The Code Corner

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High-Hazard Occupancies

2012 International Building Code

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The TRW plant located in Mesa, Arizona, has experienced a number of problems: explosions, fires, and medical emergencies. Hundreds of them in a time span of less than ten years. An explosion in 1995 cost the life of one worker. The situation became such a concern that the Mesa Fire Department issued a *cease and desist* order to the owner that lasted a couple of days, but only until TRW agreed to improve conditions. So what was at the center of all these events? The answer: sodium azide—a chemical used in the manufacture of automobile airbag devices. Although sodium azide (NaN_3) is not classified as an explosive (it is a toxic poison), when heated, the chemical reaction generates an explosive event.

It should be obvious to anyone reading the previous paragraph that those facilities associated with the TRW plant are hazardous occupancies. More specifically, the *International Building Code* (IBC) considers occupancies such as this as *high-hazard* or Group H occupancies. The IBC describes a high-hazard occupancy as one "that involves the manufacturing, processing, generation or storage of materials that constitute a physical or health hazard in quantities in excess of those allowed[.]" The key to classifying a building as a Group H occupancy lies within the last few words of that quote: *in excess of those allowed*. Without that provision, every building that has certain cleaning products in a janitorial closet would be considered a Group H occupancy.

So if hazardous materials are permitted in other occupancy groups, what is the threshold that divides any other occupancy group from a Group H occupancy? To determine the answer to that question, there are three things the design professional needs to know: 1) the categories of hazardous materials that will be used; 2) how each category of hazardous material will be used, such as storage only, in an open system, or in a closed system; and 3) quantity of each category of hazardous materials for each use indicated. These are discussed in detail later in the article.

In Section 307.1, the IBC identifies thirteen exceptions that exclude certain occupancies and uses from the Group H classification. If none of the exceptions apply, then the hazardous occupancy will be categorized into one of five subgroups. As delineated in the descriptions below, the most severe hazardous occupancy group is H-1 and the hazard severity gradually decreases as the occupancy group number increases.

- *Group H-1* includes occupancies containing materials with a detonation potential.
- *Group H-2* includes occupancies containing materials that have a deflagration potential or that create a hazard from accelerated burning.
- *Group H-3* includes occupancies containing materials that are easily combustible or pose a "physical hazard."
- *Group H-4* includes occupancies containing materials that pose a "health hazard." The IBC defines a *health hazard* to include toxic, highly toxic, and corrosive chemicals.
- *Group H-5* includes occupancies containing *hazardous production materials* (HPM) used in semiconductor fabrication and research and development laboratories.

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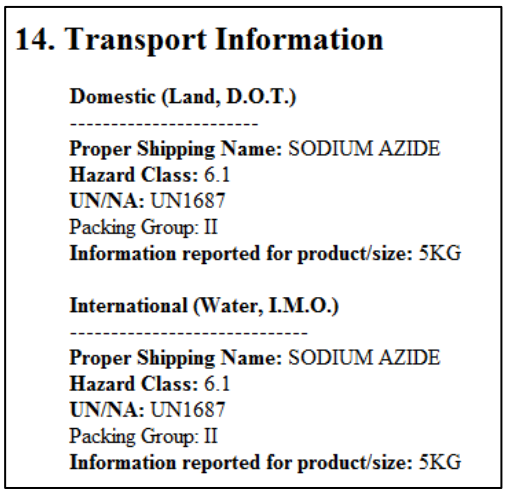
Categories of Hazardous Materials

The topic of hazardous materials is a rather large one and would take volumes of text to explain all of the issues involved. However, in the context of the IBC, hazardous materials are sorted into two major categories, *physical hazards* and *health hazards*; both are defined by the *International Fire Code* (IFC)[1]. The table below lists the categories of materials for each of the major hazard categories.

Physical Hazards		Health Hazards
Combustible dust	Flammable liquid	Corrosive
Combustible liquid	Flammable liquid, combination	Highly toxic
Combustible fiber	Flammable solid	Toxic
Consumer fireworks	Organic peroxide	
Cryogenics, flammable	Oxidizer	
Cryogenics, inert	Oxidizing gas	
Cryogenics, oxidizing	Pyrophoric material	
Explosives	Unstable (reactive)	
Flammable gas	Water reactive	

Table 1 – Hazardous material Categories.

Determining a chemical's hazard category should not be difficult. The best method is to obtain a copy of the material safety data sheet (MSDS). The Occupational Safety and Health Administration (OSHA) establishes a recommended 16-section format for MSDSs. The section that will likely provide the hazard category for a material is Section 14, "Transport Information." If the hazard category description per the IBC is not used in the MSDS, it is likely that the U.S. Department of Transportation (USDOT) hazard class will be provided (See Figure 1). The Code of Federal Regulations (CFR) provides additional information on the hazard classes (49 CFR, PART 172, Subpart B).



14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: SODIUM AZIDE
Hazard Class: 6.1
UN/NA: UN1687
Packing Group: II
Information reported for product/size: 5KG

International (Water, I.M.O.)

Proper Shipping Name: SODIUM AZIDE
Hazard Class: 6.1
UN/NA: UN1687
Packing Group: II
Information reported for product/size: 5KG

Figure 1 – A portion of a MSDS for sodium azide. Per USDOT regulations, the hazard class of 6.1 indicates that this chemical is "toxic"; thus, it is considered a health hazard placing it in Group H-4 if the quantity exceeds that allowed.

Another source that may be helpful is "Appendix E: Hazard Categories" located in the IFC. Unlike other appendices used in the International Codes, this appendix is informational only and does not require adoption to be used. The terminology used in this appendix follows closely to that used in the code text; however, the examples provided for each are limited and may not include chemicals that are not commonly used.

Use and Quantity of Hazardous Materials

After identifying the categories of hazardous materials, one needs to determine the quantities that will be used—not just stored quantities, but also the quantities that are in use. The IFC and IBC identify two types of use systems: open and closed.

A *closed system*, as defined by the IFC, includes a vessel and associated piping that does not permit the release of

[1] The IFC Development Committee is responsible for the definitions used in this article, so the IFC is referenced as the source for these definitions. However, many of these definitions are also replicated in the IBC.

vapors from a solid or liquid chemical or does not expose the chemical to the atmosphere at any time during its use. An *open system* is defined as a vessel or system that is continuously open that allows vapors from a solid or liquid chemical to be released or exposes the chemical to the atmosphere during its use.

Storage, as used within the IFC/IBC context for hazardous materials, includes materials that are both in use (open or closed systems) and in storage for future use or for disposal.

Determining Group H Classifications

Once the two essential pieces of information are gathered (*i.e.* quantity and use of hazardous materials), then the task of determining if a Group H occupancy is applicable can begin. IBC Tables 307.1(1) and 307.1(2)[2] provide the maximum allowable quantities of hazardous materials within a *control area* for physical hazards and health hazards, respectively.

A *control area* is defined in the IFC as "[s]paces within a building where quantities of hazardous materials not exceeding the maximum allowable quantities per control area are stored, dispensed, used or handled." IBC Section 414.2 (IFC Section 5003.8.3) establishes the construction criteria for control areas, which consist of fire barriers per IBC Section 707 and horizontal assemblies per IBC Section 711. The fire-resistance rating for the fire barriers and horizontal assemblies are dependent upon the height of the control area in stories above the grade plane[3] per IBC Table 414.2.2 (IFC Section 5003.8.3.2). Any control area on the fourth story or higher requires a 2-hour rating and anything below, including up to two stories below the grade plane, requires a 1-hour rating. Control areas are not permitted any lower than two stories below the grade plane. If a building has no identified control areas or no fire-resistive construction required by other provisions of the IBC complying with the requirements for control areas, then the entire building would be considered a single control area. See "Control Area Limitations" later in this article for additional requirements.

Returning to the tables, when the category of a chemical is confirmed, locate the category in column ① of either Table 307.1(1) (See Figure 2) or Table 307.1(2) (See Figure 3). The next step is to determine the quantity allowed based on how the material is used and stored. Column ③ provides maximum quantities for storage, column ④ for closed systems, and column ⑤ for open systems. If the actual quantities used or stored exceed the quantities listed in the table, then the building must be classified per the occupancy group indicated in column ②. Table 307.1(2) does not have this column, so quantities exceeding those in this table are classified as Group H-4. The only alternative to classifying the building as a Group H is to provide additional control areas, each having quantities not more than those indicated in the tables.

Using magnesium as an example, that material is considered a flammable solid. Therefore, Table 307.1(1) is applicable (See Figure 2). If the magnesium is only stored, then up to 125 cu. ft. of the material may be stored within the control area. If the actual stored quantity is expected to be 250 cubic feet, then the building is either classified as a Group H-3 or two control areas are provided, each with an allowable quantity of 125 cu. ft. If the magnesium is used in an open system, then the most that can be

[2] The IFC has identical tables, 5003.1.1(1) and 5003.1.1(2), respectively. Furthermore, since the IFC is not a building code and provides requirements for hazardous material usage indoors and outdoors, it includes Table 5003.1.1(3) for outdoor control areas.

[3] The grade plane is defined in the IBC. It is essentially the average elevation of the finished ground level around the perimeter of the building at the exterior walls.

exposed is 25 cu. ft. However, that does not mean that 125 cu. ft. of stored material and 25 cu. ft. of exposed material—a total of 150 cu. ft.—is permitted in the control area. The quantities of material in use and in storage cannot exceed the storage quantity, or 125 cu. ft. in the case of this example.

[F] TABLE 307.1(1)—(continued)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIALS POSING A PHYSICAL HAZARD[a, j, m, n, p]

MATERIAL	CLASS	GROUP WHEN THE MAXIMUM ALLOWABLE QUANTITY IS EXCEEDED	STORAGE[b]			USE-CLOSED SYSTEMS[b]			USE-OPEN SYSTEMS[b]	
			Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet at NTP)	Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet at NTP)	Solid pounds (cubic feet)	Liquid gallons (pounds)
Flammable solid	N/A	H-3	125[d, e]	N/A	N/A	125[d]	N/A	N/A	25[d]	N/A
			1	2	3	4			5	

Figure 2 - A portion of IBC Table 307.1(1) for maximum quantities of a hazardous material in a control area. Since the material indicated in this portion of the table is only a solid, there are no quantities indicated for liquids or gases.

[F] TABLE 307.1(2)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIAL POSING A HEALTH HAZARD[a, b, c, i]

MATERIAL	STORAGE[d]			USE-CLOSED SYSTEMS[d]			USE-OPEN SYSTEMS[d]	
	Solid pounds (cubic feet)	Liquid gallons (pounds)[e, f]	Gas (cubic feet at NTP)[e]	Solid pounds[e]	Liquid gallons (pounds)[e]	Gas (cubic feet at NTP)[e]	Solid pounds[e]	Liquid gallons (pounds)[e]
Corrosive	5,000	500	Gaseous 810[f] Liquefied (150)[h]	5,000	500	Gaseous 810[f] Liquefied (150)[h]	1,000	100
	1	3		4			5	

Figure 3 - A portion of IBC Table 307.1(2) for maximum quantities of a hazardous material in a control area. Since these are for chemicals posing a health hazard, if maximum quantities are exceeded, then the building or portion thereof must be classified as a Group H-4.

There are numerous footnotes to each of these tables—more than what can be covered in this article; however, there are a couple of notable ones that should be discussed. One footnote allows some quantities in the tables to be increased 100% if a sprinkler system is installed per National Fire Protection Association's standard NFPA 13, *Installation of Sprinkler Systems*.[4] Another footnote allows some quantities in the tables to be increased 100% if storage is in an approved storage cabinet, enclosure, or safety can that complies with IFC Section 5003.9.10.[5] Both of these footnotes are accumulative, which means that if both footnotes are applicable, then the allowable quantity in the table may be increased four times.

Control Area Limitations

IBC Table 414.2.2 was previously mentioned regarding the fire resistance of assemblies enclosing control areas based on height in number of stories. In addition to fire resistance, the table also limits the quantities within a control area and the number of control areas per story based on height. For control areas located on the first story above grade plane, 100% of the allowable quantities—as determined using the process provided in the previous paragraphs—is permitted, and the maximum number of control areas

[4] This is footnote 'd' in Table 307.1(1) and footnote 'e' in Table 307.1(2).
[5] This is footnote 'e' in Table 307.1(1) and footnote 'f' in Table 307.1(2).

is four. However, when control areas are located higher than the first story and below the grade plane, then the quantities of allowable materials are reduced, as well as the number of allowable control areas. For example, if a hazardous material is located on the third story, only 50% of the maximum allowable quantities per Tables 307.1(1) and 307.1(2) are allowed and the number of control areas is limited to two.

Relief for Group M and Group S Occupancies

Group M display and storage areas and Group S storage areas are given some relief in IBC Section 414.2.5 (IFC Section 5003.8.3.5). These occupancy groups are permitted quantities that exceed Tables 307.1(1) and 307.1(2) without classifying the building or use as a Group H occupancy. There are three caveats to this provision: 1) materials are displayed and stored in accordance with the IFC; 2) the quantities do not exceed those indicated in IBC Table 414.2.5(1) (IFC Table 5003.11.1) per control area; and 3) the materials are nonflammable solids, nonflammable liquids, or noncombustible liquids.[6]

Similar to the other tables that establish maximum quantities, Table 414.2.5(1) also has an extensive list of footnotes—two of which are nearly identical to the footnotes in the other tables for increases due to sprinkler system installation (footnote 'b') and storage in approved cabinets (footnote 'c'). These, too, are accumulative; therefore, a total of four times the indicated quantities are permitted if both footnotes are applicable.

Special Provisions for Group H

IBC Section 415 includes special provisions for Group H occupancies; some are general in scope and others are applicable to a specific Group H occupancy. The general requirements include an automatic fire detection system (IBC Section 415.3) and a sprinkler system installed throughout (IBC Section 415.4).

Group H occupancies also have specific fire separation distances that must be met even if other provisions of the IBC allow a closer distance. Furthermore, the distances are measured from the walls enclosing the occupancy, whether they are interior or exterior walls, to the nearest lot line—even if that lot line is on a public way (*i.e.* cannot measure to the center of the public way as provided in the definition for *fire separation distance*) (See Figure 4). The required fire separation distances per occupancy consist of the following:

- Group H-1: 75 feet, but not less than that required by the IFC Chapter 56. Buildings used for fireworks manufacturing are required to comply with the distances in NFPA 1124, *Code for the Manufacture, Transportation, Storage, and Retail Sales of Fireworks and Pyrotechnic Articles*.
- Group H-2: 30 feet when the area of the Group H-2 occupancy exceeds 1000 sq. ft. and is not required to be a detached building.
- Group H-2 and H-3: 50 feet when a detached building is required.
- Group H-2 and H-3 (containing materials with explosive characteristics): Per IFC Section 5601.8.

For buildings where explosives are manufactured or used and required separation is determined using the quantity distances in accordance with the IFC, the fire separation distance shall be the dimension

[6] The terms *flammable solid*, *flammable liquid*, and *combustible liquid* are defined in the IBC and IFC. Therefore, a nonflammable solid, a nonflammable liquid, and a noncombustible liquid would be those that do not meet the definitions of the former.

measured between buildings and not to assumed lot lines, since quantity distances are much farther than normal fire separation distances.

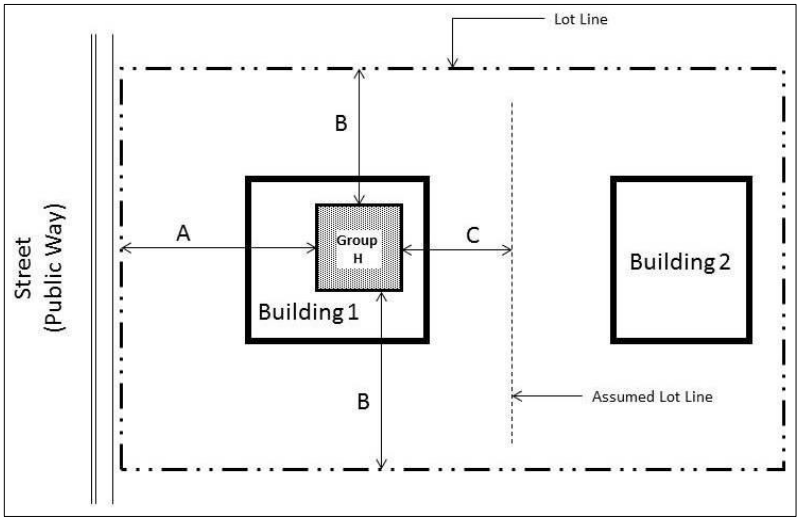


Figure 4 - Measurement of fire separation distances for Group H occupancies. Distances are measured to lot lines (Distance 'B') and assumed lot lines (Distance 'C'; except for manufacturing and use of explosives when quantity distances are used). Measurement is also to lot lines adjacent to public ways (Distance 'A') and not to centerline.

Detached buildings for Groups H-1, H-2, and H-3 are required when the quantities exceed those indicated in IBC Table 415.5.2 (IFC Table 5003.8.2). If a detached building is required, wall and opening protection based on fire separation distance is not required. Specific requirements for each of the Group H occupancies are provided in IBC Sections 415.6 through 415.10 and are too numerous to discuss in this article.

Special Requirements for Hazardous Materials

Regardless of whether hazardous materials are located in Group H occupancies or other occupancy groups, the buildings and adjacent areas where they are located must comply with some minimum requirements. The IBC and IFC provide requirements for the storage, dispensing, and use of hazardous materials for interior and exterior conditions. The IFC has extensive requirements contained in 18 chapters located in Part V. The IBC, however, provides two sections, 414.5 and 414.6, that address the building requirements related to these conditions, most of which reference back to the IFC.

For indoor conditions, explosion control is required for some chemicals that have explosive characteristics, whether they are classified as explosives or not. IBC Table 414.5.1 lists the material categories that pose an explosive hazard. For each category, the table indicates whether a barricade or explosion venting/prevention system is required. If a chemical's explosive characteristic is based on *deflagration*[7], the requirement is to provide venting or another method that prevents the potential for an explosion. If mechanical ventilation is provided, emergency or standby power is required unless one of the exceptions is applicable. Explosions created by *detonation*[8] are managed through barricade construction that deflects, vents, or withstands the blast overpressure.

Spill control and secondary containment is required for indoor and outdoor storage of hazardous materials. The intent of spill control is to prevent the flow of hazardous liquids into adjacent areas. Spill

[7] The IFC defines *deflagration* as an "exothermic reaction, such as the extremely rapid oxidation of a flammable dust or vapor in air, in which the reaction progresses through the unburned material at a rate less than the velocity of sound. A deflagration can have an explosive effect." For example, the explosion created by the ignition of natural gas due to a leak is deflagration.

[8] The IFC defines *detonation* as an "exothermic reaction characterized by the presence of a shock wave in the material which establishes and maintains the reaction. The reaction zone progresses through the material at a rate greater than the velocity of sound. The principal heating mechanism is one of shock compression. Detonations have an explosive effect."

control is required for liquids in individual containers of more than 55 gallons or when the aggregate stored capacity in multiple containers exceeds 1000 gallons. IFC Section 5004.2.1 provides four methods of spill control. Secondary containment for hazardous liquids and solids is required when liquids require spill control and when solids are stored in individual containers with a capacity exceeding 550 lbs. or the aggregate capacity of multiple containers exceeds 10,000 lbs. IFC Section 5004.2.2 provides some basic requirements for secondary containment and references—through IFC Table 5004.2.2—individual chapters for specific requirements based on material category.

Per the IBC, when weather protection for outdoor storage of hazardous materials complies with the requirements of Section 414.6.1, then the structure is still considered outdoor storage and does not need to meet the indoor storage requirements. Walls are permitted on one or more sides provided they do not cover more than 25% of the perimeter, and the overhead structure must be of noncombustible materials.

Submittal Documents

For occupancies that include the storage or use of hazardous materials, a report must be submitted to the building official that provides the following information:

- A listing of expected quantities of hazardous materials using the categories per IBC Tables 307.1(1) and 307.1(2). Each material should be broken down into quantities stored, used in open systems, and used in closed systems.
- A description of the methods of protection from the hazardous materials, such as control areas, sprinklers, barricades, venting, and any other method employed by the design team.
- Separate floor plans showing the locations of hazardous materials stored in vessels and used in systems. This is required only if hazardous materials are within a Group H occupancy.

Conclusion

High-hazard occupancies are complex uses and can challenge design professionals if they are not experienced in designing buildings containing hazardous materials. Nevertheless, the use of hazardous materials is very common; they are used in medical clinics and hospitals, manufacturing plants, research laboratories, aircraft and vehicle maintenance shops, and many other uses—many of which do not require a Group H classification. If hazardous materials are expected to be used on a project, and the design professional does not have the experience designing for hazardous material uses, then hiring a consultant may be well worth the additional fee.

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