ENGINEERING AND CONSTRUCTION BULLETIN

US Army Corps of Engineers

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SUBJECT: Proper Planning, Design and Maintenance for Variable Refrigerant Flow (VRF) and Other Energy Saving Atypical Heating, Ventilation, and Air Conditioning (HVAC) Systems

CATEGORY: Directive and Policy

1. **References:**

a. 10 USC 2867: Energy Monitoring and Utility Control System Specification for Military Construction and Military Family Housing Activities, 28 October 2009

b. UFC 3-410-01 HVAC Systems with Change 7, 1 March 2021

c. UFC 3-410-02 Direct Digital Control for HVAC and Other Building Control Systems with Change 2, 12 April 2020

d. UFGS 23 09 23.01 LonWorks Direct Digital Control for HVAC and Other Building Control Systems, 1 February 2019

e. UFGS 23 09 23.02 BACnet Direct Digital Control for HVAC and Other Building Control Systems, 1 February 2019

f. UFGS 23 81 29 Variable Refrigerant Flow Systems, 1 February 2020

g. Department of Energy, Office of Science and Technology Article, "Evaluation of Energy Savings Potential of Variable Refrigerant Flow (VRF) from Variable Air Volume (VAV) in the U.S. Climate Locations," 22 May 2017

h. Minnesota Department of Commerce Division of Energy Resources publication, "Performance and Energy Savings of Variable Refrigerant Technology in Cold Weather Climates." https://mn.gov/commerce-stat/pdfs/refrigerant-technology-cold-weather.pdf

2. **Purpose.** This directive provides information for planners, designers and end users on how to properly address energy savings HVAC systems that are atypical to the installation.

3. **Background.** Numerous reports of failed VRF Systems have recently been brought to the attention of the Office of the Assistant Secretary of the Army (Installations, Energy & Environment). Headquarters U.S. Army Corps of Engineers (HQUSACE) coordinated with various USACE Districts to determine how failure of these systems can be minimized, how to apply accepted maintenance practices and how to decide if VRF systems are the correct application for the conditioned space. It is important to note that many VRF system failures were with systems 10-15 years old (15-year lifespan being typical) and the systems were designed and installed prior to the inclusion of VRF systems in Unified Facilities Criteria (UFCs) and the United Facilities Guide Specifications (UFGS) but many failed VRF systems were installed

within the last two years as well. Although the major emphasis is on VRF systems, since most of the feedback received was from these systems, the Implementation section of this ECB will also stress the importance of the proper planning, selection and maintenance of all energy saving HVAC systems that are new or relatively new technologies to HVAC designers and installation maintenance personnel.

4. **Applicability.** This Engineering and Construction Bulletin (ECB) applies to all Army new construction and renovation projects.

5. **Implementation.** The points in this section should be considered prior to making a selection of a VRF system or any atypical HVAC system for the installation. The points were developed from information and feedback from Corps Districts, Army Directorate of Public Works and associated lessons learned. Important to note, that the designer and project manager should review all of the points mentioned below with the end user and installation prior to performing any life cycle cost analysis as the analysis may not be required.

a. VRF overview: In VRF Systems refrigerant is the cooling and heating medium. Refrigerant is circulated to evaporator blowers or air handling units with associated ductwork. Refrigerant is compressed in a condensing unit outside of the building. Energy savings are realized with variable speed motors resulting in variable refrigerant flow. This results in compressors only working as needed for partial load conditions rather than 100% speed to attain the required refrigerant pressure. Additional energy savings can be gained when the system includes both zones requiring heating and zones requiring cooling, as the heat can be drawn from the condenser coils while refrigerant in the evaporator coils provide cooling for other spaces. For these energy savings to be realized there must be situations where simultaneous heating and cooling is required such as the exterior and interior spaces of tall buildings. Although there is no definitive figure, under ideal conditions, a 40 to 50% energy savings can be realized compared to other types of heating-cooling systems such as variable air volume (VAV) air handling systems as reported by the Department of Energy's Office of Science and Technology, (ref. g)

b. VRF Advantages:

- When properly designed, installed, and maintained, provides energy savings over conventional HVAC systems

- Ability to provide heating and cooling to different zones concurrently

c. VRF Disadvantages:

- Efficiency and possibly capacity is decreased in colder weather and may not be able to operate below the manufacturer's ambient air temperature limit. Many of these systems essentially shut themselves down after reaching a minimum temperature to protect itself from damage. Although some VRF manufacturers claim to produce heat down to -25 deg F, the Department of Defense (DoD) has not tracked the performance of these low temperature systems for capacity or efficiency as of the date of this publication. As such, a backup heating system is required adding the cost of another

system plus associated maintenance. The Minnesota Department of Commerce Division of Energy Resources provides an excellent resource for cold weather applications with their publication, "Performance and Energy Savings of Variable Refrigerant Technology in Cold Weather Climates." See reference h for the link.

- Some VRF systems have been reported as being sensitive to electric power fluctuations

- Refrigerant leakage is cumbersome to locate and often tight access for repair. Buildings such as fire houses with living quarters may not be a good fit due to the leakage concern.

- Generally requires contracted maintenance, which may not be available locally, delaying response times

- Budget strained maintenance department will likely have to pay for VRF maintenance/repairs unless they receive training from the manufacturer which will likely involve cost as well

- Proprietary parts are often more expensive

- Energy savings which include simultaneous heating and cooling are diminished when only one mode is utilized

- Doesn't work well when a lot of outside air is required.

- All VRF systems as of the date of this ECB have proprietary control systems

d. Proprietary Controls: In 2012, 10 USC 2867 (ref. a) required open protocols for HVAC Controls Systems within DoD. As a result of this requirement HVAC criteria had to be created to abide by this code. As of the date of this ECB all VRF systems have proprietary controls and an exception is required to choose a VRF system. The exception requires a gateway which allows two-way controls information flow to be installed to the open controls protocols BACnet or LonWorks and to follow multiple conditions as defined in UFC 3-410-02 Direct Digital Control for HVAC and Other Building Control Systems (ref. c). Each individual device has to be non-proprietary. A key provision of this exception is acceptance by the system owner, allowing installations to consider their ability to operate and maintain these systems before they are installed and to decline the exception if the system will not work for the installation. As previously stated, it is firmly recommended that designers and project managers coordinate with the installation prior to beginning design of systems under the UFC exception. In 2020, UFGS 23 81 29 Variable Refrigerant Flow HVAC Systems (ref. f) was published to provide guide specification requirements for VRF systems which either meet the open control system specifications or have obtained an exception. **It should be strongly noted that all DoD projects must follow the UFCs, regardless of execution agent or funding source, and all designers (DoD or contracted) are required to follow the UFCs for all designs, including USACE and IMCOM designers, regarding the exception and all related information on**

VRF systems. For further information on Controls please see the VRF Controls FAQs included with this ECB.

e. Life Cycle Cost Effectiveness (LCCE): These systems can be LCCE but one needs to perform a complete analysis. The analysis requires consideration of the following:

- Life span – the approximate 15 year life span of VRF systems versus the 30-40 year life span of air handling units with variable air volume

- Energy savings

- First costs

- Maintenance and parts – In VRF systems parts are not interchangeable with other VRF manufacturers and maintenance/repair is required to be performed by the specific VRF systems representative often involving expensive maintenance contracts. Include costs for locating and repairing any refrigerant leaks.

- Training - DoD maintenance personnel can be trained to maintain VRF systems. The training involves a cost incurred by the installation. It is advised to speak to a VRF manufacturer while considering these systems and inquire about maintenance costs, contracts and training cost if the manufacturer offers it. Consider if the maintenance department has adequate personnel to add VRF maintenance.

- Backup heating costs and maintenance

f. Installing and Commissioning: It is vitally important as with any HVAC system that they are correctly installed and receive a subsequent complete commissioning. VRF system failures mentioned in the Background section of this ECB include problems with inadequate or incorrectly installed oil traps, mis-sized refrigerant lines or incorrect slope of refrigerant lines. These deficiencies are identifiable during the system acceptance process, when the system has not been accepted and the contractor can be required to remedy them. Many of these deficiencies can lead to compressor failure, greatly reducing the life of the system and affecting energy savings and operation costs.

g. Challenges with Other Atypical HVAC Systems:

- Water source heat pump systems have many compressors which installation maintenance staff must maintain

- Sometimes maintenance staff receives specific HVAC training then are hired away from the Army Installation's Directorate of Public Works (DPW) for higher commercial industry pay.

- Some maintenance staff in rural locations have minimal computer skills, which can create more of a challenge to train on newer technology

- It is difficult for maintenance staff to become familiar with the maintenance procedures of multiple manufacturers. DoD is looking at sole source with justification that can address this issue.

6. **Funding.** No specific funding is provided for the end user to determine which HVAC system is most appropriate for the new construction or renovation. The project delivery team should be sure that any HVAC system is fully analyzed per the implementation section of this ECB.

7. **Update.** UFC 3-410-01 (ref. b) will be updated during FY22 to provide more information to designers, planners and maintenance personnel.

8. **Points of Contact.** The HQUSACE points of contact for this ECB is Timothy Gordon, CECW-EC, (202) 761-4125 for VRF System questions and Joseph Bush, ERDC-CERL/CECW-EC, (217) 373-4433 for VRF Controls questions.

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Encl.
Attachment A – VRF Controls FAQs

ATTACHMENT A

VRF Controls FAQs

(Rev. 01 July 2021)

This FAQ prepared by Joe Bush, USACE subject matter expert, to help the field understand the issues related to VRF control systems and the recently updated DoD Criteria related to VRF systems.

1. **Why don't VRF systems meet the controls specifications?** {rev: 01July21}
   The primary issue is that VRF systems are proprietary (closed) systems:
   a) VRF systems use proprietary communication protocols and networks which are prohibited by the specifications. The specifications require controllers to communicate using either solely ASHRAE-135 (BACnet) or solely ANSI 709.1 (LonWorks), and further requires specific implementations of these protocols (such as the use of standard Objects or standard network variables (SNVTs).)
   b) VRF systems are not implemented in an open manner where, for example, components (controllers) can be replaced by components from another manufacturer.

   Of these two, it's not practical to meet the requirements of (b) without first using as open protocol as described in (a). Therefore, the issue of proprietary communication is often the initial focal point/concern.

PROPRIETARY SYSTEM QUESTIONS

2. **But the VRF system can be provided with a communications interface to BACnet or LonWorks, so that must meet the spec, right?** {rev: 01July21}

   Original answer prior to Change 2 of UFC 3-410-02 {rev: 26Jan18}
   No. The specifications do not allow the implementation of a proprietary network, even if there is a gateway. While the building control system specifications (UFGS 23 09 23.01 and UFGS 23 09 23.02) include requirements for a gateway, they are very clear on the circumstances under which the gateway can be used, and the only proprietary networking allowed is between a single package unit and a single gateway and cannot extend more than 10 feet.

   It's also worth noting that the control specifications apply to all devices procured as part of the project, so the gateway is intended for use in connecting existing equipment, not to allow the procurement and installation of equipment that doesn't meet the controls specification. Package units should be provided with the communications interface appropriate to the control system specifications.

   Additional information following Change 2 of UFC 3-410-02 {rev: 01July21}
   While the original answer remains the "default" case, change 2 of UFC 3-410-02 (and modification of UFC 3-410-01, UFGS 23 09 00 at the same time) introduced a method for identifying systems that can be excepted from the open protocol requirements and implemented with a gateway. VRF systems are one system that **may be** eligible for this exception, provides the requirements in UFC 3-410-02 are met. These requirements include that the system is more life cycle cost effective than open system alternatives and that the receiving system owner agrees to the exception and the use of the system.

3. **A VRF system is a packaged system, so can't it use the gateway as specified in the building control specifications?** {rev: 26Jan18}

No, for two primary reasons: 1) the specifications allow a gateway to existing, not new, equipment and 2) a VRF system is not a packaged unit. The following definition from UFGS 23 09 00 may help clarify:

> ***Packaged equipment*** *is a single piece of equipment provided by a manufacturer in a substantially complete and operable condition, where the controls (DDC Hardware) are factory installed, and the equipment is sold and shipped from the manufacturer as a single entity. Disassembly and reassembly of a large piece of equipment for shipping does not prevent it from being packaged equipment. Package units may require field installation of remote sensors. Packaged equipment is also called a "****packaged unit****".*
>
> *Note industry may use the term "Packaged System" to mean a collection of equipment that is designed to work together where each piece of equipment is packaged equipment and there is a network that connects the equipment together. A "packaged system" of this type is NOT packaged equipment; it is a collection of packaged equipment, and each piece of equipment must individually meet specification requirements.*

4. Doesn't all this mean that I can't use a gateway on other packaged equipment, like a rooftop unit, a chiller, or a simple DX split system? {rev: 11Jan18}

Original answer prior to Change 2 of UFC 3-410-02 {rev: 11Jan18}
Not necessarily. For equipment which is a single unit (rooftop unit, chiller) provided from the manufacturer with an appropriate communication interface, there is no requirement for the installation of a gateway so there is no issue. For systems with multiple components (like a split system), it depends on the architecture of the system: a system which uses hardware I/O or the required open protocol (LonWorks/BACnet) to communicate between the components can meet the specifications, whereas systems which use any other protocol than the one required cannot.

Additional information following Change 2 of UFC 3-410-02 {rev: 01July21}
The original answer still applies to individual packaged equipment, but the exception identified in Change 2 of UFC 3-410-02 now applies automatically to simple split systems of exactly 2 components.

5. But that communication interface on the rooftop unit is just a gateway, so why do you allow it and not the gateway to the VRF system? {rev: 11Jan18}

Because the line is drawn at the network interface of the component, not the internal workings. Any controller will have some internal communication between the chips on the circuit board, or between multiple circuit boards, and this is not a barrier to open communication between components.

Individual packaged units can comply with the UFGS requirements by having no external/field installed communications that don't meet the specification. A system consisting of multiple packaged units (such as a VRF system) can comply with the UFGS only when each individual unit complies (when each component only has communication that meets the spec).

6. **In FAQ #1 when you say that VRF systems aren't implemented in an open manner. Other than not using an Open protocol, what do you mean by this?** {rev: 26Jan18}
   There are several open system requirements in the specifications that have been an issue for VRF systems, including:
   a. Engineering tool software must be provided and licensed to the Government.
   b. Sequences must be fully documented.
   c. Source code for the application programs for programmable controllers must be provided.
   d. The system must be installed such that individual control equipment can be replaced by similar control equipment from other equipment manufacturers with no loss of system functionality.

   Resolution of these issues all depend on the resolution of the open protocol issue, so have taken a "back seat" to the protocol requirements. They are equally important to the competitive procurement of open, multi-vendor control systems.

7. **VRF systems are complicated, and different manufacturers have different sequences of operation, piping requirements, operational parameters etc. Doesn't item d. in FAQ 6 mean that this poses a concern as well?** {rev: 26Jan18}
   Unfortunately yes, it does. Just using an Open protocol won't be enough for a VRF system to meet the specification. For example, in order to meet the requirements it would have to be possible for a controller (or entire room unit) from Vendor A to be replaced by a controller (or entire room unit) from Vendor B. This may require that the VRF industry establish standards which would enable components from multiple vendors to work together.

8. **In the example in FAQ #7 you said the spec requires that the "controller (or entire room unit)" be replaceable by one from another manufacturer. Why isn't it just the controller, or just the room unit?** {rev: 25Jan18}
   Generally the control specifications assume that the controller can be separated from the equipment, and thus replacement of the controller would be the requirement. For package units, and particularly small, packaged units like the individual room units in a VRF system, replacement of the entire package unit would meet this requirement.

   While this may at first seem like an academic distinction, it may be important to the VRF industry as it provides two different paths to meeting the specification requirements, and one path may be easier for the industry to accomplish than another.

OTHER QUESTIONS:

9. **What about split systems, mini-split systems, multi-split systems?** {rev: 01Jul21}

   Original answer prior to Change 2 of UFC 3-410-02 {rev: 25Jan18}
   These issues/concerns are not specific to VRF systems and apply to all HVAC systems. For a specific system it depends on the system architecture and configuration. In general:
   a) If any two components communicate using a protocol other than LonWorks or BACnet as specified in the control specs for the project, the system does not meet the control specs.
   b) If one of the components cannot be replaced by a component from a different manufacturers, the system does not meet the control specs.

Additional information following Change 2 of UFC 3-410-02 {rev: 01July21}
The exception identified in UFC 3-410-02 always applies to simple split systems (two components), so simple split systems may require both components to be replaced at the same time. The exception ***may*** be applied to multi-split systems (including VRF) following all the requirements are met.

10. **Why are you treating VRF systems differently than other systems that are like it, like other packaged units?** {rev: 26Jan18}
We do not accept the comparison of a VRF system to a packaged unit. The proper system to compare to a VRF system is to a system that fills the same role as the VRF system does. In other words the question to ask is "what system would be used if a VRF system isn't allowed?" Based on having asked that exact question on numerous projects, the correct system to compare to a VRF is a hydronic fan coil system or a VAV system. It's been clearly established that neither of these systems can employ a proprietary communication protocol, so it should be clear a VRF system cannot do so either.

VRF systems are not being treated differently. In fact, they're specifically being held to the same requirements as all other HVAC systems.

11. **Why do you have requirements for VRF systems in the UFC if they don't meet the control systems specifications?** {rev: 01Jul21}

Original answer prior to Change 2 of UFC 3-410-02 {rev: 26Jan18}
Since there are likely application where VRF technology would be applicable or beneficial, this criteria has been prepared for the eventuality that the VRF industry is able to provide systems meeting the specifications. Additionally, this criteria is available for projects where the 10 USC 2867 mandated Secretary level waiver is obtained.

Additional information following Change 2 of UFC 3-410-02 {rev: 01July21}
Information in UFCs on the use of VRF, and a guide specification for VRF, exist for the reasons outlined in the original answer to this question and now also because of the exception identified in UFC 3-410-02.

12. **Why are you picking on VRF? Surely there are other systems that have these issues but you don't specifically call them out?** {rev: 11Jan18}
The intent is not to "pick on" VRF, but rather to publish criteria for VRF and to note the current limitations and considerations for the use of VRF systems.

Additionally, VRF is an often-proposed solution, but it's generally not understood that at present VRF systems don't meet the control specifications. It's necessary to explain this in the criteria both to prevent the installation of non-compliant systems and to encourage the industry to provide compliant systems.

13. <u>You said you'd like to use it… so why not just allow an exception for VRF?</u> {rev: 11Jan18}

There are two primary issues at play here:

1) 10 USC 2867 requires a waiver from the Secretary level for each project not meeting the specification, so there is no way to allow a blanket exception for VRF even if we wanted to.
2) There is no justification to treating VRF "differently". We can't justify allowing a specific HVAC system type (VRF) to use proprietary communication while continuing to prohibit other "competing" systems (VAV, hydronic fan coils) from doing the same.
3) We're not prepared to move to a less open specifications by allowing proprietary networks, and doing so would likely violate 10 USC 2867 as it requires open protocol specification.

14. <u>But [some non-DoD agency] uses VRF and loves them, so why doesn't the DoD allow them?</u> {rev: 11Jan18}

Again, the DoD is not prohibiting VRF but is enforcing its specifications. The needs of federal agencies with regards to building controls are often different, and the policy or acceptance of any technology by another agency is not reflective of DoD requirements.

15. <u>But [some DoD organization] has VRF systems already, doesn't this mean the DoD is OK with it?</u> {rev: 11Jan18}

No.

16. <u>I still have questions/concerns about the control system specifications or about VRF systems. Is there someone I can talk to?</u> {rev: 01Jul21}

1) CCRs[1] and/or emails can be submitted for the respective control system specification.
2) CCRs and/or emails can be submitted for UFC 3-410-01[2] or UFC 3-410-02[3] concerning VRFs.
3) General questions/concerns should be directed to the Mechanical or Control System CoP leads:
    - mechanicalcopleader@usace.army.mil
    - controlsystemcopleader@usace.army.mil

[1] Criteria Change Requests (CCRs) are submitted through the documents page at www.wbdg.org.
[2] The direct link for CCRs for UFC 3-410-01 is http://cms.wbdg.org/ccrs/new?ufc=3-410-01
[3] The direct link for CCRs for UFC 3-410-01 is http://cms.wbdg.org/ccrs/new?ufc=3-410-02