On a recent confidential project for the Department of Homeland Security, a design team had to address a gap in design standards for biocontainment facilities and in doing so created both a methodology to evaluate the level of risk and scalable architectural responses. PHOTO COURTESY FLAD ARCHITECTS/ ISTOCKPHOTO

Designing to Maintain Biological Containment

During a high-wind natural disaster, buildings that contain biological agents must be built to protect those inside the facilities and the communities that surround them.

BY CHRIS KRONSER, RA, NCARB, LEED AP AND CHAD ZUBERBUHLER, ASSOCIATE AIA

When planning facilities that will handle biological agents, every effort must be made to protect surrounding areas from accidental release of biohazards in the event of a natural disaster—especially a tornado. Unlike other weather-related disasters, tornadoes strike with little warning, offering no opportunity for staff to lock down facilities to ensure containment.

Current design standards for biocontainment facilities do not require that structures are capable of withstanding high-wind events. As a result, when needing to address this issue on a recent confidential project for the Department of Homeland Security, a design team from Flad Architects had to establish both a methodology to evaluate the level of risk and create scalable architectural responses. The resulting assessment and response strategies can be utilized on design and construction of facilities where hazardous biological agents could be exposed during a natural disaster.

ESTABLISHING STANDARDS

To establish the wind-hazard risk, designers utilized the *Nuclear Regulatory Commission* (NRC) *Guide 1.76, Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants*, (Revision 1, March 2007). Although biocontainment facilities do not contain the same radioactive material found in nuclear power plants, the guide's wind-hazard risk analysis was relatable. In both scenarios, a severely dangerous substance still could be spread throughout the environment should a containment breach occur.

The NRC guide requires that the systems, structures and components of the facility be capable of withstanding the maximum credible tornado threat for different regions throughout the contiguous United States. This has been defined as the worst wind event likely to strike a particular location in 10 million years: 160-mph west of the Rockies for instance or 200-mph in the Northeast.

PHOTO BY LARA SWIMMER/COURTESY FLAD ARCHITECTS

PHOTO BY C & N PHOTOGRAPHY/COURTESY FLAD ARCHITECTS

For BSL-2 (shown at left) and BSL-3 facilities, the primary source of containment is ventilated cabinets. The air within the laboratory is not contaminated with the contagion. The threat levels of BSL-3Ag (shown at right) and BSL-4 facilities on the other hand require the room to act as the primary containment barrier.

ASSESSING THREAT LEVEL

The question of how dangerous a biological agent might be is not simply a reflection of its assigned Biosafety Level (BSL). Some BSL-4 select agents—the ones requiring the highest containment—are designated as such because of the danger they pose to researchers handling them while they are inside the facility. Not all of these select agents, however, are as easily transmitted once released into the environment.

Designers also must consider the transmission vector of the contagion to understand how it can be spread. If the agent is an airborne pathogen, or can be easily aerosolized, there is an increased risk of being spread. But if the transmission vector requires exposure through saliva, blood, or bodily fluid, then the danger of it being spread far beyond the immediate disaster area is greatly reduced.

Additionally, the design team needs to examine how long the specific agent may live outside of a host or laboratory conditions. It must be determined what the likelihood is of the biological agent encountering a suitable host before it is no longer a viable threat.

And, finally, the team has to consider the overall effect of the contagion on the community. Some biological agents will cause illness with a low incidence of death; others have high mortality rates to humans or animals. Such a scenario, in which one of these types of pathogens escaped a facility and reached the "outside world," could devastate the local population or the food supply.

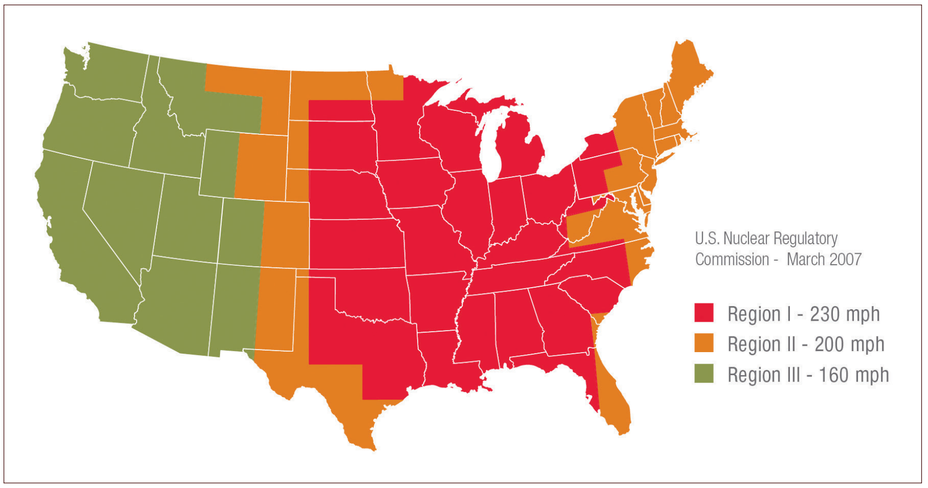
Each of these factors generates a holistic picture of what could reasonably happen if a particular agent was exposed into the environment. The resulting risk assessment can vary widely based on that. By determining the high-wind risk level, as well as the potential impact should the contagion be released, researchers and designers can develop a containment plan that is suitable for the specifics of the agent being handled in the laboratory.

CONTAINMENT REQUIREMENTS

The form of containment utilized in the design of BSL facilities changes depending upon the level of containment required. For BSL-2 and BSL-3 facilities, the primary source of containment is ventilated cabinets. The air within the laboratory is not contaminated with the contagion. BSL-3Ag and BSL-4 facilities on the other hand require the room to act as the primary containment barrier. Research protocols vary between these two BSL designations and are based upon whether they encompass animal health, human pathogens, or zoonotic diseases that may be easily transmissible between the two.

In BSL-3Ag and BSL-4, the design of the containment envelope must be airtight. Although researchers in a BSL-3Ag environment can move freely throughout the facility, those in a BSL-4 space are to be fully isolated in a protective suit with an independent air system.

This distinction is important as it directly relates to the design response. In



The maximum credible tornado threat for different regions throughout the contiguous United States is defined as the worst wind event likely to strike a particular location in 10 million years. The credible risk for region three (green) is a maximum wind speed of 160-mph; region two (orange) is 200-mph; and region one (red) is 230-mph. IMAGE COURTESY FLAD ARCHITECTS

planning BSL-2 and BSL-3 laboratories, the design team must focus on maintaining containment within the isolation cabinet. With BSL-3Ag and BSL-4 laboratories, they must focus on maintaining the integrity of the entire facility.

Generally, BSL-2 and BSL-3 facilities work with lower risk contagions. The architectural response to a possible high-wind event does not need to be as extensive. The specific contagion may have a lower risk for a variety of reasons. For example, it may not be transmitted through the air, or it may not survive outside of a host or laboratory environment for extended periods of time. For these lower-risk facilities, designers may consider increasing the structural capacity for tornado wind loading, elect to install bioseals and perimeter doors to withstand greater pressure differentials, or utilize pneumatic isolation dampers at duct penetrations.

UNIQUE CONDITIONS

A client working with the rabies virus would likely be in a BSL-2 space. Humans can contract rabies only from it entering the bloodstream. The virus, however, can be transmitted from animal to animal through bodily fluids. If researchers are studying rabies in canines, it is hypothetically possible for an infected dog to sneeze and have the HVAC system deliver an aerosolized form of the virus to the exterior of the facility where it could come into contact with a new canine host before the virus dies. Certain precautions to prevent this must be taken. The ventilation system has to include HEPA filtration to ensure any virus is cleaned from the exhaust air.

By reinforcing the structure of a BSL facility and installing bioseals and reinforced perimeter doors, the building can withstand a direct tornado hit. The air evacuated out during a tornado event would still pass through the HEPA filtration system, precluding any virus from escaping the facility.

Should containment be breached, the likelihood of transmission would be quite low, with minimal chance of animals contracting the virus and almost no chance of a human victim. In addition, rabies already exists in nature so reintroduction through a breach would not significantly upset the area's ecological balance.

BSL-3Ag and BSL-4 facilities are generally harboring select agents that are highly infectious and may not have vaccines or antidotes. These biohazards could decimate human or animal populations if released. Along with the preventive measures utilized in lower level facilities, designers should consider strengthening the interstitial and penthouse enclosures with reinforced concrete and steel to withstand high wind and missile impacts. They also should install pressure relief dampers to protect ductwork.

EXTREME HAZARD

The risk level for a facility working with Foot and Mouth Disease would be very high since the contagion is highly transmittable. Foot and Mouth, a BSL-3Ag select agent, gives cattle mouth sores so painful they stop eating and waste away. Containment of the facility must be maintained to protect the nation's food supply. Facility designers would need to include automatic bioseals and pneumatic locks on all perimeter doors. These would be activated when exterior sensors detect a significant drop in air pressure. This then leaves the reinforced room secure, with only the ventilation system vulnerable.

BSL-3Ag and BSL-4 facilities use the entire space as the means of containment, which means the ductwork and HEPA filters also are possible sources of contamination. Automatic tornado dampers need to be installed both at the air intake and exhaust locations. Ductwork would have to be automatically sealed and be rated to withstand direct impacts based on the NRC guidelines. HEPA and HVAC systems would have to automatically seal. Designers also would need to consider protecting the location both from wind and projectiles by reinforcing the surrounding structure.

As a result of these improvements, this high-risk facility would maintain containment amid winds up to 230-mph. The laboratory itself would maintain structural integrity and the HEPA filtration system containing the virus would be sealed and protected from damage.

Not every containment facility will require such extensive measures. However, a thorough understanding of the risks involved and an extensive review of practical solutions should be part of any quality design discussion and be included as a standard of practice when designing facilities for high containment. Given the worst-case scenario, the alternative is simply untenable.

TME

Chris Kronser, RA, NCARB, LEED AP, is Senior Associate, Project Manager, and Chad Zuberbuhler, Associate AIA, is Architectural Technician, Flad Architects. They can be reached at 608-232-1261, or ckronser@flad.com; and 608-232-1291, or czuberbuhler@flad.com.