Wet Floodproofing Requirements

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Technical Bulletin 7-93

Wet Floodproofing Requirements

for Structures Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program

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Key Word/Subject Index:

This index allows the user to locate key words and subjects in this Technical Bulletin. The Technical Bulletin User's Guide (printed separately) provides references to key words and subjects throughout the Technical Bulletins. For definitions of selected terms, refer to the Glossary at the end of this bulletin.

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TECHNICAL BULLETIN 7-93

Wet Floodproofing Requirements for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program

INTRODUCTION

This bulletin describes planning, design, and construction requirements for wet floodproofing certain types of structures and their uses under the National Flood Insurance Program (NFIP). The basic characteristic that distinguishes wet floodproofing from dry floodproofing is the internal flooding of a structure as opposed to providing essentially watertight protection. Specifically, wet floodproofing can be defined as:

> Permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding by allowing flood waters to enter the structure.

Flooding of a structure's interior is intended to counteract hydrostatic pressure on the walls, surfaces, and supports of the structure by equalizing interior and exterior water levels during a flood. Inundation also reduces the danger of buoyancy from hydrostatic uplift forces. Such measures may require alteration of a structure's design and construction, use of flood-resistant materials, adjustment of building operation and maintenance procedures, relocation and treatment of equipment and contents, and emergency preparedness for actions that require human intervention.

In accordance with the NFIP, Wet Floodproofing is allowed in only limited situations

Application of wet floodproofing as a flood protection technique under the NFIP is limited to specific situations in A Zones (including A, AE, A1-30, AH, AO, AR zones). For certain uses and types of structures described in this bulletin, communities may allow wet floodproofing only through the issuance of a variance from certain floodplain management requirements. The situations and conditions in which a community may allow wet floodproofing are described in detail in the section entitled **Applicability**.

For structures in V zones (includes V, VE, V1-30 zones), more stringent design and construction requirements have been established for the portion of a structure below the Base Flood Elevation (BFE). For information on V-zone design and construction requirements, refer to the NFIP regulations under 44 CFR Section 60.3, the Technical Bulletin series, and FEMA's "Coastal Construction Manual" (FEMA 55).

APPLICABILITY

New Construction and Substantial Improvements of Residential and Non-Residential Structures

An important objective of the NFIP is to protect structures constructed in floodplains from flood-induced damage. In support of this objective, the NFIP regulations include building design and construction criteria that apply to new construction and substantial improvements (including structures which have incurred substantial damage) of existing structures in Special Flood Hazard Areas (SFHA). According to these criteria, residential structures in A zones must be constructed with their lowest floors elevated to or above the BFE. Non-residential structures constructed in A zones must either have their lowest floors elevated to or above the BFE or be dry floodproofed (made watertight) to or above the BFE. Measures to accomplish dry floodproofing of non-residential structures must not only provide watertight protection but also must be designed to withstand hydrostatic, hydrodynamic, and impact forces produced by flooding. The intent is to provide complete protection at least up to the floodproofing design level which must, at a minimum, be at the BFE.

Note: To receive a flood insurance rate based on 100 year flood protection, the structure must be dry floodproofed to an elevation at least 1 foot above the BFE. (i.e. 1 foot of freeboard)

In accordance with the NFIP, there are limited enclosed areas within newly constructed and substantially improved residential and non-residential structures where the community may allow wet floodproofing without a variance as a flood protection technique. These are limited to:

Enclosed areas below the BFE that are used solely for parking, building access, or limited storage. New construction and the substantial improvement of residential and non-residential structures whose lowest floors have been constructed at or above the BFE may be constructed with enclosed areas below the BFE. These areas must; (1) be used solely for parking, building access, or limited storage, (2) be designed to allow for the automatic entry and exit of flood waters through the use of openings, and (3) be constructed of flood resistant materials.

Attached garages. A garage attached to a residential structure, constructed with the garage floor slab below the BFE, must be designed to allow for the automatic entry of flood waters. Openings are required in the exterior walls of the garage or in the garage doors. In addition to allowing the automatic entry of flood waters, the areas of the garage below the BFE must be constructed with flood resistant materials. Garages attached to non-residential structures must meet the aforementioned requirements or be dry floodproofed. For guidance on below-grade parking areas refer to Technical Bulletin 6, "Below-Grade Parking Requirements".

Certain categories of structures where FEMA has advised communities that variances to allow wet floodproofing may be issued.

Communities must determine whether a variance from local floodplain management regulations may be issued to allow wet floodproofing for the categories of structures described in this section. To make such a determination, the community must, at a minimum, apply the NFIP variance criteria set forth in the 44 CFR Section 60.6. Included in these criteria is the requirement that the variance be the minimum necessary to afford relief, considering the flooding conditions at the site. This means that when a community issues a variance from elevation or dry floodproofing requirements, the structure must still be protected to the maximum extent possible using an appropriate alternative flood protection technique, such as wet floodproofing. To properly administer the granting of a variance for wet floodproofing, communities should have variance review procedures in place. These variance procedures must be within the bounds of State enabling law and meet the minimum requirements of the NFIP.

Variances to allow wet floodproofing may be issued for the following categories of structures. **These structures must comply with floodway encroachment provisions of the NFIP Regulations in accordance with section 60.6(a)(1).**

Structures Functionally Dependent On Close Proximity to Water: Certain structures that must be located near water are functionally dependent uses, as defined in section 59.1, and are permitted to be wet floodproofed after the issuance of a variance from NFIP elevation and dry floodproofing requirements. These structures may include certain types of docking, seafood processing, and port facilities associated with marine activities. Specific criteria for issuing a variance for functionally dependent uses are established in section 60.6(a)(7). These include the requirement that the structure or other development be protected by methods that minimize flood damage and create no additional threat to public safety.

Historic Buildings: Under section 60.6, variances may be issued for the repair and rehabilitation of historic structures, as defined in Section 59.1, upon the determination that the proposed repair or rehabilitation will not preclude the structure's continued designation of a historic structure and the variance is the minimum necessary to preserve the historic character and design of the structure.

Accessory structures, used solely for parking (two-car detached garages or smaller) or limited storage (small, low-cost sheds): If a community wishes to allow a non-elevated/non-dry floodproofed accessory structures, the community must establish the meaning of low-cost and small accessory structures. Communities may allow wet floodproofing of these structures provided that they represent a minimal investment and are designed to have a low damage potential with respect to the structure and contents.

The following requirements, at a minimum, must be attached to the variance for an accessory structure:

1) it must be anchored to resist flotation, collapse, and lateral movement;

2) the portions of these structures located below the BFE must be constructed of flood-resistant materials;

3) it must be designed to allow for the automatic entry of flood waters;

4) mechanical and utility equipment must be elevated or floodproofed to or above the BFE;

5) it must comply with the floodway encroachment provisions of the NFIP Regulations; and

6) its use must be limited to parking and/or limited storage.

Some communities have included provisions in their floodplain management ordinance for permitting the construction of these low-cost, small detached accessory structures. Communities wishing to regulate the placement of such structures in this manner should contact their FEMA Regional Office for guidance and assistance.

Certain Agricultural Structures: FEMA recognizes that wet floodproofing may be appropriate for certain types of agricultural structures located in wide, expansive floodplains. A variance may be issued only if the structure is used solely for agricultural purposes in which the use is exclusively in connection with the production, harvesting, storage, drying, or raising of agricultural commodities, including the raising of livestock. Only in circumstances when it can be demonstrated that agricultural structures can be designed in such a manner that results in minimal damage to the structure and its contents and will create no additional threats to public safety, may a variance be issued. Because the wet floodproofing of a new agricultural structure with the lowest floor below the BFE is not in conformance with NFIP requirements, any variance issued must address both the nonconforming flood protection technique and the restriction of use to the above-described agricultural purposes. Types of agricultural structures that may be wet floodproofed following the issuance of a variance are:

- **Farm Storage Structures** used exclusively for the storage of farm machinery and equipment (e.g., pole and pre-fabricated metal frame structures with open or closed sides).

- **Grain bins.**

- **Corn cribs.**

▸**General purpose barns** for the temporary feeding of livestock, provided they remain open on at least one side.

In addition to the variance requirements 1-5 under the Accessory Structure category presented above, a variance for an agricultural structure must also be limited to agricultural purposes.

Existing (Pre-FIRM) Structures That Are Not Substantially Improved or Substantially Damaged

For existing structures that are not being substantially improved or that have not been substantially damaged, the NFIP elevation and dry floodproofing regulations do not apply. Owners may voluntarily choose to wet floodproof such a particular structure to reduce potential flood damage. Many existing structures are constructed of materials that are generally permeable to flood waters, difficult to make watertight, or unsuitable for flood protection techniques other than elevation or relocation. Although it may be technically feasible to retrofit some older structures by sealing the perimeter walls and creating a watertight structure, it is often unadvisable to do so because of high probability that the dry floodproofing will fail due to some unforeseen factor in these usually non-engineered, older structures. In these cases, wet floodproofing and flood protection through either relocation or elevation of structures may offer the only technically viable flood-damage reduction alternatives. In some situations, wet floodproofing may be the only realistic economic alternative for existing structures that are not substantially improved or damaged.

INSURANCE IMPLICATION

It must be emphasized that variances are granted with respect to floodplain management requirements and do not affect flood insurance rates. The Federal Insurance Administration, by statute, must charge insurance rates commensurate with the risk to which a building is exposed. Insurance rates for buildings constructed under variances are generally higher than rates for a comparable structure that is fully compliant. In some instances the additional costs of insuring these buildings, if they are not elevated or floodproofed in accordance with the NFIP requirements, would approach or even exceed the costs of meeting NFIP elevation or dry floodproofing requirements, and the structure would still be exposed to flood damages.

In accordance with the NFIP regulations, communities must notify the applicant in writing that the issuance of a variance will result in increased premium rates for flood insurance and that such construction below the BFE increases risks to life and property [44 CFR 60.6(a)(5)].

NFIP Regulations

44 CFR Section 60.3 (a)(3) of the NFIP regulations requires that the community must:

> ***"Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall (i) be designed (or modified) and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, (ii) be constructed with materials resistant to flood damage, (iii) be constructed by methods and practices that minimize flood damages, and (iv) be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding."***

NFIP regulations require that all enclosures below the BFE in A Zones must either be designed to allow for the equalization of hydrostatic forces during a flood event or be floodproofed. When water is allowed to enter, section 60.3(c)(5) of the NFIP regulations states that a community shall:

> ***"Require for all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access, or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of flood waters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following minimum criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding is provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of flood waters."***

Section 60.3(d)(3) places further restrictions on construction in floodways by stating that a community shall:

> ***"Prohibit encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge."***

Concerning the issuance of variances, section 60.6(a)(3) states:

> ***"Variances shall only be issued by a community upon (i) a showing of good and sufficient cause, (ii) a determination that failure to grant a variance would result in exceptional hardship to the applicant, and (iii) a determination that granting of a variance will not result in increased flood heights, additional threats to public safety, extraordinary public expense, create nuisances, cause fraud on or victimization of the public, or conflict with existing local laws or ordinances;"***

And section 60.6(a)(4) states that

> ***"Variances shall only be issued upon a determination that the variance is the minimum necessary, considering the flood hazard, to afford relief;"***

Concerning functionally dependent uses under the NFIP variance criteria, "Functionally dependent use" is defined in section 59.1 as:

> ***"Functionally dependent use means a use which cannot perform its intended purpose unless it is located or carried out in close proximity to water. The term includes only docking facilities, port facilities that are necessary for the loading and unloading of cargo and passengers, and ship building and ship repair facilities, but does not include long-term storage or related manufacturing facilities."***

Section 60.6(a)(7) states that:

> ***"Variances may be issued by a community for new construction and substantial improvements and for other development necessary for the conduct of a functionally dependent use provided that (i) the criteria of paragraphs (a)(1) through (a)(4) of this section are met, and (ii) the structure or other development is protected by methods that minimize flood damage during the base flood and create no additional threats to public safety."***

Concerning granting variances for historic structures under the NFIP variance criteria, section §60.6(a) states that:

> ***"...Variances may be issued for the repair and rehabilitation of historic structures upon the determination that the proposed repair or rehabilitation will not preclude the structure's continued designation as a historic structure and the variance is the minimum necessary to preserve the historic character and design of the structure."***

Lastly, concerning granting variances in designated floodways, section 60.6(a)(1) states that:

> ***"Variances shall not be issued by a community within any designated regulatory floodway if any increase in flood levels during the base flood discharge would result;"***

Note: Readers are strongly advised to become familiar with all provisions of section 60.6.

It should be noted that Technical Bulletins provide guidance on the minimum requirements of the NFIP regulations. Community or State requirements that exceed those of the NFIP take precedence. Those contemplating wet floodproofing a structure should contact the community to determine whether more restrictive local or State regulations apply to the structure or site in question. All applicable standards of the State or local building code must also be met for any structure in a special flood hazard area.

Planning Considerations

A review of the following factors for the site in question will assist in determining whether wet floodproofing is appropriate. For example, if a site will be subject to rapidly rising, high-velocity flood waters during a flood, and the available warning time is short, then the site is unsuitable for a wet floodproofed structure. In this situation, elevation or relocation of the building outside the floodplain would be the preferred alternatives.

Warning Time

The rate-of-rise of flood waters for the site in question, the established flood warning system (if any), the flood warning time available, and the reliability of the flood warning must be reviewed to determine appropriate wet floodproof design elements. The rate-of-rise or the flood warning time available through an existing reliable (community-based or regionally-based) flood warning system must be adequate to provide sufficient lead time to evacuate a flood prone structure when flooding threatens. In addition, sufficient warning time must exist to successfully implement a plan that requires human intervention which would include such items as the removal of equipment or contents, or the elevation of contents within the structure. Wet or dry floodproofed structures are not appropriate for any site in a flash flood area, because of the potentially short warning time.

Safety and Access

Safe access to a wet floodproofed structure may be a critical factor in the determination of whether wet floodproofing is an appropriate design alternative. It is anticipated that most wet floodproofed structures will not need to be accessed during flooding. In situations where there is a need to access the structure during conditions of flooding, safe access shall be considered. In 1987, Colorado State University conducted a study of human stability in flood flow conditions based on the product number of depth of flow multiplied by the floodwater velocity. Results of this study indicated that any floodplain location with a product number of 4 or greater (depth in feet multiplied by velocity in feet per second) will create a hazard for anyone attempting to escape from or gain access to the site. Such sites are only acceptable for wet floodproofed structures if modifications are made to the site to reduce the flood hazard and sufficient warning time is available to safely evacuate the site.

Other flood characteristics that must be considered include:

Floodway Encroachment; Encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway are prohibited under the NFIP unless it has been demonstrated, through hydrologic and hydraulic analysis performed in accordance with standard engineering practice, that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge. Floodways are usually the most dangerous portion of the floodplain, containing the highest velocity and debris-laden flood flows. Extreme caution must be used in the placement of any structure in a floodway.

Duration; The amount of time a structure's interior is flooded presents two major concerns. First, damage due to the deterioration of structural components, interior finishes, equipment/machinery, and contents generally increases with prolonged inundation. The other concern is the financial loss due to business interruption, determined by both the length of time inundated and time to clean-up. Financial losses due to disruption can be extreme.

Flood-Borne Contaminants; Flood waters may contain numerous contaminants and are often caustic and toxic. In urbanized and industrialized areas, floodwater can contain higher amounts of salts, alkalis, oils, wastes, chemicals, and debris. In agricultural areas flood water often contains, herbicides, pesticides, and fertilizers. Based on flooding characteristics, some flooding sources will contain higher concentrates of suspended solids than others. Due to the action of "dirty" floodwater, inundated materials can absorb and surfaces can become coated with mud, debris, and grime, exposing contents and building components to corrosive salts and chemicals. This often leads to residual deposits and odors after flood waters recede. These deposits and odors can render a structure unsafe and non-occupiable for an extended period of time after the flood waters recede.

Frequency; Frequent flooding may render a wet floodproofing strategy infeasible. Detriments that must be assessed include cumulative "wear and tear" effects of recurring inundation and the costs associated with repeated business interruption, frequent remove of contents, and frequent clean-up activities.

Depth; It is difficult to establish a safe range of flood depths for the use of wet floodproofing, and perhaps inappropriate to attempt to do so. It is somewhat more applicable to evaluate limiting factors. Many wet floodproofing actions involve some degree of either permanent or contingent elevation of contents, equipment, and machinery. A maximum depth may be established as the depth that would preclude the use of wet floodproofing procedures that can effectively protect the structure and its contents.

Water Temperature; In very cold weather, ice may pose significant problems in implementing wet floodproofing. The impact of large, water-borne, chunks of ice can damage or destroy a structure, and water that freezes inside of a structure can result

in strong expansive forces that can damage both structural and non-structural building components.

Operational Procedures

The operational procedures aspect of applying wet floodproofing techniques involves both the structure's functional requirements for daily use and the allocation of space, with consideration of each function's potential for flood damage. Daily operations and space use can be organized and modified to greatly reduce the structure and contents vulnerability to damage. The goals are to minimize damage caused by floodwater and to minimize economic losses due to business interruption. The following describes the various operations concerns involved in an effective wet floodproofing concept:

Flood Warning System . Because wet floodproofing will, in most cases, require some human intervention when a flood is imminent, it is extremely important that there be adequate time to execute such actions. Specific time required is a function of the type and degree of actions necessary in addition to the resources available for their implementation. In some areas, it may be possible to benefit from the use of an existing flood warning system. In other cases, however, it will be necessary to independently develop a system. Such a system may be as simple as a weather band radio that operates on a tone alarm from the National Weather Service for smaller watersheds and monitoring river forecast levels for larger watersheds.

Inspection and Maintenance Plan Every wet floodproofing design requires some degree of periodic maintenance and inspection to ensure that all components will operate properly under flood conditions. The necessary inspection and maintenance activities, including inspection intervals and repair requirements, must be described in the Inspection and Maintenance Plan. Components that should be inspected as part of an annual (as a minimum) maintenance and inspection program include opening covers and valves intended to equalize hydrostatic pressure.

Flood Emergency Operation Plan. A Flood Emergency Operation Plan is an integral part of any structure's floodproofing design and is critical when the floodproofing requires human intervention such as adjustments to, or relocation of contents and utilities. While such a plan is recommended for existing structures, it is a requirement for all new structures where human intervention is critical to the proper operation of the floodproofing. An adequate plan for the type of structures discussed in this bulletin shall include a list of specific duties to ensure that all wet floodproofing measures requiring human intervention are addressed. The locations of materials necessary to properly install all floodproofing components must be included in the list.

A pre-determination of the flood stages at which floodwater enters each wet floodproofed structure must be made, along with a pre-determination of the amount of warning time available. Based upon these elements, contingency actions should be

prioritized, particularly any evacuation that will be involved. The plan should be completely tested to ascertain its practicality, and also should be reviewed and updated following a flood event.

Other Considerations

Having considered all of the above, a community may choose to:

limit the size and number of structures that may be wet floodproofed,

restrict the location of wet floodproofed structures to areas where the depth of flooding and/or floodwater velocity will not result in damage to structure or its contents, and/or

consider the possibility of combining elevation and dry floodproofing with wet floodproofing where the level of risk warrants such action.

Engineering Considerations

There are three main components to wet floodproofing a structure; design elements, flood resistant materials, and protection of contents. As with the application of dry floodproofing techniques, developing a wet floodproofing strategy requires site-specific evaluations that may necessitate the services of a design professional.

Protection of the Structure

Hydrostatic forces must be counteracted to prevent wall collapse and flood-induced uplift. This is achieved through the use of wall openings that allow water to enter the structure, thereby equalizing the hydrostatic pressure. The NFIP requirements concerning openings are discussed in Technical Bulletin 1, "Openings in Foundation Walls." In addition, provisions must be made to prevent air trapped within the structure during periods of inundation from becoming pressurized and damaging on the exterior walls and roof. Because structures may become buoyant in the presence of flood water, superstructures need to be designed to prevent separation from the foundation. All structural and non-structural components must be constructed of materials that are durable, resistant to flood forces, and resistant to deterioration caused by repeated inundation by floodwater. Components not inundated with flood water must be able to resistant damage as a result of excessive humidity associated with flooding and post-flood conditions. Technical Bulletin 2 "Flood Resistant Materials" provides specific guidance on which materials are acceptable under the NFIP.

Foundations: The failure of foundations in structures subjected to inundation is a major cause of structural damage. Foundation design is a site-specific process that must take into account local soils and building load conditions. Included in the site analysis should be the influence of hydrologic and hydraulic conditions (velocity of

flow, rate-of-rise, depth, flood-borne constituents, and duration) on the foundation design. The ability of floodwater to adversely affect the integrity of structure foundations by eroding supporting soil, scouring foundation material, and undermining footings necessitates careful examination of foundation designs.

An extremely important consideration is that the structure be adequately anchored to the foundation. Uplift forces during a flood event are often great enough to separate an improperly anchored structure from its foundation.

Cavity Wall Construction: Wet floodproofing equalizes hydrostatic pressure throughout the structure by allowing floodwater to fill in all spaces and equalize internal and external hydrostatic pressure. Thus, any attempt to seal internal air spaces within the wall system is not only technically difficult, but also contrary to the wet floodproofing approach. Provisions must be made so that the cavity space fills with water and drains at a rate approximately equal to the floodwater rate-of-rise and fall.

If the cavity wall air space is filled with insulation, it should be a type that is not subject to damage from inundation. Batt and blanket types such as spun mineral fiber or fiberglass bat insulation are not acceptable as they retain water and contaminants within their voids. Foam and closed cell type insulation have characteristics that can withstand a certain level of inundation. These include polystyrene, expanded foam, and thermal glass.

The air space within the cavity wall will also be inundated by floodwater and the contaminants it carries. Silt, chemicals, and organic materials, will remain in the cavity space after the floodwater has receded. Such contaminants can be hazardous to the structure and the occupants; caustic chemicals can deteriorate building materials and debris that harbors organic growth can be have associated bacterial problems and odors. If a cavity wall is used, the cavity wall should have "clean-out" access panels that allow the internal air space to be flushed with water or other cleaning agents and fresh air to circulate within the cavity. Refer to FEMA 234, "Repairing Your Flooded Home" for further guidance on cleaning wall cavities.

Solid Wall Construction: Wall systems without internal air spaces are considered solid wall construction, which includes cast-in-place concrete, fully grouted cell masonry, pressure treated wood- or metal-frame shell. Solid walls are designed without internal spaces that could retain floodwater. Because these walls can be somewhat porous, they can absorb moisture, and to a limited degree, associated contaminants. Such porous wall systems that permit the intrusion of moisture into the wall could cause internal damage especially in a cold (freeze-thaw) climate. Solid walls made of non-porous materials are preferred over cavity walls. But in those cases where solid wall construction made of porous material is being considered, the use of both exterior and interior cladding with properties as described above for cavity wall systems is more desirable.

Wall Finishes: The exterior cladding of a structure subject to flooding should be nonporous, resistant to chemical corrosion or debris deposits, and conducive to easy cleaning. Relatively impervious cladding such as hard brick, pressure-treated wood, metal, and concrete are some of the acceptable materials.

As with exterior surfaces, interior cladding should be easy to clean and not susceptible to damage from inundation. Materials that are solid and relatively impervious such as concrete, hard brick, plastic, and pressure-treated wood, are most suitable.

Metal-clad structures such as those found in many agricultural operations should be constructed of corrosion-resistant materials. Framing and cladding must meet the same flood-resistant requirements as all other materials. Metal fasteners used with metal panel cladding systems are susceptible to corrosion and should be a corrosion-resistant type, such as hot dipped galvanized or stainless steel.

Where interior wall finishes are present, they shall meet the same flood resistant standards as all other materials located below the BFE.

Floors: Subfloor systems in wet floodproofed structures are normally concrete or gravel. Materials that are attached to the concrete subfloor, such as tile, paint, or wood, and the attachment mechanism (adhesives, nails, screws, etc.) that secures the finish material to the subfloor structure, should be able to withstand inundation associated with a base flood event without damage or alteration.

Ceilings and Roofs. When it is anticipated that flood levels will come in contact with the ceiling, flood resistant material requirements apply for ceiling materials and attachment mechanisms (hangers, adhesives, screws). To protect the ceilings and roofs from the pressure of entrapped air or water, pressure relief vents should be used. Even in those cases where flood waters are expected to be below ceiling levels, ceilings materials including attachment mechanisms should be able to withstand prolonged exposure to moisture and humidity associated with flood and post-flood conditions.

Building Envelope Openings. Openings in a structure's floors, walls, ceilings, and roofs are often enclosed by architectural components such doors, windows, louvers, vents, skylights, etc. These components include fasteners, gaskets, seals, glazing, locks, and finishes. Again, even those items not expected to be inundated must be resistant to humidity and moisture damage. NFIP flood resistant material requirements apply to all architectural components that are to be exposed to flooding or resulting excessive moisture. All materials shall be capable of resisting damage associated with a base flood event. Door systems include frame, hinges, threshold, and panels. Since solid wood, wood laminate, or hollow core wood door panels may warp, swell and/or rot, sealed metals are preferable.

Windows are susceptible to damage from debris carried by floodwater. The use of glass blocks, sealed unbreakable panes, and wire-reinforced glass will resist flood

damage. Protective screens may also be successful in preventing debris impact. The use of tempered glass or impact-resistant plastic (acrylic or polycarbonate) is recommended for large window areas of 20 square feet or more.

Protection of Mechanical and Electrical Systems: While the NFIP regulations do not prohibit the placement of mechanical and electrical components below the BFE, they are required to be designed and/or located so as to prevent flood water from entering or accumulating within them. The preferred method of meeting this requirement is to locate flood-threatened components above the expected flood level. Other options that may meet the NFIP requirements for electrical systems that can not be elevated involve emergency operation and maintenance procedures, including disconnecting and elevating or relocating electrically controlled equipment, installing elevated control panels for cutoff of electricity, or enclosing service equipment in waterproof utility enclosure areas. Mechanical systems that must be located below the design flood level should be provided with waterproofed enclosures to protect bearings, seals, gears clutches, valves, or controls that will not withstand immersion, silt damage, or water pressure.

Electrical System. Electricity is a primary source of energy for many vital building operations. Wet floodproofing an electrical system primarily involves preventing vulnerable components from coming in contact with water. Elevation of all electrical components except the minimum necessary to operate the structure (minimal number of light switches and receptacles) is required. Where switches and receptacles must be located below the BFE, sealed or capped moisture-resistant components are required. Ground Fault Circuit Interrupters shall be utilized for all electrical circuits that serve areas below the BFE. Key system components for which elevation above floodwater is desirable include transformers, switchboards, and branch panels. A possible alternative may be to enclose these elements with a waterproof protective barrier. In circumstances which dictate that it is not practicable to safely maintain power during inundation, complete cutoff must be utilized. This of course presents the need for inspections and actions to ensure complete drying of electrical components prior to power restoration.

Electrical service provided to a structure from poles or other overhead sources should enter the structure at a point above the expected flood level. Underground service cables may be feasible provided that they are waterproofed and not exposed to direct contact with flood water.

Heating and Ventilating In general, heating and ventilating equipment is not designed to withstand inundation and is prone to severe floodwater damage. Thus, elevating is recommended to preclude inundation of system components. In situations where elevation is not practical, quick release/disconnect mechanisms should be incorporated into the design. One example is fan motor components for grain bin aeration systems which are configured to be easily removed and relocated prior to flooding.

Liquid Storage Containers Liquid and gas containers are subject to extreme hydrostatic pressure during inundation. Where possible, such containers should be elevated to or above the BFE or located outside the floodplain. If a newly constructed container will be subject to inundation, it is required under the NFIP to be anchored to withstand a buoyant force acting upon it in its empty state. Containers should have watertight fill caps and vents that extend above the expected flood level, and should be labelled according to contents. Labeling will allow emergency personnel to identify the contents in the event the tanks breaks loose and floats away. It is important to note that underground tanks are also subject to uplift forces. Empty tanks, both above and below ground, should be filled with potable water prior to the arrival of floodwater. The post-flood disposal of this possibly contaminated water must be in accordance with all applicable federal, state and local regulations.

Flood Resistant Materials

In accordance with the NFIP, all materials exposed to floodwater must be durable, resistant to flood forces, and retardant to deterioration caused by repeated exposure to flood water. Generally, these performance requirements result in masonry construction being the most suited to wet floodproofing in terms of damage resistance. In some cases wood or steel structures may be candidates, provided that the wood is pressure treated or naturally decay resistant and steel is galvanized or protected with rust-retardant paint. Detailed guidance is provided in Technical Bulletin #2 "Flood-Resistant Material Requirements."

Protection of Contents and Equipment

Isolation from Floodwater. Consideration should be given to preventing, to the maximum extent possible, the contact of floodwater with damage-susceptible items. This can be accomplished through relocation prior to flooding, elevation, or in-place protection of flood-damageable items.

Relocation: The most effective method of protection for equipment and contents is to relocate threatened items out of harm's way. The interior of the structure must be organized in a way that ensures easy access and facilitates relocation. Aisles, doors, and corridors shall be wide enough and equipment size should be evaluated to allow any planned relocation or removal. Where structures are used to store bulk materials, such as grain, provisions must be made for the orderly removal and relocation of the contents to an area outside the floodplain.

Elevation: Within the flood-prone structure, elevation of key items could be achieved through the use of existing or specially constructed platforms or pedestals. Contingent elevation can be accomplished by the use of hoists or some type of overhead suspension system. Elevation techniques can be applied to a wide range of objects--machinery, utility system components (particularly electrical equipment), fuel and storage containers, and contents.

In-Place Protection: Some items can be protected, in-place, through a variety of options. Protective waterproof enclosures may be feasible for items that are difficult to move or relocate. Anchors and tie-downs, shall be used where appropriate to prevent flotation and movement, especially in the case of storage containers. Depending on flood characteristics, such enclosures may not have to be inconveniently high or completely permanent. Low barriers or flood shields may supply the necessary protection. Also, steps or ramps can be incorporated into the design to further maintain easy access.

Protective coatings can be applied to equipment to reduce inundation damage. Petroleum based greases, hot dip plastics, spray or cold plastics can all be applied to oily surfaces. If they are applied to painted surfaces they must be non-migratory and not applied to threaded surfaces. Coatings can provide protection and enhance cleanup ease.

The use of "quick-disconnect" type plug and receptacle sets on standard electrical motors and other electrical connections provides several advantages. This allows for rapid shutdown, eliminates the need for an electrician, simplifies removal operations, and enables rapid reinstallation and restart. Similarly, motor-pump type units can be equipped with quick disconnect fittings on both suction and discharge lines in addition to electrical power lines. These actions also provide the added benefit of facilitating routine maintenance and relocation of equipment.

Mounting equipment and inventory on skids or pallets contributes greatly to contingent relocation, elevation, and removal actions using a fork lift. Large items that can be lifted from overhead should be permanently fitted with lifting bars or lugs. This eliminates time for rigging and benefits routine procedures. Any accessory items required, such as motor mount shims or necessary tools, should be stored nearby.

Technical Bulletins

This is one of a series of Technical Bulletins FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in Title 44 of the U.S. Code of Federal Regulations at Section 60.3. The bulletins are intended for use primarily by State and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulations; rather they provide specific guidance for complying with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Mitigation Division of the appropriate FEMA regional office. The User's Guide to Technical Bulletins lists the bulletins issued to date and provides a key word/subject index for the entire series.

Ordering Information

Copies of the Technical Bulletins can be obtained from the appropriate FEMA regional office. Technical Bulletins can also be ordered from the FEMA publications warehouse. Use of FEMA Form 60-8 will result in a more timely delivery from the warehouse. The form can be obtained from FEMA regional offices and your state's Office of Emergency Management. Send publication requests to FEMA Publications, P.O. Box 70274, Washington, D.C. 20024.

Further Information

The following publications provide further information concerning non-residential floodproofing:

1. "Answers to Questions About Substantially Damaged Buildings," FEMA, May 1991, FEMA-213.

2 "Commercial-Industrial Flood Audit," New England District, U.S. Army Corps of Engineers, n.d.

3. "Cooperative Flood Loss Reduction," A Technical Manual for Communities and Industries, Flood Loss Reduction Associates, 1981.

4. "Design Manual for Retrofitting Flood-Prone Residential Structures," FEMA, September 1986, FEMA-114.

5. "Floodproofing Non-Residential Structures," FEMA, May 1986, FEMA-102.

6. "Flood Proofing Regulations, U.S. Army Corps of Engineers," March 1992, EP 1165-2-314.

7. "Human Stability in a High Flood Hazard Zone," S.R. Abt, R.J. Whittlen, A. Taylor, and D.J. Love, Water Resource Bulletin, August 1989.

8. "Repairing Your Flooded Home," FEMA, August 1992, FEMA-234.

9. "Sealants, Part 1," John P. Cook, Progressive Architecture, December 1974.

10. "Sealants, Part 2," John P. Cook, Progressive Architecture, February 1975.

11. "Tests of Brick-Veneer Walls and Enclosures for Resistance to Flood Waters," Carl E. Pace, U.S. Army Corps of Engineers, Lower Mississippi Division, Vicksburg, Mississippi, 1978.

Glossary

Base flood The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Base Flood Elevation (BFE) The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929 or other datum as specified.

Basement Any area of a structure having its floor subgrade (below ground level) on all sides.

Coastal High Hazard Area An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave action from storms or seismic sources. These areas are identified as V zones.

Existing Construction/Structure For floodplain management purposes, existing construction means structures for which the start of construction commences before the effective date of a floodplain management regulation adopted by a community. These structures are often referred to as "Pre-FIRM" structures.

Federal Emergency Management Agency (FEMA) The independent federal agency that, in addition to carrying out other activities, oversees the administration of the NFIP.

Federal Insurance Administration (FIA) The component of FEMA directly responsible for administering the flood insurance aspects of the National Flood Insurance Program.

Flood Insurance Rate Map (FIRM) The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analyses, areas of 100-year flood hazard in a community.

Flood Prone Area Any land area susceptible to being inundated by floodwater from any source.

Lowest Floor The lowest floor of the lowest enclosed area of a structure, including a basement. Any NFIP-compliant unfinished or flood-resistant enclosure useable solely for parking of vehicles, building access, or storage (in an area other than a basement) is not considered a structure's lowest floor.

Mitigation Directorate The component of FEMA directly responsible for administering the floodplain management aspects of the National Flood Insurance Program.

New Construction/Structure For floodplain management purposes, new construction means structures for which the start of construction commences on or after the effective date of a floodplain management regulation adopted by a community and includes all subsequent improvements to the structure. These structures are often referred to as "Post-FIRM" structures.

Special Flood Hazard Area (SFHA) Area delineated on a Flood Insurance Rate Map as being subject to inundation by the base flood and designated as Zone A, AE, A1-A30, AR, A0, AH, V, VE, or V1-V30.

Substantial Damage Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial Improvement Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed.

Wet Floodproofing Permanent or contingent measures applied to a structure and/or it contents that prevent or provide resistance to damage from flooding by allowing water to enter the structure.