or tube-sheets and only under strict supervision when necessary.
- Tagging of all refrigerant connections disturbed during maintenance to facilitate targeted leak checking during the evacuation/dehydration.

Energy Conservation Checklist for Chiller Operators

Sr. No.	Description
1	For water-cooled chillers, ensure the cooling tower fills are cleaned regularly, leading to the lowest cooling water temperature.
2	For water-cooled chillers, follow regular blowdown practice for the cooling tower, ensuring proper TDS (Total Dissolved Solids) of the cooling tower water. This will lead to lower fouling and better energy efficiency.
3	For water-cooled chillers, do not use cooling water flow control without verifying its efficacy. Many times, lowering the flow could lead to increased compressor power.
4	For air-cooled chillers, clean the condenser coils regularly using a suitable water jet system. This will ensure adequate air circulation.
5	For air-cooled chillers, do not use fan speed control to as low as 15°C (59°F) ambient; it helps to lower the compressor power. Fan speed control should be used only if the ambient temperature is below 15°C (59°F).
6	Get optimum approach temperatures from chiller manufacturers and ensure that descaling activity is taken up if the approach is higher than specified.
7	Investing in and running a good water treatment plant for the cooling tower makeup water is always better—it helps overall energy conservation versus running the chiller with a heavily fouled condenser.
8	In a multichiller system, only run as many chillers as required to cater to the load and keep the chillers running at maximum load for better efficiency. Use a chiller plant manager system to automate the chiller system.

APPENDIX 2
ANNUAL PM EXAMPLE CHECKLIST

Annual PM including Cleaning Condensers (Water-Cooled Tubes, Heat Exchangers, and Air-Cooled Condensers)

- Following an inspection of a water-cooled heat exchanger mechanical cleaning, if calcium deposits remain on the inside diameter of the tube surface, acid cleaning may be determined to be a secondary process.
- Eddy current test chiller tube for evaporator and condenser heat exchangers. Eddy testing provides an improved method of determination of tube wall and tube support conditions.
- Meg Ohm test motors annually during annual maintenance and record for historical reference trending. Disconnect semiconductors from motor wiring before meg Ohm testing chillers and equipment (standalone VFDs) to ensure accuracy.
- Refrigerant and oil analysis sampling taken during the operating season evaluated by a certified chemist, laboratory, or manufacturer to determine the chemical content of the refrigerant and/or oil provides noninvasive annual testing to compare with manufacturers' factory standards. Further consultation with the chiller manufacturer should be conducted where extremes are found.
- Water-cooled condensers pull condenser strainer annually or as required based upon operations logs of strainer pressure drop or system performance.
- Clean water-cooled cooling towers annually.
- Water Treatment Management
    - Water systems maintain both open-loop and closed-loop treatment. Ensure minimum total dissolved solid levels are at ±1000 to 1200 ppm and has a pH range of 8.0 to 9.0.
    - Water treatment criteria for water RACs ultimately adhere to conditions installed.

- Condenser and chilled-water pumps perform pump and tower fan PM. Follow O&M guidelines for greasing the motor and bearings as required.
- Pumps utilized for variable flow or air: Disconnect VFD electrically, vacuum interior, and check tightness of the electrical power connections.
- Refrigerant Management System
  - During annual inspections, verify pick-up sensing filter(s) are clean.
  - Have refrigerant specific calibration test performed annually, either in house or outsourced to a certified firm. Ensure refrigerant monitor TEL levels are calibrated for alarming for the refrigerant utilized. See ASHRAE Standards 15 and Standard 34.
  - Test refrigerant management system annually for functionality of the fan emergency purge exhaust and nonemergency ventilation exhaust and/or air handler makeup (if provided).
- Emergency Purge Exhaust: cfm = 100 × G (0.5), where *G* equals the largest chiller quantity. (For example, refrigerant charge = 1600 lbs. So, 100 × [1600 (0.5)] = 100 × 40, or 4000 cfm.
- Normal MER Ventilation: 0.5 cfm/ft^2 = RAC MER cfm (e.g., Quantity 3500-ton chillers comprise a RAC plant of nominally 1750 ft^2. 1750 ft^2 × 0.5 = 875 cfm RAC MER ventilation exhaust.)
- Where a refrigerant management system uses a 100% air-handling makeup unit, verify condition monthly. Where RAC MER outdoor air louvers are installed, inspect for debris at louvers biannually.
- Where refrigerant management system alarms MER within plant and external to plant entrances, verify system safety sequences annually in testing protocol.
- Self-Contained Breathing Apparatus (SCBA), if used: Annually verify functional operation. Have the safety officer test for appropriate form fit of those utilizing equipment. (Note: see regulatory requirements.)
- Electric Infrastructure:

    - Perform PM and testing of electric switchgear annually.
    - Thermal imaging of equipment for heat points, including buss bars, power contacts, and contactors.
- Verify building automation system (BAS) controls operation for starting/shutdown for plant equipment annually.
- If the plant uses pneumatic control, verify air compressor operation for O&M PM. Ensure that the refrigerant air drier is functional with an annual condenser coil cleaning. Change oil and filter as noted in manufacturer O&M.

APPENDIX 3
ABSORPTION CHILLER MAINTENANCE CHECKLIST

The performance of the absorption chiller degrades, mainly due to the following reasons:

- **Condenser tube scaling or fouling.** Scaling or fouling in the condenser tube results in an increase in condensing temperature and pressure by reducing the COP. Defection is possible by measuring the temperature of the refrigerant of a condenser outlet. Temperature difference (TD) between the condensing liquid and cooling water at the outlet indicates condenser tube scaling or fouling.
- **External to Internal Leakage or Only Internal Leakage.** An absorption chiller works in a vacuum, and the most intense vacuum is in the absorber. Air leakage to the absorber causes performance degradation. If the leak is minor, the machine will still work but at a lower capacity and lower COP. If the leakage is higher, the machine may go into crystallization and must be stopped for decrystallization. Air leakage can be detected by observing the temperature difference between LiBr at the pump outlet and cooling water, which is normally around 6°C (42.8°F).
    - In case internal leakage occurs, the dilute solution of LiBr will mix with concentrated solution going to the absorber, causing a reduction in the capacity of the chiller. Pressure higher chilling capacity, chiller will need more heat input, resulting in a lower COP. Indication of leakage can be seen by sampling of concentrated Li-Br solution at inlet and outlet of heat exchanger.
- **Corrosion.** Corrosion can cause
    - generation of noncondensable gases
    - fouling/choking of heat exchangers
    - effect on absorber and generator performance
    - reduction in the flow of LiBr solution
- An increase in purge tank pressure and LiBr solution pressure at the pump's outlet are indicators of corrosion. It is a good practice to

remove all LiBri in the tank once a year and allow it to settle for 24 hours before refilling it, leaving corrosion products at the bottom of the tank.

- The reduced flow of LiBr solution will reduce the capacity of the chiller.
- This can be avoided by observing increased pressure drop across the heat exchanger. The corrosion products may also get locked in the pump impeller, affecting pump performance.
- **Note:** Corrosion causes depletion of the inhibitor. It is necessary to check the inhibitor’s level at least twice a year. If the level goes down considerably, corrosion can be concluded.

APPENDIX 4
FURTHER ENERGY SAVINGS CHECKLISTS

Operations management can consider the following add-on systems to achieve energy/water savings.

- Air-to-air heat exchanger (energy recovery) unit for outdoor air by energy exchange with outgoing air. Benefit: approximately 70% in cooling outdoor air.
- Condenser air precooling using adiabatic cooling in case of high ambient temperature. Benefit reduction in air temperature lower conducting temperature.
- Heat recovery systems offer advantages in generating hot water from the waste heat available at the compressor discharge side.
- Collect condensated rainwater and feed it to a cooling tower or evaporative condenser. Benefit: water savings.
- VFDs on compressors, pumps, cooling tower fans, and air-cooled condenser fans, where beneficial during part loads.
- Using solar energy as best as possible.

The most effective method to reduce energy costs—both economically and environmentally—is through discretionary operations, such as turning off energy systems when they provide no benefit. Extensive labeling and inclusive, clear instructions on operating systems lead to better control of their use. The following are additional suggestions for basic energy management to control and reduce energy consumption.

- shutdown HVAC&R systems when not required
- reduce air leakage
- reduce ventilation rates during periods of low occupancy
- shutdown exhaust fans when not required
- seal or repair leaks in ducts and pipes
- reduce water leakage
- turn off lighting: remove unnecessary lighting, add switched circuits, and use motion sensors and light-sensitive controls

- use temperature setup and setback
- cool with outdoor air
- seal unused vents and ducts to the outside
- tune up systems before heating and cooling seasons
- take the transformer offline during idle periods
- disconnect or turn off all nonessential loads
- educate tenants and occupants on energy-saving practices

The other most effective method for reducing energy costs is to tune energy systems to optimal performance, an ongoing process combining training, preventive maintenance, and system adjustment. Tasks for optimizing performance include the following:

- training operating personnel
- tuning combustion equipment
- adjusting gas burners to optimal efficiency
- following an established maintenance program
- cleaning or replacing filters
- cleaning fan blades and ductwork
- cycling ventilation systems to coincide with occupied spaces
- using water treatment

APPENDIX 5
INSTRUMENTATION AND CONTROLS FOR CHILLER SYSTEMS CHECKLIST

The following instruments and controls are used to monitor and control the chilled-water plants for air conditioning of the office area, malls, residential buildings, etc.

- **Suction Pressure Switch/Transmitter.** This is mounted on the suction line of the compressor. It is used as safety for low suction pressure. It also can be used for load sharing of multiple compressors running in parallel as well as for monitoring purposes.
    - Normal Range: (0 to 5 kg/cm^2g) (psig)
- **Discharge pressure Switch/Transmitter.** This is mounted on the discharge line of the compressor. It is used as safety for high discharge pressure. This can also be used for monitoring purposes.
    - Normal Range: (0 to 25 kg/cm^2g) (psig)
- **Oil Pressure Switch/Transmitter.** This is mounted on the oil line in case of recip. compressor and on the external oil circuit in case of a screw compressor. Actual oil pressure is the difference between oil pressure and suction pressure for recip. compressor and oil pressure and discharge pressure for screw compressor. It is used as a safety control for low oil pressure. This can also be used for monitoring purposes.
    - Normal Range: 0 to 25 kg/cm^2 (0 to 355.5 psig)/ 0 to 5 kg/cm^2 (0 to 71.1 psig)
- **Discharge Temperature Switch/Transmitter.** This is normally used for a screw compressor. This is mounted on the discharge line of the screw compressor. It is used as safety for high discharge temperature. This can also be used for monitoring purposes.
    - Normal Range: 0°C to 100°C (32°F to 212°F).
- **Temperature Sensor (PT100) on Chiller Outlet/Chiller Inlet.** A temperature sensor on a chiller outlet is used as safety for frizzing of chiller as "ANTIFREEZ." Chiller capacity is calculated by the chilled-water flow and the difference in chiller outlet and inlet temperatures.

- Normal Range: (0 ohms to 750 ohms).

- **Temperature Sensor (PT100) on Condenser Inlet/Outlet.** The heat rejected by the condenser is calculated by difference in the inlet and outlet condenser water temperatures and the water flow.
- **Flow Switch/Transmitter on the Chilled-Water Line.** This is used as safety for low chilled-water flow. It is also used to calculate chiller capacity.
- **Flow Switch/Transmitter on the Condenser Water Line.** This is used as safety for low condenser water flow.
- **Pressure Relief Valves.** These are normally provided on the high-pressure vessel like condenser for safety of the vessel. The relief valve opens to the atmosphere when the pressure inside the vessel increases above safety limits.
- **Variable Frequency Drive (VFD).** A VFD may be used for capacity control of the compressor. It can be connected to the control/monitoring system for automatic operation and to view RPM and other electrical parameters of the drive viz current, frequency, etc.
- **Electrical parameters viz. current/voltage/power are measured by the instruments mounted on electrical panel.** The power consumed by the plant is measured by the kWh meter on the panel. The COP of the plat is calculated by the power consumed and the chiller capacity.

All the above instruments must be connected to the receiver switch/panel to perform suitable actions. If used as digital instruments, all process parameters stated above can be viewed/monitored/controlled by the PLC/SCADA. Further, the parameters can be transmitted to various users via email or cloud technology.

Automatic control of central cooling and heating plants in building management is advantageous because performance and monitoring of the main plant and ancillary equipment is possible at one single point. The software to include is an energy management system (EMS) control, using VFDs for equipment such as chillers and pumps, cooling tower fan speed to improve system performance and control energy consumption to meet designed parameters, computer-aided facility for integrating other software, computerized maintenance management system, integration of the fire alarm system, etc.

Local instrumentation such as pressure gauges, temperature gauges, flowmeters, balancing devices, dampers, and energy meters is also important to monitor the effective performance and commissioning of the plant. In addition, caped thermowells, gauge cocks, duct openings, and volume dampers should be installed for system balancing.

ADDITIONAL INFORMATION AND RESOURCES

- ASHRAE. 2012. ASHRAE Guideline 22-2012, *Instrumentation for Monitoring Central Chilled-Water Plant Efficiency*. Peachtree Corners, GA: ASHRAE.
- ASHRAE. 2018. Chapter 6, “Controls and Control Strategies.” In *Guide for Sustainable Refrigerated Facilities and Refrigeration Systems*. Peachtree Corners, GA: ASHRAE.
- ASHRAE. 2020. Chapter 3, “Central Cooling and Heating Plants.” In *ASHRAE Handbook—HVAC Systems and Equipment*. Peachtree Corners, GA: ASHRAE.
- ASHRAE. 2020. Chapter 18, “Variable Refrigerant Flow.” In *ASHRAE Handbook—HVAC Systems and Equipment*. Peachtree Corners, GA: ASHRAE.
- ASHRAE. 2023. Chapter 36, “Solar Energy Use.” In *ASHRAE Handbook—Applications*. Peachtree Corners, GA: ASHRAE.

O&M Best Practice Checklist

5

Energy-Efficient Operation

OBJECTIVE

Follow proper maintenance procedures for refrigeration systems to operate energy efficiently.

MEASURES OF SUCCESS

- ✓ Minimizing total energy use: kWh, kWh per year (Btu/h or Btu/yr)
- ✓ Minimizing operation costs: energy, water, maintenance, etc.

Topic	Notes
J. Chilled-Water Systems with Air-Cooled Chillers	
	☐ **General Observations** • Refrigerant • Visual condition of condenser coil: clean/needs cleaning • Visual condition of chiller and piping installation • Compressor/motor vibrations/noise • Visual condition of adiabatic cooling system (pad or mist) (if installed) for condenser air cooling
	☐ **Measurement of Operating Parameters** • Saturated evaporating pressure kg/cm² (psig) • Saturated condensing pressure, kg/cm² (psig) • Heat exchanger inlet/outlet temperatures, °C (°F) • Evaporator water inlet/outlet temperature, °C (°F) • Evaporator liquid flow, l/s (gpm)

- Pressure at evaporator liquid inlet and outlet, kg/cm^2 (psig)
- Pressure drop through evaporator, kg/cm^2 (psig)
- Condenser air inlet/outlet temperature (TD), °C (°F)
- Condenser airflow, m^3/h (cfm)
- Refrigerant temperature at condenser inlet/outlet, °C (°F)
- Degree of superheat at inlet, °C (°F)
- Degree of subcooling at outlet, °C (°F)

☐ **Power Consumption Readings**

- Compressor power consumption
  - At full load, kW/hp/(Btu/h)
  - At partial load .... (%)....... kW (Btu/h)
- Condenser fan power, kW (Btu/h)
- Number of fans × power of each in kW = total kW (Btu/h)
- VFDs, kW (Btu/h)
- Belt drive loss, kW (Btu/h)

K. Chilled-Water Systems Water-Cooled Chillers

☐ **General Observations**

- Refrigerant
- Visual condition of chiller and piping insulation
- Compressor/motor vibrations/noise

☐ **Measurement of Operating Parameters**

- Evaporating pressure, kg/cm^2 (psig)
- Condensing pressure, kg/cm^2 (psig)
- Heat exchanger inlet/outlet temperatures, °C (°F)
- Evaporator liquid flow, l/s (gpm)
- Pressure at evaporator liquid inlet and outlet, kg/cm^2 (psig)
- Pressure drop through evaporator, kg/cm^2 (psig)

- Water temperature at condenser inlet/outlet (TD), °C (°F)
- Water flow through condenser, L/s (gpm)
- Water pressure at condenser inlet and outlet, kg/cm^2 (psig)
- Pressure drop through condenser, kg/cm^2 (psi)
- Condenser water pump discharge pressure, kg/cm^2 (psig)
- Refrigerant temperature at condenser inlet/outlet, °C (°F)
- Degree of superheat at inlet, °C (°F)
- Degree of subcooling at outlet, °C (°F)
- Evaporator water inlet/outlet temperature, °C (°F)

☐ **Power Consumption Readings**

- Compressor power consumption
    - At full load, kW (Btu/h)
    - At partial load .... (%) .... kW (Btu/h)
- Chilled-water pumps, kW (Btu/h)
- Condenser water pump, kW (Btu/h)
- Cooling tower fans, kW (Btu/h)

L. Chilled-Water Systems: AHUs/FCUs for Water-Cooled Systems

☐ **General Observations**

- Visual condition of AHU insulation
- Noise and vibration of the AHU/FCU
- Filter condition
- Cooling coil condition

☐ **Measurement of Operating Parameters**

- Air inlet/outlet temperature (TD), °C (°F)
- Water temperature at coil inlet/outlet (TD), °C (°F)
- Water flow, l/s (gpm)
- Water pressure drop through coil, kg/cm^2 (psig)

☐ **Power Consumption Readings**

- AHU/FCU motor power consumption
  - At full load, kW (Btu/h)
  - At partial load .... (%) .... kW (Btu/h)
- VFDs, KW (Btu/h)

M. Centralized Direct Expansion Systems: (AHUs/FCUs and Air Coolers (ACUs) for Cold Stores for Direct Expansion Systems)

☐ **General Observations**

- Visual condition of AHU insulation
- Noise and vibration of the AHU/FCU
- Filter condition check
- Coil condition check

☐ **Measurement of Operating Parameters**

- Evaporating pressure, kg/cm² (psig)
- Air inlet/outlet temperature (dry-bulb), °C (°F)
- Air inlet/outlet temperature (wet-bulb), °C (°F)

☐ **Power Consumption Readings**

- AHU/FCU motor power consumption
  - At full load, kW (Btu/h)
  - At partial load .... (%) .... kW (Btu/h)
- VFDs, kW (Btu/h)

N. VRF/VRV Centralized Direct Expansion Systems

☐ **Outdoor Unit**

- Main power source voltage
- Operation circuit voltage

- Fan noise and vibration
- Fan operating current, amp
- Outlet air temperature—inlet air temperature (TD), °C (°F)
- Suction pressure, kg/cm^2 (psig)
- Discharge pipe temperature, °C (°F)
- Compressor operating current, amp
- Oil sump heater

☐ **Indoor Unit**

- Power source voltage
- Room temperature, °C (°F)
- Supply air temperature, °C (°F)
- Fan rotation direction
- Fan noise and vibration

O. Air-Cooled Refrigeration Systems

☐ **Refrigeration System**

- Compressor suction pressure, kg/cm^2 (psig)
- Compressor discharge pressure, kg/cm^2 (psig)
- Compressor oil pressure, kg/cm^2 (psig)
- Compressor motor current, amp
- Condenser fan motor current, amp
- Air-cooling unit fan motor current, amp
- Ambient air temperature, °C (°F)
- ACU Airflow, m^3/h (cfm)

Operation & Maintenance Guidance Sheet

6

Proper Commissioning and Recommissioning Practices to Optimize System Performance

Mindset: If you are not measuring, you are only practicing.

GENERAL INFORMATION

Commercial and industrial facilities are dynamic: load changes, performance degradation, and end-user demands or changes all create a need to periodically reevaluate system performance and adjust. The sustainable operation and maintenance (O&M) of refrigeration and air-conditioning installations require an intimate knowledge of equipment with a firm understanding of the facility demand on those installations. Hence, commissioning is an integral and essential component for sustainable O&M throughout the life cycle of the equipment.

Commissioning is the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent. It begins with planning and includes design, construction, start-up, acceptance, and training and can be applied throughout the life of the equipment.

Recommissioning is the process of periodically repeating commissioning activities as needed when the end-user demands change (e.g., facility additions, technology improvements) or after significant time has passed. Recommissioning identifies opportunities to correct equipment and/or system deficiencies.

Retrocommissioning is the application of the commissioning process to existing equipment and facilities that had not been formally commissioned to improve how equipment and systems work together. This may help resolve problems due to oversights or omissions made during the original design and/or construction of the building or problems that have developed during the life of the equipment. Retrocommissioning improves building O&M procedures to enhance overall equipment and systems performance.

OBJECTIVES

This guidance sheet establishes benchmark data to review and evaluate performance over time. Additionally, using records management for refrigerant leakage helps assess how well the leak management program works.

ADDITIONAL INFORMATION AND RESOURCES

- IOR. 2009. *Safety Code of Practice—Ammonia Refrigerant.* Carshalton, UK: Institute of Refrigeration.
- IOR. Institute of Refrigeration. Refrigerant Safety and Risk Assessment for Flammable Refrigerants. https://ior.org.uk/public/downloads/ie4tY/Refrigeration%20Safety%20and%20Risk%20Assessments%20for%20Flammable%20Refrigerants.pdf
- EFTC. European Fluorocarbon Technical Committee. Toxicology and Safety. *https://www.fluorocarbons.org/toxicology-and-safety/*
- ACRIB. 2001. *Guidelines for the Use of Hydrocarbon Refrigerants in Static RAC Systems*. Carshalton, Surrey: Air Conditioning and Refrigeration Industry Board. https://fairconditioning.org/wp-content/uploads/2019/03/Hydrocarbon-Refrigerants-Guidelines.pdf
- Air Conditioning and Refrigeration Guide. http://www.air-conditioning-and-refrigeration-guide.com/.
- IOR. 2009. Safety Code of Practice for Ammonia Refrigeration Systems. Carshalton, UK: Institute of Refrigeration.
- IIAR. 2021. ANSI/IIAR CO2-2021, *Safety Standard for Closed Circuit Carbon Dioxide Refrigeration Systems.* Alexandria, VA: International Institute of Ammonia Refrigeration.
- IIAR. 2019. ANSI/IIAR 6-2019, *Inspection, Testing and Maintenance of Closed-Circuit Ammonia Refrigeration Systems*. Alexandria, VA: International Institute of Ammonia Refrigeration.

- IIAR. 2021. ANSI/IIAR 2-2021, *Design of Safe Closed Circuit Ammonia Refrigeration Systems.* Alexandria, VA: International Institute of Ammonia Refrigeration.
- EPA. 2022. Refrigerant Safety. Washington, DC: US Environmental Protection Agency. https://www.epa.gov/snap/refrigerant-safety

O&M Best Practice Checklist

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Proper Commissioning and Recommissioning

Objective

Establish benchmark data so that operation of equipment can be reviewed and evaluated.

Measure of Success

- ✓ Keep a thorough record of benchmark data to look back at system performance over time.

Topic	Actions	Notes
	Direct Systems	
P. Commissioning	*The following actions are required to be performed.*	
	☐ **Planning:** Decide which process is needed and when to apply the procedure for minimum disruption of service.	
	☐ **Design:** Ensure design parameters fit the performance of installed equipment. Record readings in commissioning report.	
	☐ **Budgeting:** Allowance criteria, payback expectations.	
	☐ **Commissioning staff:** Testing and Balancing (TAB) personnel with contractor staff and independent engineer.	
	☐ **Instrumentation/Tools:** Through accredited, independent third parties.	

Topic	Actions	Notes
	☐ **Testing:** Benchmark equipment and decide if objectives have been met; has required system performance been reached?	
	☐ **Results/Repairs/Retest:** Performed by contractor staff and witnessed by an independent third party.	
	☐ **O&M:** Training by contractor's staff or owner's staff.	
	☐ **Commissioning Documentation:** Completed by contractor and checked by an independent engineer.	
	☐ **Monitoring Performance/Energy Utilization:** Completed by contractor staff and given to owner representative after independent engineer approval.	
	☐ Monitoring Performance/Energy Utilization: Completed by contractor staff and given to owner representative after independent engineer approval.	
Q. Retrocommissioning	*The following actions are required to be performed*	
	☐ Perform commissioning activities on equipment that has not been commissioned before. Repeat all commissioning steps.	
	Indirect Systems	
R. Commissioning	*The following actions are required to be performed.*	
	☐ Same steps as above.	
S. Recommissioning	*The following actions are required to be performed*	
	☐ Same steps as above.	
T. Retrocommissioning	*The following actions are required to be performed*	
	☐ Same steps as above.	

Operation & Maintenance Guidance Sheet

7

Proper Disposal of Equipment and Refrigerant at the End of Product Life

Mindset: Protect the environment, worker, and community safety in compliance with local requirements.

GENERAL INFORMATION

Proper disposal of equipment at the end of product life is just as important as proper maintenance during the useful life of a refrigerating system.

Refrigerant disposition should be considered before removing it from the equipment or system. That decision will be based on considerations that may include the reason for system shutdown and refrigerant removal, the condition of the equipment and system, and whether it is to be returned to service (see Section A7.1 in ASHRAE Standard 147-2022).

A thorough review of the service history and why the system is being shut down may provide insight into whether there is potential for contaminated refrigerant and/or mixed refrigerants. Documentation is important.

At decommissioning, the refrigerant is to be removed from the system and recycled, reclaimed, or disposed of in accordance with regulations and local requirements. The refrigerant is not to be vented into the atmosphere (see Section 9.1 in ASHRAE Standard 147-2022).

Below are some useful terms related to decommissioning from Chapter 9, "Refrigerant Containment, Recovery, Recycling, and Reclamation" of *ASHRAE Handbook—Refrigeration* (ASHRAE 2022):

- **Recover:** To remove refrigerant in any condition from a system and store it in an external container.

- **Recycle:** To reduce contaminants in used refrigerants by separating lubricant, removing noncondensable, and using devices such as filter driers to reduce moisture, acidity, and particulate matter. This term usually applies to procedures implemented at the field job site or a local service shop.
- **Reclaim:** To process used refrigerant to new product specifications. It usually implies using processes or procedures available only at a reprocessing or manufacturing facility. Chemical analysis of the refrigerant is required to determine that appropriate product specifications are met.

OBJECTIVES

This guidance sheet identifies good decommissioning practices; however, compliance with local laws and procedures must take precedence.

The refrigerant must be identified before removing it from a system. Hazards associated with each refrigerant type must be understood. Some refrigerants are flammable (Class 2L, 2, or 3 in ASHRAE Standard 34 [ASHRAE 2022b] or ISO 817 [2014]), and others are toxic (Class B in ASHRAE Standard 34 or ISO 817). Therefore, removing fluids from the system in a manner that will protect the environment, the workers, and the community is critical. Again, check your local laws before proceeding.

Successfully decommissioning and disposal of RAC equipment is defined as:

- Refrigerant has been recovered without intentional venting to the atmosphere.
- Where purity requirements can be met, refrigerant is stored in approved recovery or storage vessels for future use.
- Refrigerants and all fluids have been properly disposed of in accordance with all local laws and safety requirements.
- Proper disposal of all equipment, refrigerants, and fluids has been documented.

BEST PRACTICES

Recovery

A simple (infrared dispersion) refrigerant analysis should be done before removing refrigerant from a refrigeration plant. This analysis will confirm the type of refrigerant and any associated hazards. The analysis will also confirm whether the refrigerant could be recycled for use in another refrigeration plant with the same owner or should be sent out for reclamation or destruction.

If it is not possible to have this analysis done before recovering the refrigerant, it should be transferred to a container suitable for shipping and sent to a reclamation facility.

The recovery/recycling equipment must be designed for the refrigerant being recovered. Consideration must be given to the vapor pressure of the refrigerant and the safety classification as per ASHRAE Standard 34 (ASHRAE 2022) or ISO 817 (ISO 2014). If the refrigerant is flammable (flammability safety classification of 2L, 2, or 3), the recovery/recycling equipment must be rated to handle flammable refrigerants.

Transfer the refrigerant to an external container suitable for the refrigerant being recovered. These could be cylinders, ton tanks, or steel drums, depending on the refrigerant pressure and quantity to be recovered. If the refrigerant is shipped, the container must meet the requirements of local regulations to be transported on public roads.

It is recommended containers used for recovered refrigerant be dedicated to a specific refrigerant to avoid mixing refrigerants with different refrigerant numbers in the same container. Do not mix refrigerants when filling containers.

Recovery cylinders should be clearly labeled following international GHS labeling recommendations with all pertinent information, which at a minimum, should include the following:

- Refrigerant type
- Date
- Operator
- Quantity

Do not fill containers over 80% capacity. Liquid expansion occurs with rising temperature and could cause loss of refrigerant through the pressure-relief valve or even rupture the container if the container is 100% full of liquid (ASHRAE 2022).

Recovered refrigerant containers must be clearly marked to differentiate them from containers for new or reclaimed refrigerant. In the US, it is customary for the body of the recovered refrigerants container to be gray with a yellow top or end (AHRI Guideline K).

The refrigeration plant should be evacuated to atmospheric pressure or below to ensure that all the refrigerant has been recovered.

Recycling

If the intention is to recycle the refrigerant, it can often be done as it is being recovered using specialized recovery/recycling equipment. This equipment is designed to separate oil, remove noncondensables, and reduce moisture, acidity, and particulate matter as the refrigerant is transferred to a recovery container. The equipment should indicate when any filter/drier(s) must be replaced.

Reclaiming the Refrigerant

If the refrigerant is to be reclaimed, it must be properly stored in a container suitable for transport and sent to a refrigerant reclaimer.

Destruction

If the refrigerant is too contaminated to be recycled or reclaimed, it must be properly stored in a container suitable for transport and sent to a destruction facility that uses a destruction technology such as liquid injection incineration, reactor cracking, gaseous/fume oxidation, rotary kiln incineration, cement kiln, or radio frequency plasma.

Recycling of Refrigerant Cylinders

For practical, safety, and environmental reasons, there is a need for proper recycling of refrigerant cylinders at the end of their useful life (AHRI 2016). Before recycling refrigerant cylinders, any residual contents should be transferred to a suitable container, and the cylinder evacuated to a pressure at or below atmospheric.

ADDITIONAL INFORMATION AND RESOURCES

- ANSI/ASHRAE Standard 147-2022: Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems.
- 2018 ASHRAE Handbook – Refrigeration, Chapter 9: Refrigerant Containment, Recovery, Recycling, and Reclamation.

- AHRI Guideline K-2015: Containers for Recovered Non-flammable Fluorocarbon Refrigerants.
- AHRI Guideline Q-2016: Content Recovery & Proper Recycling of Refrigerant Cylinders
- AHRI 700 (2019): Specifications for Refrigerants
- AHRI 740 (2016): Performance Rating of Refrigerant Recovery Equipment and Recovery/Recycling Equipment
- ANSI/ASHRAE Standard 34
- ISO 817
- ANSI/IIAR 8-2020 Decommissioning of Closed Circuit Ammonia Refrigeration Systems

O&M Best Practice Checklist

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Proper Disposal of Equipment and Refrigerant at the End of Product Life

OBJECTIVE

Follow good decommissioning practices to ensure that is not refrigerant vented to the atmosphere.

MEASURES OF SUCCESS

- ✓ Refrigerant has been recovered without intentional venting to the atmosphere.
- ✓ Where purity requirements can be met, refrigerant is stored in approved recovery or storage vessels for future use.
- ✓ Refrigerant and all fluids have been properly disposed of in accordance with all local laws and safety requirements.
- ✓ Proper disposal of all equipment, refrigerants, and fluids has been documented.

Topic	Actions	Notes
U. Refrigerant	*The following actions are required to be performed.*	
	☐ Identify refrigerant and safety classification according to ASHRAE Standard 34 or ISO 817.	
	☐ Verify refrigerant vapor pressure at room temperature.	
	☐ Recovery/recycling equipment is rated for this refrigerant.	

Topic	Actions	Notes
	☐ Refrigerant from a plant taken out of service due to mechanical failure or motor burnout is sent to a facility for reclamation or destruction.	
	☐ Analyze refrigerant to be reused for contaminants and reprocessed before reuse.	
	☐ Recycle and store refrigerant to be reused by the same owner in a suitable container, per AHRI Guideline K.	
	☐ Recover refrigerant that the same owner will not reuse into a container suitable for shipping to a reclaimer or destruction facility.	
V. Recovery/ Recycling Equipment	*The following actions are required to be performed.*	
	☐ Recovery/recycling equipment is appropriately sized for the refrigerant being recovered.	
	☐ Externally and internally (if possible) examine containers for recovered refrigerant for corrosion or other damage that may weaken the walls, heads, or joints.	
W. Recycling Refrigerant Cylinders	*The following actions are required to be performed.*	
	☐ For nonrefillable cylinders, the refrigerant has been recovered, the valve has been opened, and the cylinder punctured, per AHRI Guideline Q.	
	☐ For nonrefillable cylinders that held flammable refrigerants, use a nonsparking pick to puncture the side of the cylinder and place the tank with other steel recyclables, per AHRI Guideline Q.	
	☐ Return refillable cylinders to the supplier or owner with the valve closed tightly and the hood cap securely placed.	

Operation & Maintenance Guidance Sheet

8

Competencies of Operating and Service Personnel

GENERAL INFORMATION

Competence is the ability of an individual to do a job properly. Competency is a set of defined behaviors that provide a structured guide, enabling the identification, evaluation, and development of skills in individual employees. It is also the possession and application of knowledge, skills, and attitudes to meet the standard of performance required in the workplace. Together, all the above is referred to as a competency standard.

A person can be proven competent by an authorized assessment body, such as an accredited assessment center or an industry organization mandated by the government or other authority. Such centers or organizations can attest or certify that an individual is competent after fulfilling all the required knowledge, skills, and behaviors stated in a competency standard.

OPERATING AND SERVICE PERSONNEL ASSESSMENT

Assessment is one of the methods implemented by a country or other authority to validate an individual's competence. This method demonstrates a person's competence through written tests, documentation of outputs produced in previous jobs, and/or obtaining education and training certificates.

For the HVAC&R technician, typical certified coursework could highlight the importance of preventive and regular maintenance, safety issues, and energy savings measures and practices. A minimum level of experience (for example, three to four years) in handling similar plants may also be a requirement.

A competency assessor is a trained person authorized by the assessing authority to conduct the assessment of candidates by collecting evidence and making a judgment as to whether a person is qualified to be issued a competency certificate.

To be competent, operating and service personnel must keep up with new technologies by regularly attending conferences, seminars, forums, and exhibitions, either online/virtual or in-person.

Competent personnel emphasize safe practices, such as wearing appropriate personal protective equipment (PPE), conducting a risk analysis of the working environment before proceeding, and always observing environmentally conscious practices.

RAC plant operating and service personnel must know how to maintain proper documents, including:

- Plant operation manual prepared by the contracting agency.
- Full set of "As-Built Drawings" for the whole installation.
- Details of contractors and suppliers, such as contact numbers, etc.
- Insurance certificates for plant and machinery and operating personnel.

In addition to knowing about various system components, operating and service personnel should also have a working knowledge of the automation and controls systems and programmable logic controllers (PLC) panels incorporated into the systems.

A responsible practitioner maintains their skills and is aware of the latest trends in RAC technology.

SUPPORT COMPETENCIES

Competent operating and service personnel should not only possess core competencies such as installing, servicing, and repairing certain equipment, they must also possess support competencies.

These may include maintaining tools and equipment and understanding basic electricity, masonry, and benchwork. They must also know how to take advantage of technology by using manufacturers' apps, downloading articles and being aware of the latest news on innovations, policies, regulations, and standards.

To be successful, technicians are advised to:

- Ensure that any legal documents (license, business permits, certifications, etc.) in their possession are all up-to-date and unexpired.
- Keep current on the latest trends in technology, norms and standards, and government policies by attending/joining seminars, conferences, technical forums, and other gatherings related to advancement and continuous learning.
- Join industry associations with the aim of advancing the welfare and updating the knowledge and skills of service practitioners.
- Be responsible with their words and actions whenever dealing with co-workers, subordinates, supervisors, and clients.
- Be aware of their responsibility in protecting the environment, equipment, and people while performing their duties and responsibilities.
- Treat the company they are representing as their own.

Personnel should always be aware of professional obligations to the company, clients and government, and companies can reinforce the importance of meeting professional obligations by making sure operating and service personnel are certified or licensed practitioners.

OBJECTIVES

This guidance sheet provides a means for identifying competent personnel. Competent operating and service personnel will contribute to:

- Lower system downtime and better equipment performance
- Fewer safety incidents and unintentional refrigerant releases
- Creating full redundancy and backup for operating and servicing personnel.

BEST PRACTICES

Many books, manuals, other publications, and training in print and non-print are already available that help operating and service personnel learn about RAC practices. This guidance sheet is not meant to supersede other existing materials.

This guidance sheet aims to enhance existing educational materials to assist RAC plant operators and technicians in maintaining and verifying their competencies. It also aims to encourage companies to support continuous learning by plant operating and service personnel and their pursuit of licenses, certifications, and other appropriate qualification programs.

Requiring core competencies for RAC plant operators and technicians will lead to improved job opportunities as well as sustainable and efficient operation of RAC plants.

ADDITIONAL INFORMATION AND RESOURCES

- UNEP-AHRI. 2023. Refrigerant Driver's License. https://rdlprogram.org/exam_preparation/.
- UNEP Division of Technology, Industry and Economics (DTIE), OzonAction.2015. Good Servicing Practices: Phasing out HCFCs in the Refrigeration and Air-Conditioning Servicing Sector: https://www.unep.org/ozonaction/resources/publication/good-servicing-practices-phasing-out-hcfcs-refrigeration-and-air-conditioning.

UNEP OzonAction. 2018. Good Servicing: Flammable Refrigerants Quick Guide. https://www.unep.org/ozonaction/resources/mobile-app-toolkits-manuals-and-guides/good-servicing-flammable-refrigerants-quick-guide.

- UNEP Law Division OzonAction. How to set up and manage logbooks for refrigeration, air-conditioning, heat pump, and other types of equipment. https://www.unep.org/ozonaction/resources/factsheet-toolkits-manuals-and-guides/how-set-and-manage-logbooks-refrigeration-air.
- UNEP OzonAction. Gas Card Tool: https://www.unep.org/ozonaction/resources/gas-card/gas-card-tool.

AHRI. 2022. Technician Best Practices for A2L Installation and Servicing. https://www.ahrinet.org/system/files/2023-06/A2L%20Refrigerants%20Best%20Practices_0.pdf.

O&M Best Practice Checklist

8

Competencies of Operating and Service Personnel

OBJECTIVE

Achieve sustainable and energy-efficient RAC operation by ensuring operators and servicing personnel have and maintain the necessary core competencies in related technology and support.

MEASURES OF SUCCESS

- ✓ Lower system downtime and better equipment performance
- ✓ Fewer safety incidents and unintentional refrigerant releases
- ✓ Full redundancy and backup for operating and servicing personnel

Topic	Competencies	Notes
X. **Fundamental Skills**	*The following competencies are required.*	
	☐ Demonstrates mechanical aptitude	
	☐ Basic understanding of thermodynamics and refrigeration cycles	
	☐ Basic understanding of electricity and electrical power distribution	
	☐ Understands plant safety practices and procedures	
	☐ Basic understanding of sustainability objectives, minimizing environmental footprint, etc.	
	☐ Demonstrates ability to prepare, use, and maintain basic tools, materials, instruments, and equipment	

Topic	Competencies	Notes
	☐ Ability to interpret technical drawing and schematics	
	☐ Observes and follows procedures, specifications, and instruction manuals	
	☐ Performs measurements and calculations	
	☐ Performs basic electrical tasks and benchwork	
	☐ Performs housekeeping and safety practices	
	☐ Documents work accomplished	
Y. Specialized Knowledge	*The following is a general list of specialized competencies.*	
	☐ Identify components of an HVAC&R plant including various types of pumping loops, fan curves and operation, Cooling tower and condenser heat rejection systems.	
	☐ Execute operating procedures and characteristics of various types of equipment encountered in an HVAC&R installation	
	☐ Understand general maintenance requirements and procedures for vapor-compression, absorption, and the accompanying ancillary systems needed to support the HVAC&R plant	
	☐ Can accurately identify types of vapor compressor system types (centrifugal, scroll, reciprocating, and rotary)	
	☐ Uses proper refrigerant handling procedures and/or holds a valid Refrigerant Driving License	
Z. Understanding	*The following is a required basic understanding.*	
	☐ Understands the importance and proper use of personal protective equipment (PPE)	

Operation & Maintenance Guidance

Annex

Minimum Requirements for Tools and Servicing

Mindset: Be safe and be prepared.

GENERAL INFORMATION

When the design of a refrigeration circuit is done, the component manufacturing is completed. The operation's success lies in the hands of the contractor and, even more so, the technician that installs the equipment. Only when all the steps from beginning to end are carefully executed can the equipment run for the envisioned time and with the envisioned performance levels.

The technician who installs, maintains, repairs, or, if necessary, decommissions the equipment must do so with the proper tools and equipment to ensure efficiency, speed, and performance.

Note: Regionally or locally, there could be labor and/or environmental laws or regulations that mandate the use or availability of certain tools and equipment. It is the responsibility of the client and/or contractor to adhere to these local rules and regulations.

BEST PRACTICES

Safety and Personal Protection Equipment

Working in the HVAC&R industry combines most of the competencies that technicians work in and all related safety hazards. Preparation is needed to account for health and safety precautions related to mechanical hazards, chemical hazards, and electrical hazards.

Table 1 Safety Equipment for Mechanical, Chemical, and Electrical Hazards

	Mechanical	Chemical	Electrical
Safety Shoes	X	X	X
Safety Goggles	X	X	
Helmet	X		
Ear Defenders	X		
Safety/Work Gloves	X	X	X
Exposure monitors (for certain refrigerants)		X	
First Aid Kit	X	X	X
Face Mask*	X	X	X

* If required by the establishment.

General Hand Tools

A technician always needs access to a set of good quality general tools and the tools must be of suitable quality. The collection of general tools (listed in the following tables) should be "packaged" in a sturdy and simple to carry/roll tool bag or trolley.

In the HVAC&R industry, it still is common to find a mix of metric- and imperial-sized nuts, bolts, and threads in regular equipment. Verify whether the equipment being serviced on is suitable for metric- or imperial-sized tools. A list of general handtools is included below:

- Set of screwdrivers (insulated to 1000 V)
- Set of Torq Drivers
- Set of Allen Keys
- Pliers (insulated to 1000 V)
- Universal Pliers (180 mm)
- Long Nose Pliers (160 mm)
- Diagonal Cutting Pliers (160 mm)

- Wire Stripping Pliers (160 mm)
- Adjustable wrenches
- Voltage Probe
- 3/8 in. Drive Socket Set (SI and I-P)
- Hammer
- Half Round File
- Hacksaw
- Measuring Tape
- Vernier Caliper
- Flashlight (Pocket)
- Terminal Crimping Pliers
- Utility Multitool Knife
- Jaw Locking Pliers
- Abrasive Linen

Tubing Tools

The refrigerant in a system runs in a closed loop that mainly consists of copper tubing. Some aluminum tubing has found its way into the field in recent years, but not nearly as much as the copper versions. As stated, the system must be closed—no refrigerant can leak out. This creates a system whereby the copper tubes are manipulated into shapes and forms to fit the equipment or the installation location. To manipulate the (copper) tubes, specific tools are needed.

The equipment in the following list of required tubing tools is used to connect tubing using primarily brazing. This is currently the most common method of connecting tubes; however, newer, more convenient, but generally more expensive methods such as Lokring™, Zoomlock™, and SmartSplice™ can be found in the industry today. If a company's system is equipped with these technologies, the company should check with the respective manufacturers as to which specific tools may be required.

- Tube Cutters:
- Mini 3 to 6 mm

- Standard 7 to ~41 mm
- Flaring and Swaging Tool (SI and I-P sizes available)
- Deburring Tool
- In and Out Deburrer
- Pen Type Scraper
- Tube Bender 3-in-1 (Si and I-P sizes available)
- Tube Bender (SI and I-P sizes available)
- Capillary tube cutter
- Simple and portable brazing outfit
- Up to 1 in. brazing capacity
- Flint lighter
- Suitable brazing rods/flux

Pressure Testing Equipment

The proper procedure is to check for possible leaks prior to charging a system with refrigerant as well as when a system is repaired for a leak. It is highly recommended to always use oxygen-free dry nitrogen (OFDN) and a double-stage nitrogen regulator.

Vacuum Equipment

One of the most critical aspects of refrigeration and air-conditioning commissioning, maintenance, and repair is "pulling a vacuum" in the system. There are several reasons to pull a vacuum in a system, including:

- Removing air and other noncondensable gases in the system
- Verifying (vacuum) tightness
- Removing moisture

High accuracy bellow-type compound gauge.

Because the vacuum level required in air-conditioning and refrigeration operations is very low, the one tool that *cannot* be used to measure vacuum properly is the "compound gage" from the manifold gage set. The compound gage on a standard manifold gage set does not give enough accuracy to ascertain the proper vacuum level. In the vacuum range, a compound gage is only indicative.

Until recently, a Bourdon-type vacuum gage was used; however, these gages are cumbersome because they are sensitive precision instruments that get damaged easily *and* require barometric pressure compensation calculations. In other words, not useful in today's world.

J/B micron gauge—Pirani type.

A range of better-suited electronic vacuum gages are available from many sources. Most of them are relatively inexpensive, accurate, and easy to use. There are several types of electronic vacuum gages, namely hot wire, Piezo, and Pirani. Some manufacturers use a double Pirani gage to increase accuracy in the low vacuum levels while providing a reliable reading in the upper levels.

ASHRAE Standard 147 and most OEMs require a vacuum of 500 µm to be met and held for a specific timeframe before charging with refrigerant. This level will ensure that noncondensables are not in the system and leaks do not exist.

Vacuum Pump: Type and Size. In the refrigeration and air-conditioning industry, the commonly used type of vacuum pump is the rotary vane design. Rotary vane vacuum pumps are available in single- and dual-stage configurations. Single-stage pumps are primarily used in very small applications—such as for white goods (e.g., residential freezers and refrigerators)—where weight and portability are important. Single-stage pumps take slightly longer to reach the *final vacuum* (i.e., the maximum vacuum level the pump can theoretically reach).

Dual-stage vacuum pumps are more common. With dual-stage pumps, a second stage is "cascaded" onto the first stage. In this configuration, it is easier for the first stage to reach the desired low vacuum levels.

The "size" (or capacity) of the vacuum pump is measured in cfm, lpm, or m^3/h. The correlation between these is in the following table.

Table 2 Vacuum Pump Capacity Measurement Conversions

	cfm	lpm	m^3/h
cfm	1	28.3	1.7
lpm	0.35	1	1.44
m^3/h	0.588	16.66	1

The vacuum pump size depends on the size of the system to be evacuated; in other words, the volume of the system to be evacuated as well as the amount of moisture to be removed.

A general rule of thumb is that the size of the vacuum pump (in cfm) is ($\sqrt{\text{(refrigeration tonnage)}}$. For instance, a 100-refrigeration tonnage (RT) system would need a minimum of a 10-cfm vacuum pump. A 49 RT system would require at least a 7-cfm pump. The vacuum pump must be able to reach the level of vacuum required divided by two as a minimum. If the vacuum required is 500 µm, the pump must be capable of at least 250 µm.

Important note: When selecting a vacuum pump, it is important to understand that the frequency of the electric net plays a vital role in the capacity. If the capacity is given at 60 Hz, the capacity of the same pump on a 50 Hz power supply is 50/60 (or a factor of 0.83) less than the given capacity. The manufacturer's specifications for the frequency of a power system should always be checked.

An important feature of a larger size dual-stage vacuum pump is the *gas ballast*. A gas ballast is a small, needle-type valve that introduces a small amount of ambient fresh air between stages one and two of a dual-stage vacuum pump. It dilutes the moisture-laden air from the system so that the compression of the second stage will not condensate the moisture in the vacuum pump lubricating oil. Condensed moisture in the vacuum pump oil reduces the pump capacity and damages the vacuum pump itself.

Gas ballast.

Do *not* use a pump that is oversized for the system—it may drop the pressure in the piping too quickly and freeze any free water that is in the system.

When pulling a vacuum, start with the gas ballast in the open position. Once the vacuum reading on the vacuum gage reaches approximately 3000 μm, close the gas ballast and finalize the vacuum process.

Check the color of the vacuum pump often. If it is milky white, the oil in the pump has absorbed a large amount of water. Replace the oil in the pump.

Refrigerant (Service) Manifolds, Gages, and Service Hoses

From the early days of refrigeration and air-conditioning installation and servicing, there has been a need to connect to the refrigerant-filled closed loop. Almost every system was designed with a set of fixed pressure gages. By reading the pressures (suction and discharge) and correlating them to pressure/temperature charts, a basic "system health check" can be made.

As systems got more compact and expensive, system manufacturers removed the gages and installed an access port (through Schrader valve, back seated valve, or similar) to allow easy (i.e., standardized) access points. These points now require the technician to use a special tool.

Hence for over the past 70 years, the industry has become accustomed to a small bar of brass or aluminum fitted with some valves and (two) gages. In the industry, this is called a "manifold gage set." Most manifold gage sets use a low side gage as well as a high side gage. The gages typically have a faceplate that indicates the pressure and the corresponding saturated vapor temperature for a specific refrigerant.

There are three types of valve setups in the manifold gage set: diaphragm type, piston (floating) type, and ball valve type. The most prevalent valve setup in the market is the piston type due to its simplicity and reliability.

There are several options for configuring manifold sets; to select the proper one, it is important to decide what the manifold gage set will be used for. The manifold gage set has four basic functions, and each function has a preferred configuration, detailed in the following table.

Table 3 Manifold Gage Set Functions

Function	Two Valve	Four Valve	Notes
Diagnosis	OK	OK	Preferably use Class 1 gages.
Recovery	Acceptable	Better	
Vacuum	Not recommended	Preferred	Four-valve systems have larger bore vacuum hoses.
Charging	Acceptable	Preferred	Easy changeover from vacuum to charging.

For standard refrigerants (CFC, HCFC, HFC, HFO), using a common cast or machined bar brass or aluminum stock provides sufficient strength to withstand the common pressures and chemical reactions in air-conditioning and refrigeration systems. However, users need to be extra careful with R-744 (CO2) or R-717 (NH3) refrigerants. Be extra attentive to the manufacturer's declarations of compatibility with these refrigerants. Under no circumstances should hoses with a lower rating than the expected refrigerant pressure be used.

In the case of CO_2 hoses, it is important to have safety cords fitted to the hoses, so the hose will not "whip" uncontrollably in case of an accidental burst.

Manifolds/hoses for A3 refrigerants must have a ground strap or a metal cover design to feed away any static, thus preventing sparks.

Hose Ends. Within 6 in. (15 cm) of the point where the service hose is connected to the system, it is recommended to have full flow, ball shutoff valves. This allows the operator to eliminate uncontrolled refrigerant emissions during refrigerant interventions.

Valve (Core) and Access Tools

It is important to have full flow and unrestricted access to the refrigerant system for refrigerant recovery, vacuuming, and refrigerant charging operations. The most widely used access systems are Schrader valves and back-seated valves.

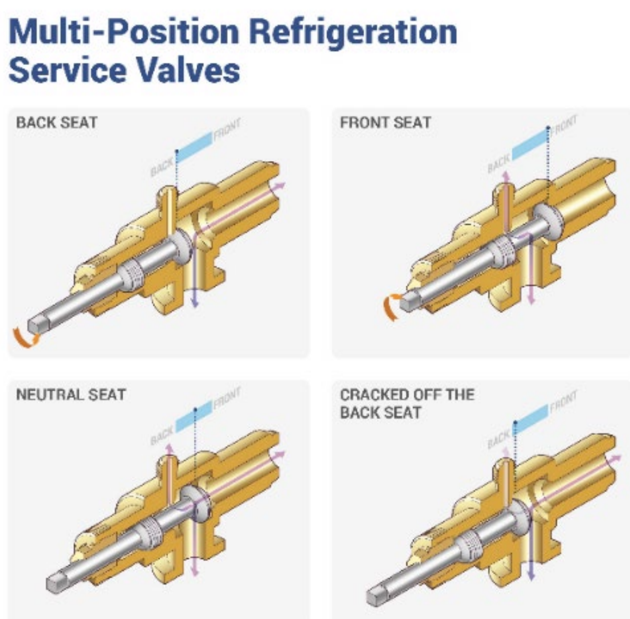
Schrader valves are an inexpensive way to prevent most of the refrigerants from leaking out. Unfortunately, a Schrader valve always leaks some refrigerant. For that reason, it is important to always cover the access port of a Schrader valve with a sealing cap. Usually, these are fitted; however, many times are "displaced" after service interventions. Make sure these are fitted.

Standard "Schrader" type valve.

To speed up recovery, vacuuming, and charging operations, it is important to remove the Schrader valve. With the valve removed, the flow resistance is as low as it can possibly be.

"No-refrigerant-loss" valve core remover.

Fortunately, the industry has developed systems whereby the valve core can be removed for service operations without losing the refrigerant charge of vacuum levels. These tools are available in the common ¼" and 5/16" SAE flare sizes. Unfortunately, there is no common name for these "contraptions," but a "no-loss valve core remover" comes close.



Multiposition refrigeration service valves.

Much better than Schrader valves are the "back seated" valves. These valves offer a better sealing and full flow when required. As can be seen in Figure 8, these valves need to be operated through the stem. Typically, a ¼" shank, although other sizes and configurations are employed as well. For this reason, a proper set of back seated valve tools is recommended.

Refrigerant (Charging) Scales

In any refrigerant operation, it is important to know the quantity of refrigerant that is moved, not only to ascertain that the refrigeration/air-conditioning system is charged properly but also to comply with mandatory regulations pertaining to refrigerant consumption.

The industry has long developed a wide range of refrigerant charging scales that can be carried by the technician and are suitable to work with "manageable" cylinders. Typically, the capacity of these portable scales is up to 100 kg (220 Lbs.). Resolution typically is in the range of 10 grams—with a few exceptions offering a 5-gram resolution.

Portable Test Instruments

To calculate the performance and efficiency of a refrigeration or air-conditioning system, it is essential to measure temperature, humidity, airflow, and the electrical power consumed by the system. After all, efficiency is a simple relation between power in and power out. The instruments required for these measurements include:

- Thermometer: Preferably one with multiple temperature probes. Ensure the temperature range and accuracy match the system being worked on.
- Psychrometer: Humidity plays a vital role in judging the system's performance. A proper psychrometer will assist.
- Anemometer; Often, an anemometer is combined with a psychrometer; if not, use an anemometer to calculate the airflow.
- A proper clamp meter: Make sure that the clamp meter features details such as voltmeter and resistance. Check the required range for the equipment being worked on. Verify the manufacturer's safety certifications for the instrument. High voltage and high current are hazardous. Safe clamp meters for HVAC&R applications should meet IEC CAT III (600 V) as a minimum. A CAT IV (1000 V) is recommended if users are required to work outside.

Recovery Cylinders and Refrigerant Transfer Equipment

Since refrigerants are always under pressure, and the pressure varies as a function of refrigerant type, cleanliness, and temperature, the cylinders the refrigerant is stored in must be capable of handling these various pressures. Disposable refrigerant cylinders (which are banned in Europe) should never be used to store recovered refrigerant since using these cylinders for recovered refrigerants causes a significant risk of explosion.

In many countries, there are strict regulations regarding the certification of refrigerant cylinders. EN cylinders need to be hydrostatically (without determination of expansion) tested every ten years. The required retest date must be stamped or printed on the cylinder.

Recovery Machines. For recovery quantities less than 50 kg, there is an abundance of portable equipment that can handle this quantity.

It is important to know that the equipment is suitable for the refrigerant that is to be recovered. This means that the recovery machine needs to be compatible with the refrigerant and refrigerant oil that is used. Essentially, the refrigerant/oil combination should not attack the materials used in the recovery unit.

The recovery machine must have a pressure rating that exceeds the maximum expected pressure of the refrigerant during recovery. This is especially important for newer, high-pressure refrigerants such as R-410A or R-32. A special type of recovery machine must be used when recovering A2L, B2L, A3, or B3 refrigerants (i.e., flammable refrigerants).

A high-pressure shut-off switch must be included in the machine and should shut the equipment down before the tested rating of the machine. The compatibility of the recovery machine with modern A2L refrigerants is important. It should be noted that there is no proper standard for rating recovery machines with A2L refrigerants at the time of publication. Recovery of A2L refrigerants requires strict knowledge of handling (slightly) flammable refrigerants and includes knowledge about lower flammability levels of the refrigerant. The heat generated by and in the recovery machine must stay below the flash points of the refrigerant.

Leak Detection and Leak Monitoring

There are several methods to locate leaks, which are described in further detail in the following table.

Table 4 Leak Detection Methods

Method	Advantages	Disadvantages
Soap and Bubbles	• Cheap • Pinpoints exact location	• Not for small leaks—only finds large leaks • Very labor intensive • Sometimes aggressive to materials
Electronic Refrigerant Leak Detection	• Quick and effective	• Could be costly • Requires easy access to system
Pressurizing with Inert Gas	• Inexpensive, depending on the gas used • Effective	• System needs to be empty of refrigerant • Requires easy access to system
Ultrasonic Leak Detection	• Accurately pinpoints leak	• Sometimes difficult to hear with background sound • Expensive
UV Leak Detection Fluid	• Can be used as continuous monitoring • Exactly locates the leak spot	• Can have negative effect on system's lubrication • Compressor manufacturers not always in favor of this method • May void warranty
Infrared Thermal Imaging	• Quick scan possible • Can be done from a distance	• Very expensive • Needs training • Not always accurate • Not always possible

Essential RAC Plant Guidance from ASHRAE and UNEP

Assessing RAC Plant Sustainability is a technical guide that provides valuable insights and best practices for the sustainable and efficient operation of refrigeration and air-conditioning (RAC) plants. This summary provides an overview of the document's key points and areas of focus.

This guide enables technicians and managers to assess sustainability practices and implement improvements where needed. It is structured to provide succinct guidance in an easy-to-follow format.

The guide covers the key dimensions of practice related to RAC plant sustainability in Guidance Sheets. These guidance sheets address each dimension of practice, providing detailed information, recommendations, and additional resources.

1. Safe Storage and Proper Handling of Refrigerants
2. Periodic Leak Checking and Proper Documentation
3. Preventive Maintenance of Equipment
4. Preventive Maintenance of Automatic Controls
5. Energy-Efficient Operation
6. Proper Commissioning and Recommissioning Practices
7. Proper Disposal of Equipment and Refrigerant
8. Competencies of Operating and Service Personnel

An annex covers requirements for tools and servicing.

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