UFC 3-130-04
16 January 2025

UNIFIED FACILITIES CRITERIA (UFC)

ARCTIC AND SUBARCTIC BUILDINGS

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UNIFIED FACILITIES CRITERIA (UFC)

ARCTIC AND SUBARCTIC BUILDINGS

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

This UFC supersedes UFC 3-130-07, dated 16 January 2004.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website http://www.wbdg.org/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

The field of Arctic and Subarctic engineering, also known as cold regions engineering, covers a wide range of multidisciplinary topics and principles. Unique issues exist in the planning, design, construction, and operation of infrastructure and facilities in Arctic and Subarctic regions. Among them are permafrost, seasonal ground frost heave and thaw settlement, extreme low temperatures, high wind loads, heavy snow loads, and remote construction sites. Additionally, the implications of the rapidly changing climate in Arctic and Subarctic regions exacerbate these unique challenges.

The Unified Facilities Criteria (UFC) Arctic and Subarctic series includes five volumes that summarize relevant information and the most feasible approaches and solutions for planning, design, construction, and maintenance of infrastructure and facilities in the Arctic and Subarctic areas of the globe.

1-2 REISSUES AND CANCELS.

This document supersedes and cancels inactivated UFC 3-130-07, 16 January 2004.

1-3 PURPOSE AND SCOPE.

The Arctic and Subarctic UFC series provides technical guidance and available technical requirements for planning, design, construction, and maintenance of DoD facilities worldwide for all service elements in Arctic and Subarctic environments. These guidance and technical requirements are based on the International Building Code (IBC) and the requirements in UFC 1-200-01. The UFC 3-130 series covers many aspects of Arctic and Subarctic engineering with the specific exception pavements, which is incorporated into the UFC 3-250 and 3-260 series as discussed in UFC 3-130-01, paragraph 1-6.3. In addition to this volume, there are four other series volumes:

- UFC 3-130-01, *Arctic and Subarctic Engineering*. UFC 3-130-01 serves as an introduction to the Arctic and Subarctic UFC series.
- UFC 3-130-02, *Arctic and Subarctic Site Assessment and Selection*. UFC 3-130-02 provides applicability and technical guidance for geotechnical site assessment for the Arctic and Subarctic environment conditions.
- UFC 3-130-03, *Arctic and Subarctic Foundations for Freezing and Thawing Conditions*. UFC 3-130-03 includes horizontal and vertical foundations, considerations affecting foundation design, and construction and monitoring of facilities in the Arctic and Subarctic areas.

- UFC 3-130-05, *Arctic and Subarctic Utilities*. UFC 3-130-05 provides criteria and guidance for the design of utility systems for military facilities in Arctic and Subarctic regions.

This UFC provides criteria and guidance for the planning, design, and construction of DoD-owned facilities in Arctic and Subarctic regions. Only criteria and guidance unique to cold regions (the Arctic and Subarctic) are provided. The Arctic and Subarctic regions present unique challenges in every aspect of facility planning, design, construction, operation, and maintenance. Refer to UFC 3-130-01 for background and general criteria for Arctic and Subarctic engineering. This UFC references the fundamental building design and construction requirements from UFC 1-200-01, and the associated core UFCs and the UFCs referenced therein. It adapts those criteria for Arctic and Subarctic conditions, and transitions activities from completed Installation Master Planning, Area Development Plans, or other planning products described in UFC 2-100-01.

1-4 APPLICABILITY.

This UFC follows the same applicability as UFC 1-200-01, paragraph 1-3, for those geographic locations in Arctic and Subarctic regions worldwide.

1-5 GENERAL BUILDING REQUIREMENTS.

This UFC is an integrated part of the Arctic and Subarctic UFC 3-130 series. Use the other documents of this series in conjunction with this UFC to address construction aspects unique to cold regions. See UFC 3-130-01, Chapter 2 for the definitions of Arctic and Subarctic.

Often, conventional construction practices are acceptable in Arctic and Subarctic regions with appropriate modification to account for extreme cold temperatures, frost heaving soils, and permafrost areas. This UFC modifies and supplements the criteria found in the core UFCs. Utility provider’s or Installation specific requirements must be considered.

1-6 LEVEL OF CONSTRUCTION.

See UFC 1-200-01, paragraph 1-3.2, for the definitions of permanent construction, temporary construction, and facilities in support of military operations.

1-7 CYBERSECURITY.

Facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-8 BEST PRACTICES.

Appendix A contains guidance rather than requirements. It communicates proven facility solutions, systems, and lessons learned, but these are not the only solutions that meet requirements. It identifies additional background information and practices for accomplishing building design and construction. The Designer of Record (DoR) must review and interpret this guidance and apply the information according to the needs of the project. If a Best Practices document guideline differs from a UFC, the UFC requirements take precedence. For Best Practice guidelines not discussed in a UFC, the DoR must submit to the Government Project Manager a list of the guidelines or requirements being used for the project with documentation sufficient for review and approval prior to completing the design.

1-9 GLOSSARY.

Appendix B contains acronyms, abbreviations, and terms specific to this document. UFC 3-130-01 provides additional terms commonly used in cold regions engineering.

1-10 REFERENCES.

Appendix C contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

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CHAPTER 2 DESIGN CONSIDERATIONS

2-1 ENVIRONMENTAL FACTORS AND CONSIDERATIONS.

The Arctic and Subarctic environment affects most stages of building design, construction, operation, and maintenance. UFC 3-130-01 and UFC 3-130-02 cover the important environmental considerations for the configuration and orientation of individual structures in Arctic and Subarctic locations. Reference UFC 3-130-03 for criteria and guidance on ground conditions, the presence of permafrost, or seasonally frozen and thawing soils as needed for building design.

[C] 2-1 The interior building environment is usually drastically different from ambient Arctic and Subarctic conditions, placing severe stresses on building components. Rapid deterioration and costly maintenance are inevitable unless these stresses are carefully considered during planning, material selection, and throughout construction. In addition to designing for occupant comfort, building design must account for hazardous conditions, such as poor visibility caused by whiteout conditions, fog, or darkness, coupled with high winds, blowing snow, and low temperatures. It is essential to minimize personnel encounters with the environment.

2-2 ENVIRONMENTAL SEVERITY AND HUMID LOCATIONS.

Comply with UFC 3-101-01 and associated references therein, such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) *Cold-Climate Buildings Design Guide* and ASHRAE *Handbook—Fundamentals*, for appropriate climate design values. See also UFC 3-400-02.

[C] 2-2 Knowledge of individual site conditions is important for developing effective facility designs. The winter months in Arctic and Subarctic locations exhibit the greatest range and severity of conditions on the planet.

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CHAPTER 3 ARCHITECTURAL

3-1 GENERAL.

Comply with UFC 1-200-01 and UFC 3-101-01 and associated references therein for architectural considerations. See Appendix A for guidance on Architectural Best Practices.

[C] 3-1 Consider issues related to snow and ice early in the design process. Special designs and construction techniques are required for buildings, primarily due to prolonged and extreme low temperatures, snow, wind, seasonally frozen and thawed ground, permafrost ground conditions, and special transportation, equipment, and maintenance requirements. Designers must provide a functional building while considering the factors required to provide an environment that meets the total needs of the occupants, contributes to high morale and productivity, and is energy efficient and sustainable.

3-2 BUILDING ORIENTATION.

Refer to UFC 3-101-01, Appendix A, for general guidance on building orientation.

[C] 3-2 Snow and ice significantly affect the design, operation, and maintenance of buildings and the safety of the building's occupants. Building orientation, building geometry, and climatic conditions are factors in snow shedding (snow sliding) off roofs, snow drifting, and drainage.

3-2.1 Snow Drifting.

Comply with UFC 3-301-01 criteria on snow loads, to address snow drifting potential. See Appendix A for guidance on Best Practices to reduce issues from snow drifting for buildings. Properly seal penetrations through the building envelope.

[C] 3-2.1 Snowdrift accumulations can have severe implications for occupant health and safety, such as when emergency equipment access is blocked or building egress is obstructed in an emergency.

3-2.2 Snow and Ice Creeping, Sliding, and Falling from Roofs.

To prevent falling snow and ice from blocking entrances, locate building access at the gable ends or control with the use of dormers and canopies. Refer to the *Site-Specific Case Studies for Determining Ground Snow Loads in the United States,* by Buska et al., to address this and other related design issues.

Refer to the Cold Regions Research and Engineering Laboratory (CRREL) Sliding Snow Calculator Summary Sheet and Sliding Snow Calculator tool (https://www.erdc.usace.army.mil/Portals/55/docs/CEERD-RV/CEERD-RR-H/BuildingTechnology/Tools/Sliding%20Snow%20Calculator.xls) to estimate the potential zone impacted by snow and ice shedding from roofs.

3-2.3 Local Site Conditions.

Observe site-specific conditions during winter site visits for indicators of potential snow-drifting problems. Aerial photographs also provide valuable information. Consult historical weather records to determine the intensity, direction, variability, and frequency of storms. Refer to Appendix A to estimate snow transport directions and volumes, which are useful for site planning with a snow transport analysis.

> [C] 3-2.3 The primary factors facilitating snow transport and influencing potential drift locations are high winds and dominant wind directions. Snow-drifting conditions are highly variable, even at nearby sites, and are affected by topography, vegetation, surrounding buildings, and so on, even when the locations are not separated by large distances.

3-3 PREFABRICATED STRUCTURES.

Prefabricated systems must be specifically designed for extreme cold climates—most off the shelf prefabricated options currently available may fail in the Arctic and Subarctic. The design factors that govern the selection of primary systems and backup systems are system reliability, ease of access for regular operation or to conduct maintenance, system simplicity, and cost. See Appendix A for further information.

3-4 BUILDING ENVELOPE.

The building’s exterior envelope must provide a continuous barrier to air infiltration, a layer of insulation, and a vapor retarder around heated spaces. Maintain the continuous air barrier and air-vapor barrier at penetrations, windows, doors, and around elements of the structural system. Design thermal breaks in locations with little resistance to heat loss, such as between metal framing and the outside air. Comply with UFC 3-101-01, Appendix A, and associated references therein. Refer to ASHRAE *Cold-Climate Buildings Design Guide* for specific building-envelope considerations for Arctic and Subarctic climates.

> [C] 3-4 It is critical to control the transfer of heat and infiltration of air and moisture through the individual components of walls, ceilings, roofs, and floors and to maintain a continuous barrier at their transitions.

3-4.1 Heat.

Reduce heat loss and maximize energy efficiency. Provide insulation with effective R-values in foundations, walls, ceilings, roofs, and elevated floors to meet the minimum requirements of applicable energy codes. Install insulation carefully, completely filling the spaces between wall framings, door frames, and window frames to provide continuous insulation and minimize cold air penetration and infiltration. In exterior walls avoid gaps, uninsulated gaps can create air currents. For above-grade floor systems where the under-building surface is exposed to the ambient air temperature, for example in a building on a pile foundation, insulate floors in a manner that is similar to that used for exterior walls.

[C] 3-4.1 Different insulation R-values are appropriate for different geographic locations, depending on the severity of the thermal conditions, and for above- and below-grade walls.

3-4.1.1 Insulation.

Install insulation in walls, ceilings, roofs, floors, and elevated floors to regulate thermal transfer between interior and exterior surfaces according to the specific requirements of the application. Exterior foundation walls must have properly designed perimeter insulation board extending from the top of the footing to the bottom of the floor slab. Depending on the wall construction, the insulation may be on the exterior or interior face of the wall. Design insulation to meet fire protection requirements, flame spread and smoke development rating requirements, and to comply with UFC 3-600-01.

3-4.1.2 Thermal Bridging.

Design for thermal breaks to avoid problems such as below-freezing temperatures on warmer interior surfaces, at the connections, and at places of contact between the interior and exterior surfaces. On the cold portions of interior sheathing, add thermal breaks to reduce condensation and mold growth.

[C] 3-4.1.2 Thermal bridging is the conduction of heat between two areas of high thermal conductivity where there is little resistance. This phenomenon is observed in construction materials such as metal, masonry, wood, and concrete, which exhibit higher thermal conductivity compared to insulation materials. While wood-frame construction has lower thermal conductivity and fewer issues with frost buildup, it is also subject to issues of thermal bridging, shrinkage and water damage.

3-4.2 Air.

Use a well-sealed and continuous air barrier to control air leakage into and out of the building envelope, including walls and floors. The wall assemblies must be designed to minimize both moisture intrusion and air infiltration. In accordance with ASHRAE guidelines, it is imperative that wall assemblies integrate well-designed vapor and air barriers to regulate the movement of air and moisture. These barriers play a crucial role in preventing exterior air infiltration while facilitating the escape of interior moisture, ensuring an optimal balance in moisture control within building structures. Comply with the air barrier requirements of UFC 3-101-01, and the references therein.

[C] 3-4.2 Air leakage is a significant issue for buildings located in Arctic and Subarctic regions; however, appropriate mechanical ventilation needs to be addressed during the design process.

3-4.3 Moisture.

Moisture from exterior and interior sources, and vapor ladened indoor air, can become trapped in the insulated cavity between the vapor retarder and the exterior surface material. The building envelope must be designed to limit moisture intrusion into these cavities as much as possible. Take extra precautions when dealing with transitions and penetrations in walls, floors, and ceilings. These areas are critical for minimizing the movement of air and moisture. Provide vapor relief if needed to avoid trapping moisture that can freeze within the building envelope and build up ice, leading to deterioration of the insulation material and rendering it ineffective. Refer to UFC 3-101-01, ASHRAE *Cold-Climate Building Design Guide,* and *Guide for Resilient Thermal Energy Systems Design in Cold and Arctic Climates*, by Zhivov. During winter in the far north, some facilities require humidification due to low air humidity and the low relative humidity associated with heated structures. Humidifying facilities in cold climates is often problematic and requires careful design.

3-4.3.1 Vapor Retarder.

Exterior wall systems require a layer that retards the infiltration of interior moisture into the insulation. A Class I or II vapor retarder (such as 6-milimeter polyethene sheeting) is required by the International Building Code for the Arctic and Subarctic climate zones. Use vapor retarders on or near the warm interior side of the building envelope. Vapor retarders must extend below slabs on grade, and along crawlspace walls and floors. See Appendix A for further information.

3-4.3.2 Ventilation.

Design ventilation to prevent trapping moisture or provide relief to allow moisture to escape. Ventilate the space between the roof insulation and the roof finish to maintain the integrity of the insulation and the roof structure and help prevent ice dams and water leakage. See Appendix A for further information.

3-4.3.3 Condensation.

Controlling condensation in Arctic and Subarctic regions requires a complete and continuous vapor retarder on the warm side of the exterior enclosure of the building; insulation to maintain the interior surfaces and the vapor retarder at a temperature warmer than the dew point; and a vapor-permeable exterior surface of the building enclosure (for a roof, this may require ventilation). Where a facility requires or there is high humidity within a building, such as in medical facilities or water-treatment plants, exercise special care to control air leakage and prevent condensate from forming on or within cold walls, windows, and ceilings. Make provisions to avoid water dripping onto personnel and critical equipment. Allow no condensate to drip on floors, particularly in front of doors that open to the outside.

[C] 3-4.3.3 Satisfactory building-envelope design requires balancing three factors—vapor retarder, insulation, and vapor dissipation.

3-4.4 Daylighting.

Window design must consider the range of available daylight hours throughout the year and its effect on energy use and efficiency. Comply with UFC 3-101-01, paragraph 3-7.1, and include design considerations for snowdrift previously discussed in paragraph 3-2.1. See Appendix A for further information.

3-5 ROOFS.

Comply with UFC 3-110-03 and applicable paragraphs of UFC 3-600-01. Keep roof geometry simple. Complex roof geometries and configurations create problems if they contain valleys, dormers, ice dams, or other features that restrict or block ventilation. Minimize the adverse effects of snow and ice on roofs. Design roof systems to prevent ice damming and excessive snow accumulation. Increase roof pitches, use low friction materials, or site buildings to avoid areas of low wind where blowing snow may accumulate. Roof system designs must be able to withstand ice and snow removal activities. For further guidance, see:

- "Minimizing the Adverse Effects of Snow and Ice on Roofs," by Buska and Tobiasson;
- "Electric Heating Systems for Combating Icing Problems on Metal Roofs," by Buska et al.;
- "Guidelines for Ventilating Attics and Cathedral Ceilings to Avoid Icings at their Eaves," by Tobiasson et al.;
- "Roof Ventilation to Prevent Problematic Icings at Eaves," by Buska et al.,
- "Standing Seam Metal Roofing Systems in Cold Regions," by Tobiasson and Buska; and
- "Snow Guards for Metal Roofs," by Tobiasson et al.

Ventilated roofs need careful design consideration in non-wood framed structures due to thermal bridging, condensation, and other issues noted paragraph 3-4. A 'hot roof' system may be used in conjunction with a low sloped roof for non-wood framed structures but must be carefully designed as the roofing materials and insulation need to be compatible. Avoid large roof steps as lower roofs must be designed for snow drift loading and this additional load can be significant with large roofs and high ground snow loads. Pitched roofs require consideration of unbalanced snow loads. Steep roofs with slippery surfaces, such as standing seam metal roofing, pose a sliding snow hazard at entrances and usually require snow guards (also called “snow stops”) or some other mechanism to help restrain sliding snow. Restrained snow adds to roofing down drag forces that must be considered for roofing attachment. Specify pre-engineered metal building (PEMB) roof systems for more collateral loading assuming another roof system will need to be installed over the original roof system in the future. Extreme changes in temperature at Arctic and Subarctic sites result in large roof panel expansions that tend to work open typical PEMB roof panel attachment fastener locations causing roof leaks. This can be mitigated by using an insulated metal panel standing seam roofing system instead of PEMB standard panels. Protect roof stacks and vents from sliding snow on sloped roofs with slippery surfaces.

[C] 3-5 Address roof design and drainage issues early in the design process. Problems are avoided, and more functional designs developed, when snow and ice issues are considered as the building design evolves. Both low-slope and steep-slope roof designs are commonly used in cold regions. Metal, conventional built-up, and protected-membrane roofs perform satisfactorily if properly constructed.

3-5.1 Drainage for Low-Sloped Roofs.

Comply with UFC 3-110-03. Heat trace roof drains to keep drains functional during freezing weather.

[C] 3-5.1 On low-sloped roofs, secondary roof drainage, such as scuppers, that drain to cold eaves can become blocked by ice formation and build-up and create ponding that increases the potential for leaks and possible roof collapse. Problems commonly occur at scuppers placed along a raised edge.

3-5.2 Gutters.

In Arctic and Subarctic regions, where snow slides off slippery roofs, gutters are not recommended. For low roofs featuring asphalt shingles and areas with lower slopes, incorporate gutters to manage moisture and reduce icicle formation. Integrate heating elements, such as heat tape, into the design of the gutter systems and extend along the entire length of the gutter system, including downspouts.

3-6 FENESTRATION DESIGN.

Comply with UFC 3-101-01. Window design must consider features to avoid condensation and frost buildup. Use higher performing windows with insulated frames including thermal breaks and insulated glazing units to prevent condensation and frost build up in the cold temperatures.

3-7 SEALANTS.

Sealant compounds normally used in temperate regions do not perform satisfactorily in cold regions. Select sealant materials that remain flexible and provide permanent cohesion and adhesion in extremely low ambient air temperatures to seal joints of precast concrete panels, metal roofing, around window and door frames, and in similar transitions.

[C] 3-7 The extreme variation between low and high summer and winter temperatures causes common sealant compounds to become brittle and lose their cohesion and adhesion.

3-8 EXTERIOR DOORS.

3-8.1 Exterior Personnel Doors.

Provide vestibules, or arctic entrances, near high-humidity areas in buildings and in buildings located in windy areas. An arctic entrance is a vestibule used in Arctic and Subarctic locations to shut out cold air, high wind, or drifting snow after the exterior door closes and before the inside door is opened. Use exterior doors that open inward to preclude being blocked by drifting snow and possibly damaged by high winds. A door that swings inward permits burrowing out when blocked, although it violates the fire code for certain occupancies and functions. Separately evaluate each inward-swinging-door requirement in terms of risk, alternate exits, and other factors related to occupant safety. See Appendix A for further guidance on arctic entrances.

Because of high winds and extreme cold, doors located on the prevailing windward side of the building require special protection (windscreen or baffle) in addition to arctic entrances. Provide wind screens, baffles, or heavy bumper stops mounted on steel posts to protect the doors and hinges from damage and to prevent injury. Insulate and weather-strip both doors and frames to provide an integral thermal break. Where drifting snow is not a problem, follow standard codes for exit doors. Exclusive use of insulated metal or composite doors and frames is highly recommended. For buildings that support child development or other youth programs, provide a protected warming area for patrons to await transportation.

[C] 3-8.1 Exterior personnel doors are normally free from frost buildup unless there is high humidity within the building. Typical high-humidity areas include laundry, showers, kitchen areas in mess halls, dormitories, and indoor swimming pools. For exterior use, metal and composite doors and frames are sturdier, look better longer, are better insulated, and retain their shape better than wooden doors and frames.

3-8.2 Accessibility.

Cover exterior access ramps for accessibility. Otherwise, designs for accessibility must conform to current criteria. See Appendix A for further information.

3-8.3 Overhead Doors.

On shop and warehouse buildings with large doors, use insulated sectional overhead doors. Separate the outside and inside panels with a thermal break. Provide seals at the head, jambs, the sill, and between sections. Individual sections and the entire door assembly must withstand design wind loads. Doors can operate manually or electrically, depending on their location and function. Do not use metal rollup doors in exterior walls. Do not slope floors to the door because melted snow will freeze at the doorsill and hinder the door operation.

> [C] 3-8.3 When using electric operators, an important safety feature to incorporate is an automatic safety edge that stops or reverses the door's downward motion when the bottom edge strikes an object.

3-9 FINISHED FLOOR ELEVATION.

In Arctic and Subarctic areas, establish the minimum floor elevation 6 in. (150 mm) to 12 in. (300 mm) above the exterior finish grade to eliminate the possibility of water backing into the building during thaw periods. In extremely flat terrain and where snow drifting is anticipated, the higher elevation is justified. Provide a stoop at exterior doorways other than emergency exits. Construct the stoop to avoid frost heaving by placing additional non-frost susceptible fill material under stoop and anchoring or doweling the stoop to the main foundation wall. A 6 in. (150 mm) step may be an ABA code violation depending on egress points. Ventilated floors or floors in buildings sited on permafrost are not subject to this requirement.

3-10 EXTERIOR LANDINGS, STAIRS, AND RAILINGS.

For elevated walking surfaces on exterior landings and stairs, use materials with serrated open grating to prevent ice and snow accumulating on horizontal surfaces. Interior or enclosed stairways are preferable. Separately support or hinge exterior stairs and landings from the building or cantilever them from the building to allow for movement from frost heave. If differential heave is anticipated, isolate large landing structures or docks from the main structure. Proper foundation treatment may minimize differential movement between warm and cold structures. Refer to UFC 3-130-03 for foundation design.

3-11 INTERIOR FINISHING.

Ensure there are acceptable tolerances for movement and consider that the structure may not always be warm in the interior and may undergo periods of cold soaking during mothballing or prolonged power or mechanical outages. See Appendix A for further information.

3-12 BUILDING RETROGRADE OR MOTHBALLING.

Mothballing or retrograding Arctic and Subarctic buildings involves using strategic measures to protect structures during extended periods of inactivity, typically due to seasonal shutdowns or temporary closures. Key considerations for effective mothballing include comprehensive winterization efforts, ensuring protection against extreme cold temperatures. This involves conducting insulation checks, sealing gaps, and safeguarding plumbing systems from freezing. Additional measures encompass the implementation of a controlled heating system to maintain an adequate temperature within the building, preventing issues like frozen pipes and ensuring the interior environment remains within acceptable limits. Proper ventilation is essential to prevent moisture buildup, condensation, and mold growth, while sealing openings and entry points helps keep out pests. Managing moisture using absorbent materials or dehumidifiers is crucial, as is safeguarding the electrical system and implementing security measures. The drain traps must also be considered as they may need to be filled with propylene glycol or other fluids.

[C] 3-12 Conducting a thorough inspection of the building envelope, preserving equipment according to manufacturer guidelines, and developing a comprehensive mothballing plan with detailed procedures are integral components of the mothballing action. Establish an emergency response plan, adhering to local regulations, and implementing regular monitoring practices, especially before and after extreme weather conditions. In no case is it recommended to totally remove heat from a previously heated structure. These actions help to preserve the integrity of Arctic and Subarctic buildings during periods of inactivity.

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CHAPTER 4 STRUCTURAL

4-1 GENERAL.

Structural designs for buildings situated in Arctic and Subarctic regions present unique challenges. Unlike more temperate locations, these areas experience compounded challenges arising from distinctive design loads and extensive seasonal climate variations. Comply with UFC 1-200-01 and UFC 3-301-01 and associated references therein. For structures designated as Risk Category V, comply with UFC 3-301-02 and the references therein.

4-2 DESIGN LOADS.

Refer to UFC 3-301-01, Chapters 2 and 3, and UFC 3-301-02, Chapter 2, for design requirements. There are several sources of design load information available. UFC 3-301-01 describes the Structural Load Data Tool (SLDT), hosted on the Whole Building Design Guide website https://www.wbdg.org/ar/tools/sldrt, that provides structural load information for wind, snow, frost penetration, and seismic data for DoD Installations within the U.S. and its territories. The American Society of Civil Engineers (ASCE) ASCE 7 Hazard Tool (https://asce7hazardtool.online/) provides load information for flood, ice, rain, seismic, snow, tornado, and wind for U.S. locations not included in the SLDT. Alaska-specific snow-load data are available from the Structural Engineers Association of Alaska website https://seaak.net/alaska-snow-loads. Ground snow load case studies may be needed for site-specific locations in the U.S. that are not included in published maps due to extreme local variations in snow loads. Use the methodology in *Site-Specific Case Studies for Determining Ground Snow Loads in the United States,* by Buska et al., and the accompanying spreadsheet-based calculator, Snow Load Case Studies (https://erdc-library.erdc.dren.mil/jspui/handle/11681/37574). At locations where load data is lacking, use the best locally available criteria with the approval of the Authority Having Jurisdiction (AHJ).

4-3 MATERIALS.

Common structural materials, such as concrete, wood, and steel, are successfully used in Arctic and Subarctic areas in conditioned (heated) structures with few problems. Comply with UFC 3-301-01 Best Practices for additional information on using these materials in Arctic and Subarctic areas. In non-conditioned (unheated) structures, thermal expansion/contraction must be considered. Comply with American Concrete Institute (ACI) ACI 318 concrete durability requirements for exposure. When using concrete as a building material, additional construction measures are required when ambient temperatures fall below 40°F (4.4°C) to ensure timely strength development and prevent damage due to freezing at early placement ages. These measures may include enclosing and heating the concrete placement, insulation of formwork, or use of accelerating admixtures, solely or in combination. The ACI 306R *Guide to Cold Weather Concreting* provides recommendations for the use of these measures in varying cold weather conditions. Consider low temperature steels with high-notch toughness where structural steel is exposed in arctic conditions. Design with proper joints to account for thermal expansion/contraction.

4-4 FOUNDATIONS.

Comply with UFC 3-130-03. UFC 3-130-03 provides a complete discussion of foundations for freezing and thawing conditions.

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CHAPTER 5 MECHANICAL

5-1 GENERAL.

Comply with UFC 1-200-01, UFC 3-401-01, and the government criteria referenced therein. Standardize components whenever possible to reduce the necessary inventory of repair materials. Employ redundant or backup heating options that reduce risk to other systems and personnel.

[C] 5.1 While the design and operation of mechanical systems in Arctic and Subarctic regions share similarities with those in the northern regions of the continental U.S., it is crucial to note that extended periods of exceptionally low temperatures and high wind conditions in the Arctic and Subarctic can lead to failures in systems that typically function effectively in more moderate climates. Therefore, mechanical system design for cold regions must be simple, robust, and utilize Arctic-type technical changes and economic considerations. Operation and maintenance considerations are crucial because isolated Arctic sites may lack expert technical assistance.

5-2 PLUMBING.

5-2.1 General Design Requirements.

Comply with UFC 3-130-05 for cold regions utilities requirements to include various types of piping and utilities connections.

[C] 5-2.1 Designing plumbing systems for Arctic and Subarctic regions requires careful consideration of extreme weather conditions, freezing temperatures, and the unique challenges posed by the environment. Some considerations are, insulation, heating pipes, below frost level installation of utilities, and decoupling frost zone penetrations both thermally and mechanically. Thermal decoupling is achieved using thermal breaks and insulation, while mechanical decoupling involves employing flexible joints, slip connections, isolation pads, and other methods.

5-2.1.1 Energy Efficiency and Water Conservation.

Comply with UFC 1-200-01, UFC 3-420-01, and the criteria referenced therein.

[C] 5-2.1.1 Where adequate water supplies are available and normal sewage systems can be installed interior plumbing facilities vary little from those used in temperate climates. However, water is not always readily available. In areas with permafrost, it is difficult to treat and dispose of sewage.

5-2.1.2 Reliability.

To prevent potential freezing in sewage pipes and systems, collect small waste flows and discharge them in slugs rather than allowing the sewage to trickle by gravity within the lines.

5-2.1.3 Piping Arrangement.

Avoid locating plumbing on the exterior walls. Buildings in permafrost areas that are elevated above ground on a piling system expose the area under the floor to cold arctic air. Protect underfloor piping from freezing. See Appendix A for further guidance.

5-2.1.4 Siting.

Do not divert drainage from roof and floor drains into the sewage treatment systems because this increases the volume of sewage requiring treatment and is frequently a violation of applicable plumbing or public health codes. Dispose of sewage (black water) separately from excess surface moisture (snow, ice, or water) runoff. Dry wells located below the depth of seasonal frost may be used in Subarctic regions that are permafrost free and have free-draining soils. Prevent dry wells or connecting drains from freezing with regular monitoring and maintenance to clean out and inspect for the buildup of silt, leaves, or other debris. Avoid frozen conditions that cause wells to back up water toward the roof and create leaks within the building. Install roof drain lines that discharge through an exterior wall onto a splash block and into a concrete trench covered by a grate to carry water away from the building and minimize ice formation on paved surfaces. In shops, install floor or trench drains to collect and carry away melted snow brought in on vehicles; drains, traps, and piping must be kept clear of blockages created by the considerable amounts of mud, gravel, sticks, and vegetation carried in on vehicles. Provide baskets, strainers, and sand and oil traps to keep drains operational. Frozen oil traps become inoperable. Heating is required to keep these traps operational. Alternately, install traps inside buildings. Make sure drains and piping are located such that there is no impact to the building foundation if a thaw bulb is created.

5-2.2 Supplemental International Plumbing Code (IPC) Technical Criteria.

The IPC lays out the general plumbing code, below are considerations for Arctic and Subarctic regions for specific use cases.

5-2.2.1 Food Waste Disposer.

Garbage disposals are generally not installed in Arctic and Subarctic locations at small, remote Installations where sewage treatment and disposal are particularly difficult. Grease traps become inoperable when water within them freezes. To keep these traps operational, they must be either heated or installed inside the building.

[C] 5-2.2.1 If disposals are installed, consider grease removal. Grease may congeal and clog cold sewer lines and may also create operation and maintenance problems at the sewage treatment facility. Oversized exterior grease traps require frequent cleaning. The normal foodstuffs that are run through a garbage disposal tend to reduce the life of a septic system drain field or leach pit.

5-2.2.2 Water Storage Tanks.

Water storage tanks may need to be heated to avoid freezing. Conduct appropriate thermal analysis to determine if this applies to a specific case.

5-2.2.3 Exterior Faucets or Hose Bibs.

Avoid frozen hose bibs by use of a valve on the supply zone inside the heated space that can be turned off in the winter. In this case drain the hose bib and leave open for the winter. Alternatively, frost-proof faucets or hose bibs can be installed to minimize the risk of freezing. Provide adequate drainage paths from exterior hose bibs so that the building foundation is not impacted by excess water.

[C] 5-2.2.3 Frost-proof faucets are designed to drain water away from the remote valve when turned off, preventing water from standing in the exposed portion of hose bib.

5-3 FACILITY HVAC SYSTEMS.

5-3.1 General.

Comply with UFC 3-401-01 and UFC 3-410-01. Minimize cold floors and downdrafts from windows by using adequate floor insulation and locating heating units below windows.

[C] 5-3.1 A reliable and easy-to-maintain heating system is extremely important for personnel comfort and safety. Remote locations, severe climatic conditions, and short daylight hours tend to confine personnel to the site and are the primary reasons for maintaining a good physical environment. While constant circulating heat systems usually provide more uniform room temperatures, it is important to evaluate available information before selecting a system.

5-3.2 Ventilation.

Comply with UFC 3-410-01. Utilize heat recovery ventilation systems to minimize the impact of ventilation on the heating load of the building. Ventilation systems require designs that temper incoming cold air so as not freeze equipment that can cause failures.

[C] 5-3.2 The fresh air requirements for ventilation are principally the same as those in temperate climates. Avoid issues resulting from inadequate or improper ventilation-system design during the design process.

5-3.2.1 Freezing of Heating Coils in Ventilation Units.

Provide a low limit thermostat control in the air discharge from the coil to stop the fan and close the outside air dampers when air temperatures drop to about 35°F (2°C), such as during a power outage. Refer to UFC 3-410-01 for further freeze protection criteria. Prevent air stratification in the mixing box by bringing warm air in at the bottom and cold air in at the top. Refer to UFC 3-410-01 for further ventilation criteria, and Appendix A of this UFC for Best Practice guidance.

5-3.2.2 Outside Air Openings.

See Chapter 3 of this document, UFC 3-410-01, Appendix B, and the ASHRAE *Cold-Climate Buildings Design Guide*.

[C] 5-3.2.2 High winds, blowing snow, rain, damage from falling ice, and the need for screens cause problems with outside air openings used for air ventilation intake and exhaust.

5-3.2.3 Frosting of Filters in Ventilation Systems.

Because fresh air intakes, including filter banks, are generally under negative pressure, seal openings and penetrations that permit more humid air to enter the intake duct or filter bank. Several methods to correct this issue are possible. One method is to install a preheat coil ahead of the filter to heat the air to 30°F (−1°C), but that coil can plug with dirt, lint, and other material during normal summer operation. To obtain the best results, use heat recovery ventilators or energy recovery ventilators, frost resistant filters, or increase the airflow to minimize icing. Refer to UFC 3-410-01, Appendix B.

[C] 5-3.2.3 Icing and frost closure occur when saturated freezing air, usually below −20°F (−29°C), is brought in through a filter. The same problem can occur when fresh air intakes are too close to the exhaust openings and plumbing vents. . Icing and thawing cause throwaway-type filters to get wet, collapse, and jam the face and bypass dampers within a relatively short duration.

5-3.2.4 Insulation of Ducts and Pipes Handling Cold Air.

Provide insulation for pipes and ducts subjected to cold air and seal at the vapor retarder penetration, as described in Chapter 3.

5-3.3 Humidification.

The need to address and control variations in humidity is discussed in Chapter 3. During winter a building may need humidification to be comfortable for habitation. The system must be balanced between humidification and the need to control condensation in the structure.

5-3.4 Condensation.

Maintain an adequate difference between the dew point and the temperature to avoid condensation. Refer to paragraph 3-4.3 for moisture within the building envelope, and to UFC 3-410-01 for heating and cooling load calculations.

[C] 5-3.4 Condensation can cause interior damage when excessive levels of humidity are maintained within the building. Condensation can freeze on the vapor barrier if it is too cold and over repeated cycles.

5-3.5 Low-Temperature Lubricants.

Fans or other moving equipment mounted on a building's exterior or located within unheated portions of the building must be capable of operating at the lowest recorded ambient temperature. Use special low-temperature lubricants. Require manufacturers to guarantee their equipment under the extreme weather conditions expected at the site.

[C] 5-3.5 Many bearings and races may be coated in materials that have incompatible thermal conductivities and expansions. In a cold and dry condition, they may fail exponentially faster.

5-4 HEATING CONCERNS.

Minimize cold floors and downdrafts from windows by using adequate floor insulation and locating heating units below windows. While constantly circulating heat systems usually provide more uniform room temperatures, it is important to evaluate available information before selecting a system. Further design criteria for various types of heating systems are discussed in detail in paragraphs 5-4.1 through 5-4.8. The advantages or disadvantages of each system when used in the arctic environment are noted. Comply with UFC 3-410-01 and the references therein on the selection and design of appropriate heating systems.

[C] 5-4 A satisfactory, reliable, and easy-to-maintain heating system is extremely important for personnel comfort. Remote locations, severe climatic conditions, and short daylight hours tend to confine personnel to the site and are the primary reasons for maintaining a good physical environment.

5-4.1 Freezing of Water and Steam Systems.

Comply with UFC 3-410-01. Guard against system freezing by protecting heating lines and equipment. Properly protect hot water lines located in exterior walls. Constant circulation delays water freezing in the pipes if a boiler, furnace, or heat exchanger stops working. Where automatic room temperature control is not provided, personnel may open windows to provide necessary control, and lines may freeze when the room is left unattended. For this reason, provide individual room thermostat controls. In garages or hangars, interlock unit heaters installed within 20 ft of doors with those doors so that the fans on the unit heaters shut off when the doors open. When fans are left running, cold outside air is blown over the coil, frequently causing the coil to freeze. Install a temperature alarm system in each remote, unoccupied building to alert maintenance personnel when the building interior temperature approaches freezing.

5-4.2 Shop and Hangar Heating.

Comply with UFC 3-410-01, paragraph 3-6. To address Arctic and Subarctic heating challenges in large buildings, several issues must be considered. These include the frequent opening of large doors, the presence of high ceilings, and the imperative for swift heat recovery. It is essential to appropriately size and select projection-type heaters, ensuring their efficiency in managing the vast spaces. Installing snow melting systems beneath hangar doors and ramps helps mitigate ice and snow accumulation, ensuring the doors remain operational. Additionally, incorporating radiant floor heating alongside the standard heating system enhances overall warmth. To minimize heat loss, focus on reducing air infiltration through strategic measures such as well-designed doors, effective weather stripping, and minimizing the use of operable windows. Factor estimates for infiltration into comprehensive heat loss calculations, emphasizing the need for meticulous data and calculations to optimize heating systems in these expansive structures.

5-4.3 Heating Control.

Generally, provide automatic controls for heating and ventilating systems. Provide manual control systems to preclude complete shutdown if automatic controls fail. Consider night temperature setback wherever practical. Heating coils require adequate controls to protect them against freezing. Keep control systems simple because expert maintenance is often not available.

5-4.4 Cooling Water and Recharge Wells.

Cool the water supply and use recharge wells where outside temperatures are too high to cool electronic equipment during summer months. During winter months, discharging wastewater in recharging wells, rather than on the ground surface, can effectively reduce ice fog and glaciation. Reducing ice fog is especially important near airfields. Well water in Subarctic regions typically does not exceed 39°F (4°C).

5-4.5 Fuel Oil Piping and Storage.

Comply with UFC 3-410-01. Fuel oils used in cold regions must comply with proper grading. When used in areas where low temperatures prevail, consider special heating and insulation of fuel lines. When commercial diesel fuels with a higher pour point are used, heating may be required for the system to function properly. Lines may be increased one pipe size; however, larger-diameter pipes reduce velocity and cause sluggish operation. It is not advisable to bury exterior fuel oil tanks in permafrost areas because the supply and return connections are extremely vulnerable to breakage when settlement occurs. Aboveground tanks, however, are exposed to lower temperatures, and a protective shelter may be required. When installing aboveground tanks that are higher in elevation than the burner unit, install a vacuum relief on the fuel oil supply line. Double-wall construction or containment is required for fuel tanks.

5-4.6 Air Elimination.

Provide systems for positive air removal and for draining the piping and equipment.

[C] 5-4.6 Eliminating air in a hot water heating system can be a problem in every climate. It is more critical in Arctic regions because of the need for continuous operation.

5-4.7 Piping in Hot Water Heating Systems.

Maintain positive flows in piping systems unless using an antifreeze-filled system. Antifreeze systems are preferred; however, they do lower the thermal conductivity of the working fluid. Avoid feeding numerous parallel zones from one circulating pump. If parallel zones must be used, provide accessible balancing control, indicating devices, and a manual bypass to allow operation during maintenance.

[C] 5-4.7 An improperly piped system may perform satisfactorily in a temperate zone, but the same system may cause heating problems when exposed to extreme Arctic conditions. Careful design minimizes these problems. Parallel zones are difficult to balance, and eliminating air from the many circuits is difficult. Flow can easily stop in one zone because of poor air elimination. A freeze-up may result, which, when concealed, is extremely difficult to correct.

5-4.8 Design Considerations for Simple, Effective Mechanical Systems.

Ensure adequate space in the mechanical room and around equipment to facilitate inside maintenance during cold weather. Arrange piping connections and space to permit the removal of coils, tube bundles, and filters. Provide ready access to maintain motors, automatic controls, dampers, traps, and so on. Provide systems subject to interior condensation with drain valves to drain moisture annually. Simple mechanical systems that can be serviced by inexperienced maintenance personnel are required.

[C] 5-4.8. Inaccessibility is one of the most frequent problems encountered by maintenance personnel, especially when repairs must be made immediately to reduce system outages; fast repairs require sufficient maintenance space. Sites may be in remote areas where experienced personnel and ready sources of spare parts are not available. In specifications for heating and plumbing piping, emphasize the need to keep dirt and gravel out of piping during construction. Alert inspectors to assure compliance. After years of operation, military bases in Arctic regions are still plagued with stoppages and restrictions from gravel remaining in glycol-grid snow melting systems. Gravel and other debris have also caused stoppages in steam heating and plumbing systems many years after entering service.

5-5 COMPRESSED AIR SYSTEMS.

Colder outdoor air contains less moisture than warmer inside air. Include removal of the excess water vapor in the design of compressed air systems. Use low temperature exterior air as the air source for large compressors because it requires less water removal from the system. Reference UFC 3-401-01, paragraphs on Compressed Air Systems.

[C] 5-5 This applies to instrument air and compressed air systems in shops and hangars where water vapor, if not removed, can freeze and cause the system to quit functioning. Pneumatic control systems require dry air to function properly.

5-6 REFRIGERATION SYSTEMS FOR COLD STORAGE FACILITIES.

Standard refrigeration design for cold storage or air conditioning can be used effectively and must comply with UFC 3-410-01.

CHAPTER 6 ELECTRICAL

6-1 GENERAL.

Standard electrical system design criteria are suitable for buildings in Arctic and Subarctic regions because buildings are heated. However, some special consideration must be addressed. Comply with UFC 1-200-01, UFC 3-501-01, and the UFCs and government criteria referenced therein.

6-2 GROUNDING.

Comply with UFC 3-501-01; UFC 3-550-01; and UFC 3-130-05, paragraph 11-2. UFC 3-130-05 paragraphs 11-2 and A-11.2 provide additional information and resources on electrical grounding.

> [C] 6-2 It is difficult to obtain an effective electrical ground in Arctic and Subarctic regions because of soil and climatic conditions. Grounding is not difficult during summer months but is a problem during the winter if the ground electrode is completely enclosed in frozen soil and cannot achieve an effective ground. In frozen conditions the grounding method may include multiple grounding rods, grounding mats, or grounding wells.

6-3 EXTERIOR LIGHTING AND CONTROLS.

Comply with UFC 3-501-01 and UFC 3-550-01. Exterior wiring and lighting must be rated to −40°F (−40°C). Ensure NEC compliant circuit wiring and protection are provided for heat trace cables used for heating liquid carrying pipes exposed to cold temperature as indicated in Chapter 5.

> [C] 6-3 It's important to emphasize that considerations regarding the temperature rating of wiring, particularly related to the insulation material, extend beyond just exterior lighting and controls. This applies to exterior wiring, whether for power, communications, signaling, etc., installed in low-temperature environments. The challenge arises during installation or movement of wires in cold conditions. In such instances, certain insulation materials may become brittle, making them susceptible to cracking when force is applied, leading to potential damage. This concern is mitigated when wiring is installed within or above the insulation's temperature rating, and post-installation, the wires remain static within the protective raceway.

6-4 EXTERIOR DISTRIBUTION SYSTEMS.

Comply with UFC 3-501-01 and UFC 3-550-01. Where damage from snowplows is likely, elevate utility pedestals that are near roads, typically about 3 ft (1 m) above grade. Provide exterior vehicle electrical plug-ins for parking areas as required by parking practices.

Seal raceways transiting from outdoors to indoors in accordance with NEC requirement for sealing raceways exposed to different temperatures.

6-4.1 Exterior Enclosures.

Use heated enclosures for outdoor-mounted equipment and devices susceptible to adverse effects from cold temperatures. This includes LCD displays, backup batteries in electronic equipment, and mechanisms vulnerable to seizing due to lubricant hardening or freezing.

Utilize specialized Arctic enclosures for outdoor equipment and devices susceptible to adverse impacts from snow, ice, and sleet. This is particularly relevant for devices like cameras and satellite dish antennas, ensuring their functionality despite challenging weather conditions.

[C] 6-4.1 Additionally, heated enclosures prevent moisture buildup from condensation and address concerns like fogging on lenses, especially in outdoor cameras.

6-5 INTERIOR DISTRIBUTION SYSTEMS.

6-5.1 Service Entrance.

Comply with UFC 3-501-01 and UFC 3-520-01. Install the overhead service entrance on the gable end of the building, as explained in Chapter 3. Within a building, locate service entrance equipment in a readily accessible area to allow for quick power disconnection in case of an emergency. Provide one service disconnect for each facility. Provide climate-control for electrical rooms.

For underground services in cold regions employ liquid-tight flexible metallic conduit for the exterior riser conduit leading into the meter base. This mitigates concerns related to frost heaving, which could potentially elevate rigid metal conduit, risking the displacement of the meter from its mounting.

6-5.2 Generators.

Comply with UFC 3-501-01 and UFC 3-540-01. Power interruptions, outages, and reliability must be considered. Generator backup power is needed when extreme winter conditions cause issues with power (a life and safety concern) and increase the danger of building freeze-up if power is disrupted for a significant period. For cases of power fluctuations and interruptions, protect sensitive equipment from potential damage.

Use manufacturer recommended Arctic options for generators such as jacket water heaters (preheats the generator coolant), battery heaters, and fuel heaters (this helps the generator during cold startup). The use of generator space heaters maintains the air around the generator at a suitable temperature to prevent moisture buildup due to condensation.

6-5.3 Corrosion Control.

Comply with UFC 3-570-01. In some Subarctic regions, corrosive conditions caused by wind-driven rain, snow, and salt spray are so severe that vault space must be provided inside buildings for transformers and associated service equipment. See Appendix A for further information.

6-5.4 Lightning Protection and Static Electricity.

Comply with UFC 3-575-01. Lightning protection is needed during the summer months. Provide humidity control and use low-static floor coverings in interior spaces to mitigate static electricity.

[C] 6-5.4 During the winter months, static electricity is a significant problem due to low humidity.

6-5.5 Communications.

Comply with UFC 3-580-01. Terminal blocks are routinely installed on the exterior of residences. These must be protected from moisture intrusion and able to withstand the extreme temperature ranges.

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CHAPTER 7 FIRE PROTECTION

7-1 GENERAL.

Fire protection is critical in Arctic and Subarctic regions. Evaluate the isolation and climate conditions of each site to determine the extent of required fire protection facilities. Principally at isolated sites, guard against fire hazards because the loss of facilities and materials during extreme low temperatures constitutes a major threat to survival. Evaluate the fire hazard at each site by considering the distance to other facilities and the availability and reliability of alternate forms of shelter and transportation. Evaluate each building in terms of the effects of local winds and temperatures on firefighting capability and on survivors. Strong winds can occur for extended periods of time, causing fires to spread rapidly and be difficult to control. Comply with UFC 1-200-01, UFC 3-600-01, and UFC 3-130-05.

7-2 FIRE PROTECTION ENGINEERING SERVICES.

Consult experienced fire protection engineers at the Installation or Command level with expertise in Arctic and Subarctic conditions to develop comprehensive and effective fire protection strategies that address the specific challenges of these environments.

[C] 7-2 Fire protection involves a holistic approach that encompasses design, materials, systems, and emergency response planning tailored to the unique conditions of the Arctic and Subarctic.

7-2.1 Water Supplies for Fire Protection.

Comply with UFC 3-230-01 for developing water sources and distribution. Applicable fire protection engineering services must comply with local standards and practices.

7-2.2 Water Storage Tank Vents.

Take preventative measures to avoid ice buildup blocking tank vents on facility water storage tanks. Where heavy ice buildup is expected, such as in coastal locations include special protection for tank vents. Alternately, provide protection by venting tanks into the pump house and omitting an exterior vent. The facility storage tank must either have the capacity to store several months' supply of domestic water, in addition to reserve water for firefighting, or be dedicated solely for firefighting.

[C] 7-2.2 Driving winds have blocked 6 in. (152 mm) vents, and the vacuum resulting from water drawdown can cause a tank to collapse.

7-3 FIRE PROTECTION SYSTEMS.

7-3.1.1 All-Weather Ground Access.

In Arctic and Subarctic regions, locate fire room access doors on the gable end of the building to prevent snow and ice buildup.

7-3.1.2 Fire Department Connection.

Locate exterior fire department connections on the gable end of the building to avoid snow and ice buildup. To eliminate freeze potential, install a ball drip assembly on the supply low point (more than one may be required) and route to an interior drain.

7-3.1.3 Exterior Antennas.

To prevent snow and ice buildup, mount antennas on the gable end of the building exterior. For a pitched roof, mount each transmitter antenna on the gable end on the face of the eave closest to the fire department or mass notification central station location. Mount each antenna a minimum of 6 in. (152 mm) above the roofline and secure it, using nuts and bolts, to withstand the wind load. It is unacceptable to secure the mounting bracket into the building exterior with screws. Proper installation and operation of each antenna is required for the correct frequency and transmission. Each antenna cable must have a lightning arrester installed inline in a weather-proof box, and each assembly must be properly grounded per the manufacturer’s specifications. Show antenna locations on each floor.

7-3.1.4 Valves.

In Arctic and Subarctic locations, use street valves and then a primary shut-off valve inside buildings, as permitted by NFPA 24, a National Fire Protection Association regulation. Ensure that recirculation and heating systems are working properly to avoid issues. The use of post-indicating valves is not recommended in Arctic or Subarctic climates because they create a thermal bridging issue.

7-3.1.5 Facility On-Site Water Storage.

Heat and insulate water storage tanks exposed to extremely low temperatures with continuous water circulation. Heating techniques include circulating tank water through a heat exchanger or using a flow-through type electric heater.

> [C] 7-3.1.5 Water storage from surface sources may be inaccessible during the winter months due to ice formation, and underground water sources may be unavailable.

7-3.1.6 Fire Pumps.

The use and maintenance of fire pumps in Arctic and Subarctic regions involve special considerations due to the extreme cold temperatures and challenging environmental conditions. Some key factors to consider for fire pumps in these regions, cold weather start-up, enclosure and insulation, heated enclosures, fuel considerations, battery heating, emergency power sources, snow management, and materials and corrosion resistance.

7-3.1.6.1 Fire Pump Room.

To protect against freezing, do not locate fire pumps, jockey pumps, or sensing lines near an exterior door. Provide an acceptable method to continuously monitor the sensing lines within the fire pump room to maintain a minimum temperature of 68°F (20°C).

7-3.1.6.2 Drainage Piping.

In cold climates, include drainage systems in fire protection rooms. To mitigate the risk of freezing and potential blockages, implement freeze protection measures for drains. This can involve the installation of insulation or heating elements as preventive measures.

7-3.1.6.3 Discharge to Exterior.

Locate main drains and auxiliary drains within 2 ft (0.6 m) of grade and not less than a 10 ft (3 m) distance from both the exterior doors and the fire department connection.

7-3.1.7 Fire Pump Controllers.

To protect against freezing, do not locate fire pump controllers or jockey pump controllers near an exterior door. Within the fire pump room, provide an acceptable method for continuously monitoring the controllers to maintain a minimum temperature of 68°F (20°C).

7-3.1.8 Fire Alarm and Mass Notification System Installation.

In Arctic and Subarctic regions, locate or install lines of communication, fire alarm and mass notification panels, transceivers and releasing panels or annunciators inside the building. Do not locate or install these devices in an artic entryway or vestibule. The interior of the building provides better access to and climate control for these systems.

7-3.1.9 Fire Suppression System Testing.

Water recirculation systems used for freeze protection, and other connected systems, must be tested at the same hydrostatic pressure as required for the sprinkler system. Apply this same hydrostatic pressure when testing other systems connected to the sprinkler system, except the incoming domestic water. Pumps on the recirculation system must also be rated for both the working and static pressure of the sprinkler system. To prevent freezing, the domestic lines and fire-suppression line may be combined.

7-3.1.10 Automatic Sprinkler Systems.

Protect wet pipe systems from freezing by providing heat trace for sprinklers under overhead doors. Supply heat trace and insulation for wet pipe sprinkler lines that must cross a hangar. The heat trace must be Underwriters Laboratory (UL) listed or FM Approved for sprinkler systems. The heat trace may need to be on a dedicated breaker in an emergency panel, though this depends on various factors, including local electrical codes, the specific requirements of the heat trace system, and the overall electrical design of the facility. It is essential to consult with a qualified electrician or an electrical engineer who is familiar with local codes and regulations to determine the specific requirements. Provide sprinklers in maintenance vestibules where air-handling units (AHU) are located. Dry sprinklers are also an option for spaces where freezing may occur. Dry sprinklers can be used with a wet system or as a standalone system.

7-3.1.11 Arctic Vestibules.

Provide dry sprinklers in arctic vestibules.

7-3.1.12 Standpipe Systems.

To mitigate the risk of freezing in multi-story buildings, incorporate a standpipe in a heated location for water lines connected to fire trucks exposed to freezing temperatures. This design approach enhances the resilience of the firefighting system in colder conditions.

7-3.1.13 Fire Alarm Systems.

Freeze-protection monitoring guards against lines freezing. Connect fire protection life safety equipment to the Fire Alarm Reporting System. Include freeze-protection monitoring on the fire alarm reporting system when monitoring the incoming water line. The freeze-protection connection to the fire alarm reporting system monitors the proper operation of the main fire protection water line must include, at a minimum, low-temperature alarms, circulation pumps, and no-flow conditions.

To protect against freezing, the fire alarm system must monitor heat trace breakers for sprinkler systems and hydrant systems. Provide a low-temperature alarm near the sprinkler riser in every high-expansion foam room and in sprinkler riser locations. Upon activation of the low-temperature alarm, a supervisory signal must be sent to the fire department. Low-temperature alarms must also be provided in rooftop AHU enclosures with maintenance vestibules that are provided with sprinkler protection. Low-temperature devices must be mounted within 18 in. (457 mm) of the lowest point in the room and must be coordinated with the District Fire Protection Engineer (FPE) for location. For rooms with pits, coordinate with the District FPE for location.

APPENDIX A BEST PRACTICES

A-1 INTRODUCTION.

The Best Practices Appendix contains guidance and not requirements. Its main purpose is to communicate proven facility solutions, systems, and lessons learned. However, these recommendations are not the only viable solutions.

A-2 CANADIAN EXPERIENCE.

The Canadian Arctic covers over 40% of Canada's land mass. Canada has extensive experience with cold regions engineering and infrastructure. The documents provided by the Government of Canda on the Codes Canada website (https://nrc.canada.ca/en/certifications-evaluations-standards/codes-canada) provide valuable guidance for cold regions engineering and construction on a variety of topics.

A-3 SNOW DRIFTING.

The accumulation of blowing snow causes snow drifts. Snow accumulates on buildings in areas of aerodynamic shade created by roof design. Inadequate separation between structures causes intersecting drifts. A single storm can quickly create large drifts on and around structures and block access to utility systems that are necessary for maintenance or repairs and can quickly bury items, such as construction materials, that are stored outside. Snowdrifts often cover doorways. Drifting snow may enter buildings in a variety of ways. For example, it is difficult to tightly seal doors on a building's upwind face to prevent snow infiltration. Dry, windblown snow can enter small cracks in doorways, windows, or louvers that are intended for ventilation.

A-3.1 Snowdrift Indicators.

High winds, rather than the prevailing wind direction, better indicate the direction of drifting snow and where snow drifts will form. The quantity of snow transported by wind is roughly proportional to the 4th power of wind speed. This causes high winds to disproportionately transport more snow than either moderate or low winds.

Determine the transport direction from the orientation of drifts, onsite visits, or aerial or satellite images taken during the winter. Late-winter observations give the best indication of the average transport direction. To determine the drift location and building orientation, use the windward direction and wind orientation based on dominate wind transport directions rather than the prevailing wind direction alone. Lacking direct observations of drift orientation for a snow transport analysis, use meteorological data to estimate transport directions and volumes for site planning. Refer to "Blowing Snow Transport Analysis for Estimating Drift Orientation and Severity," by Haehnel, and *Design Guidelines for the Control of Blowing and Drifting Snow,* by Tabler, for additional information on snow transport analysis.

A-3.2 Problems Due to Snow Drifting.

The list that follows contains additional guidelines and concerns about snow drifting for building design:

- Poorly oriented generator intakes can be become blocked, and ice can coat, or snow can block, warm exhaust stacks and vent pipes.
- Large snowdrifts can accumulate on low roofs and in other areas of aerodynamic shade.
- In permafrost areas, snow infiltration in ventilated foundations can be a serious problem.
- Material and equipment must not be stored adjacent to or under buildings elevated above permafrost because doing so can cause snow drifts that allow soil warming in winter.

A-3.3 Solutions to Snow Drifting Problems.

While drifting patterns are difficult to predict, following the guidelines listed here minimizes problems:

- Place utility distribution systems within or below elevated walkways to facilitate repairs. Walkways placed on grade tend to aggravate snow drifting problems.
- Use trees, shrubs, snow fences, or other obstructions to precipitate snow before it reaches the site proper. Where storms may come from every direction, provide protection for every quadrant.
- Place major roads parallel to the dominant snow transport direction. This may differ from the prevailing wind direction.
- Do not locate roads directly upwind or downwind of large obstructions. Where possible, maintain 100 ft (30 m) upwind and 200 ft (61 m) downwind clearances.
- Locate parking lots alongside roads to function as buffer zones. Do not place parking lots among buildings. Expect additional snow accumulation around parked vehicles and provide ample room for snow storage away from roads and on the downwind end of the lot. Because curbed islands hinder snow removal operations, they are rarely suitable.
- Place parking aprons alongside, not upwind or downwind of, hangers and garages.
- Orient surface structures with their longest side parallel to the winter snow transport direction. Winter storm winds and snow transport may come from a different direction than prevailing summer or winter winds.

- Locate doors along the sides of the building facing toward the upwind end. Doors on the downwind end of the structure may be rapidly blocked by drifting snow; those on the upwind face are difficult to seal. Though main entrances and exits need to open out, it is advisable to have at least one alternate set of doors that open inward for use if drifting snow blocks the main doors. Establish and maintain clear pathways from the building interior to these alternate exits.
- Orient large garage doors parallel to the dominant snow transport direction, even if this results in a building orientation that is perpendicular to the wind. Adjust this orientation slightly to assure that the doors are not in the lee of the upwind corner of the building.
- Place structures in rows perpendicular to the wind. Allow ample space (such as a minimum of two times the width of the snow removal equipment) between buildings to permit effective snow removal. Place each row of structures downwind from the preceding row, either abutting the windward structure or spaced at least the length of the building in the windward direction from the preceding row.
- Provide snow dumping areas to eliminate large piles or windrows of snow in the camp area. Piles and windrows are obstructions that increase future snow removal requirements.
- Avoid decorative earthen berms around buildings and in parking lots. Berms can cause additional snow accumulation problems and interfere with snow removal operations, disrupt building access for maintenance and fire protection, and create moisture problems at the foundation wall.
- For AT/FP structures they may need to be placed further from buildings and have dedicated paths for snow removal and water drainage.
- For buildings on a permafrost foundation system such as thermopiles, elevate the building adequately to allow free flow of air under the building and avoid snowdrift buildup around condensers.

A-4 SNOW AND ICE CREEPING, SLIDING, AND FALLING FROM ROOFS.

In Arctic and Subarctic climates, anticipate that snow and ice will creep, slide, and fall from roofs; this situation can cause significant property damage and injure, or even kill, pedestrians. This is particularly the case with roofs that drain to cold eaves and for steep roof slopes and slippery surfaces. Snow and ice sliding off pitched metal roofs can damage property and injure people as far as 20 to 30 ft (6 to 9 m) away from two-story facilities. Snow sliding off these roofs can block vehicle access to and from critical facilities.

A-5 LOCAL CONSTRUCTION METHODS, MATERIALS, AND SKILLS.

Generally, in Arctic and Subarctic regions, construction methods, materials, and skills are major factors tied to overall project cost. Maximum factory prefabrication is an economical solution to reduce on-site construction, especially given the short construction season, but the benefits of prefabrication must be weighed against higher handling and shipping costs, the risk of damage and breakage during transport, and the effect of shipping delays. Scheduling work so that construction of the outer building shell is completed during mild weather and interior work is completed during severe weather expedites completion, reduces costs, and eliminates many problems. Many materials used in standard temperate construction are used in Arctic and Subarctic locations; however, their availability and transportability are significant concerns. A shortage of skilled labor can cause higher costs.

A-6 BUILDING ENVELOPE.

A-6.1 Vapor Retarder.

A well-constructed and continuous vapor retarder can significantly control air leakage. During installation, exercise care to ensure that joints, corners, and penetrations of the vapor retarder are completely sealed with properly specified mastic or sealants. Create detailed designs and provide careful supervision during construction to obtain maximum retarder continuity between the walls and roof.

A-6.2 Ventilation.

Moisture can become trapped in the insulated cavity between the vapor retarder and the exterior surface material. Given sufficiently low temperature conditions, this trapped moisture can freeze and, over time and with successive moisture trapping and freezing, create ice within the insulated cavity that melts when temperatures warm, deteriorating the insulation material.

An air gap exterior to the envelope insulation, but behind the exterior finish, helps to keep the insulation dry, and does not reduce the insulation value of the envelope. A small air gap behind the wall finish material (also called a rain screen) can also help dry out the wall in the event of bulk water intrusion and offers some drying if vapor enters the wall cavities.

A-6.3 Daylighting.

The positive effects of introducing daylight into interior spaces to improve productivity and the wellbeing of the occupants is well documented. During the three months in midwinter when the sun is at its lowest angle and shines for only a few hours each day, little natural illumination is available through windows. Conversely, during the summer months, there is continuous daylight. Low sun angles during both the fall and spring seasons increase light entering the building and contribute to increased heat gain and glare.

A-7 ARCTIC ENTRANCES.

Where practical, depress the floor and provide grating and a pan to allow snow and water removal from footwear. Provide mats or carpets at the inside door of the arctic entrance to collect snow and dirt at the entry and prevent slippery floor surfaces. Use a canopy over the entrance to protect personnel from falling icicles and dripping water. Protect exterior walkways from falling ice and snow and from water that may freeze, causing a safety hazard.

A-8 INTERIOR FINISHING.

For structures located in Arctic and Subarctic regions, considerations for thermal expansion and contraction, and structural movement due to asymmetrical high wind and snow loading, are crucial when choosing joining methods for interior finishing work. Structures move to some degree throughout the seasons, and the typical tight tolerances for finish work are not appropriate. This is particularly relevant when large areas of sheet products are installed and finish-joined at the seams, both on walls and ceilings. For gypsum board, cracks will propagate along vertical and horizontal finish seams, and diagonally from door and window openings in walls. This is also very important where different materials meet, or where materials meet orthogonal to each other, such as drywall-to-steel ceiling joints, doorways, penetrating beams, and other interfaces in concrete and various finishes where movement and tight finish tolerance induce finish material cracking, especially originating at corners of openings (window and doors).

A-9 HVAC SYSTEMS.

"Best Practices for HVAC, Plumbing, and Heat Supply in Arctic Climates," by Winfiled et al., discusses common HVAC system approaches used in Arctic climate. This paper describes best practice examples of robust and reliable systems with the emphasis on system redundancy, durability, and functionality

A-10 MECHANICAL SYSTEMS MAINTAINABILITY.

System reliability, ease of access for regular operation or maintenance, system simplicity, and cost are governing factors when selecting primary and backup systems. Carefully select backup and emergency systems to account for an outage to prevent issues with freezing under harsh environmental conditions because this poses a danger to station personnel. To address high maintenance costs, consider whether a high initial cost is outweighed by decreased maintenance costs, resulting in a lower total life cycle cost. Maintenance costs may be high due to high local wages, scarce skilled local labor, the need to provide room and board at remote locations, decreased worker and machine efficiency due to environmental conditions, the length and cost of communications and resupply channels, and the difficulties, costs, and risks in shipping materials and equipment. These issues are critical in the event of an emergency.

A-11 PLUMBING PIPE ARRANGEMENT.

A special enclosed and heated crawl space immediately below the ground floor elevation is an option in Arctic and Subarctic building design. The floor can be constructed with removable insulated panels. Run piping, including hot and cold water, heating lines, and waste piping, in this protected space. Tightly seal the area to avoid air infiltration. The benefits of this approach include ready access for maintenance, easy replacement, and a buffer zone to warm the floor above. Another approach places the utility lines underneath the building within insulated enclosures and protecting pipes with heat to prevent freezing. Heat may be applied by wrapping a heat cable in a spiral pattern around the pipe under the insulation layer; installing an immersion cable within the pipe containing the liquid; installing heat cables in small-diameter conduits attached either directly to, or in close proximity to, the carrier pipe under the insulation layer; or preheating the liquid prior to entering the pipeline.

A-12 FREEZING OF HEATING COILS IN VENTILATION UNITS.

Whenever flow of the heating medium within a coil is modulated and coils are subjected to outside air, they are vulnerable to freezing. Circulating an antifreeze solution can avoid freezing while allowing the system to operate at low temperatures. Recirculating air that reheats return air and mixes it with outside air has been successfully used in Arctic and Subarctic regions. Air stratification can occur when warm return air and cold air are improperly mixed before going through the heating coil. An air-to-air heat recovery coil system is useful in locations such as maintenance shops or fuel storage areas where only outside air and exhaust are used for ventilation and the incoming outside air is preheated prior to entering the fan and heating coil assembly.

A-13 CORROSION CONTROL FOR INTERIOR ELECTRICAL SYSTEMS.

Corrosion slows as temperatures fall below freezing. Consider this fact when installing cathodic protection because anodes installed in frozen earth do not protect a heated structure. For an unheated structure, the required cathodic protection current drops significantly and could result in overprotection if the current is not adjusted. Corrosion from the earth is mild when structures require freeze protection. Wind-blown salts in marine environments are so corrosive that summer months provide enough warmth for substantial corrosion.

APPENDIX B GLOSSARY

B-1 ACRONYMS.

AFCEC	Air Force Civil Engineer Center
AHJ	Authority Having Jurisdiction
AHU	Air-handling unit
ACI	American Concrete Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIA	Bilateral Infrastructure Agreements
cm	Centimeter
CCR	Criteria Change Request
CDC	Child development center
CRREL	Cold Regions Research and Engineering Laboratory
°C	Degrees Celsius
°F	Degrees Fahrenheit
DoR	Designer of Record
ft	Feet
FPE	Fire Protection Engineer
HNFA	Host Nation Funded Construction Agreements
HQUSACE	Headquarters, U.S. Army Corps of Engineers
in.	Inches
m	Meter
mm	Millimeters
NAVFAC	Naval Facilities Engineering Systems Command
NFPA	National Fire Protection Association

SLDT	Structural Load Data Tool
SOFA	Status of Forces Agreements
TRB	Transportation Research Board
UFC	Unified Facilities Criteria

B-2 DEFINITION OF TERMS.

UFC 3-130-01, Appendix B, provides a list of general terms for Arctic and Subarctic engineering. This appendix includes terms specific to UFC 3-130-04.

Aerodynamic shade: An area protected from wind and strong air movement. An area of relatively calm conditions conducive to the settling of snow.

Arctic entrance: A type of vestibule. The exterior door of the vestibule is closed to shut out the cold air, high wind, or drifting snow before the inside door is opened to enter the building.

Downwind: In the direction that the wind is blowing.

Ice dam: An ice buildup on building eaves that occurs when snow melted by escaping building heat flows to the eaves and freezes when air temperature drops below 32°F (0°C).

Ice fog: Results when a dew point air temperature below 32°F (0°C) meets an available supply of moisture. Ice fog can seriously impair visibility for extended periods.

R-value: A material’s ability to resist heat flow. Otherwise known as *thermal resistance*.

Snow fences: Lath-type fences designed to stop windblown snow and protect a downwind facility from snowdrifts.

Snow transport (Q): The mass of snow transported by the wind over a specified time and width across the wind within the first 16 ft (5 m) above the surface, per meter of width across the wind.

Thermal break: An area of low thermal conductivity between two areas of higher thermal conductivity. The opposite of a thermal bridge.

Thermal bridge: An area of high thermal conductivity between two areas of high thermal conductivity. An example is a through-metal connection in a building envelope component.

Upwind: In the direction from which the wind is blowing.

Whiteout: An optical phenomenon occurring in the Arctic and Subarctic regions in which the snow-covered ground blends with a uniformly white sky, blotting out shadows, clouds, horizon, and so on, and destroying all sense of depth, direction, or distance.

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