



USG Presents

LIFE SAFETY IN BUILDING DESIGN: Specifying Fire-Rated Assemblies

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It goes without saying that life safety in building design is of paramount importance. However, because the standards and codes that regulate life safety design are continually evolving and improving, it is often difficult for

architects to stay abreast of the latest requirements, systems and design specifications.

While life safety encompasses everything from personnel security to blast resistance to redundant protection against structural collapse, the core life safety issues still revolve largely around fire containment and control. Proper design of interior wall and floor/ceiling assemblies is an essential component of fire-resistant construction and, as such, a review of the fundamental specification principals behind fire-rated assembly design is timely and important.

The Systems Approach

A systems approach is a key principle behind successful fire-resistant wall and floor/ceiling design. These assemblies must be viewed and specified as complete systems. Why? It has long been recognized that the fire resistance of an assembly is strongly influenced by the interaction and compatibility of the individual components comprising it. Building codes require that wall and floor/ceiling assemblies be tested by independent bodies, such as Underwriters Laboratories Inc. (UL), and that the resulting rating be assigned to the complete system. This systems approach best reflects the reality of how an assembly performs when exposed to fire.

A wall system, for instance, may consist of products such as gypsum panels, framing members, fasteners, joint compound and finish treatment. The system may also include penetrants (e.g., pipe or conduit) breaching the wall that must be compensated for through the proper application of firestopping materials. The performance of the wall is dependent on how well these various products and materials function as an integrated wall assembly, or system. Performance will vary depending on:

- the type of gypsum panel used;
- how the panels are applied (horizontally or vertically);
- the type and spacing of framing;
- the type and spacing of fasteners;
- the size, type and number of penetrations;
- where and how the partition intersects with a floor/ceiling assembly;
- and a variety of other issues.

AIA/ARCHITECTURAL RECORD CONTINUING EDUCATION Series

Use the learning objectives below to focus your study as you read **LIFE SAFETY IN BUILDING DESIGN: SPECIFYING FIRE-RATED ASSEMBLIES**. To earn one AIA/CES Learning Unit including one hour of health safety welfare credit, answer the questions on page 145, then follow the reporting instructions on page 231 or go to the Continuing Education section on www.architecturalrecord.com and follow the reporting instructions.

Learning Objectives:

- Understand why fire-rated wall and floor/ceiling assemblies must be specified as systems;
- Realize the role that gypsum panels play in fire-rated systems and know how the panels perform under fire conditions;
- Understand the basic criteria for specifying firestopping systems, gypsum cavity walls and area separation walls.

Individual products that are included as part of a system cannot compensate for any deficiencies in the overall system design. For instance, specifying an enhanced fire-resistant gypsum panel will not compensate for using an under-sized stud or an inadequate number of fasteners.

Proper installation of a fire-rated assembly is also important. Good construction practices, executed in accordance with manufacturers' recommendations, are needed to ensure that the assembly built in the field is representative of the one tested.

The type of fire rating required for a specific partition or assembly is further impacted by a number of additional building design issues. Are the walls load-bearing or non-load-bearing? Are automatic sprinklers installed in the building? What is the anticipated building occupancy? How tall is the building? What is the proximity of the building to neighboring lot lines? All of these factors and others affect the fire-resistant rating that a partition or assembly must achieve.

In view of all these issues, it's no wonder that fire-resistant assembly design and construction is one of the more complex issues that architects and specifiers face on a day-to-day basis.

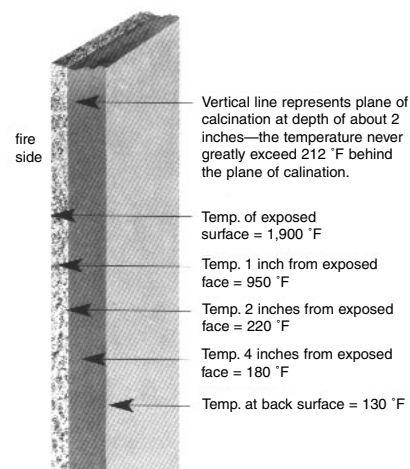


Diagram of a 6-inch-thick structural mass illustrates the fire resistance of gypsum materials at the end of a test conducted by UL.

panel relatively cool. The panel will effectively limit the transmission of heat as long as there is water left in the gypsum, or until the panel is breached.

Type X, or fire-resistant gypsum panels, contain additives such as chopped glass fiber that are incorporated into the gypsum core. When exposed to fire, these additives serve to bridge the gypsum crystals and reduce the size of cracks that form as the panel's water is converted to steam. This further prolongs the integrity of the panels, enabling them to continue to act as fire barriers and thus retard the passage of heat through the assembly.

A wall or floor/ceiling assembly fire test simply measures the time it takes for the system to reach the limiting criteria specified in Standard ASTM (the American Society for Testing and Materials) E119. For a wall assembly, the limiting criteria is defined as passage of flame through the wall, exceedance of a prescribed temperature rise on the unexposed face of the wall, the ability of the wall to carry a superimposed design load during the fire (for load-bearing walls), or projection of water through the assembly. Per ASTM C36, a 5/8-inch-thick Type X panel must provide no less than a one-hour fire resistance rating when applied in a single layer on each face of a load-bearing wood-stud wall when tested in accordance with ASTM E119. A 1/2-inch Type X panel must provide a 45-minute fire resistance rating on the same assembly.

A second type of fire-resistant gypsum panel, known as Type C (enhanced Type X), provides even better performance. In addition to glass fiber additives, Type C

panels contain additives that expand in the presence of heat, somewhat compensating for the panel shrinkage resulting from the dehydration of the gypsum. This helps add stability to the core, significantly enhancing the panel's fire-resistant performance.

The distinction between Type X and Type C panels is important. Unless clearly stated by a recognized independent testing body such as UL, Type X and Type C panels are not interchangeable. A Type C panel may generally be substituted for a Type X panel of the same thickness, but the reverse is not true; nor can a 5/8-inch Type X panel be substituted for a 1/2-inch Type C panel without a case-specific evaluation. This is particularly important on floor/ceiling assemblies, where the enhanced Type C performance is deemed essential.

Another important factor to consider is that in fire-rated steel-stud wall assemblies gypsum panels must typically be installed with all board joints (i.e., the edges and ends of the panel) backed by framing. Horizontal joints must also be staggered, so they do not align on each side of the wall. The reason for this is that joints normally open as the wall is exposed to fire, allowing heat and flame to enter the cavity and pass through the wall. The backing and staggering of joints helps compensate for this condition.

However, there are exceptions to this. Some manufacturers' Type X panels have been extensively tested to demonstrate that they may be installed without the need for backing the horizontal board joints. Furthermore, the horizontal joints of these panels do not need to be staggered on opposite sides of the studs. Details on this specification are explained in UL Design Nos. U419 (for non-load-bearing walls) and U423 and U424 (load-bearing walls). These designs offer architects a one-stop source for meeting a wide range of fire-rated performance requirements for wall scheduling. Within single designs, they provide all the details required for specifying non-load-bearing walls up to four hours duration and load-bearing walls up to two hours duration.

Listings of many other fire-rated designs are available from UL's *Fire Resistance Directory*, from the Gypsum Association's *Fire Resistance Design Manual* and from individual gypsum board manufacturers.

However, the fact that tested results are available for thousands of different wall and floor/ceiling assemblies does not eliminate the "gray areas" that architects may encounter when specifying fire-resistant systems. When the issues are

Gypsum Area Separation Wall Installation



Steel H-stud slides in place over gypsum liner panels.



An aluminum breakaway clip is screw-attached to studs and framing. Under fire exposure, the clips break away, permitting the fire-damaged wall to fail while leaving the separation wall intact.



Steel C-runner fits over the studs and panels. A second C-runner is then screw-attached back to back to lower the runner to hold the next level of studs and liner panels.

unclear, it is advisable to contact either the gypsum board manufacturer or the independent testing agency for clarification. For complex projects, independent fire code consultants may be brought in to recommend specific approaches for meeting code requirements. Ultimately, however, it is the local building code officials who function as the final decision-makers. As such, it is best to involve code officials as early as possible in the design process. This often helps to keep small problems from developing into costly, complex issues.

Cavity Shaft Walls

From a life safety standpoint, cavity shaft walls are among the most important assemblies in any building. These engineered wall systems deliver critical fire resistance and structural integrity around stairwells, elevators and other building enclosures. During a fire, they provide a means for occupants to exit, while allowing access for rescue and fire-fighting personnel. They also offer a channel for communications, and enable the movement of power, water, fresh air and exhaust.

When creating cavity shaft wall specifications, tested system performance should be given top priority. While this premise holds true for virtually any fire-resistant design, it is especially critical for cavity shaft walls. When it comes to tested performance, no other type of cavity shaft wall system has undergone more extensive research, testing and refinement than gypsum panel wall systems.

Gypsum shaft wall systems provide fire ratings up to four hours. The assemblies are lightweight—a two-hour system weighs only approximately 9 pounds per square foot and is only 3½ inches thick. They install more quickly and cost effectively than “wet” cavity shaft walls, such as concrete block, and are erected from outside the shaft at each floor, eliminating the need for scaffolding. The shafts are enclosed early in the construction process and finished later, along with other interior partitions.

Although various types of gypsum shaft wall systems are available, the most extensively tested and most widely used system is built using C-H studs. This stud profile combines a conventional “C” shape with an “H” pocket. A two-foot-wide gypsum liner panel is slid into the H pocket, requiring access from only one side of the wall. Conventional four-foot-wide Type X or Type C gypsum panels are screwed into place on the C side of the stud. The C-H studs, which are engaged to steel J-runners fastened to the floor and ceiling, produce a stronger wall and enable greater limiting heights compared to competing systems.

Gypsum liner panels have a fire-resistant core and are treated to resist moisture penetration. Multiple layers of gypsum panels can be applied to obtain fire ratings of up to four hours duration. If required per the specification, Type X or Type C gypsum plaster base panels may be used to accommodate a veneer plaster finish.

When specifying cavity shaft walls, look for tested performance that accurately represents actual job conditions. For instance, determine whether the cavity shaft system has been tested (per ASTM E152) with the type of elevator door that will be used. Review the system’s tested performance for call-button and floor-indicator penetrations (per ASTM E119), and seek a system with UL-listed smoke and fire dampers.

To ensure system longevity, make sure that the manufacturer has not only conducted structural testing to develop limiting heights (the maximum wall span that may be built for a given design load without exceeding stress or deflection limits), but has tested the wall to a high number of repeated cycles or oscillations. Cavity shaft walls are subjected to both positive and negative pressures as elevator cabs rise and descend. Oscillation testing provides assurance that the walls will withstand this continual flexing throughout the life of the building.

FIRESTOPPING – AT A GLANCE



To achieve a desired fire rating for a partition or floor/ceiling assembly, all penetrations through that assembly must be treated with a firestopping material.

In order to achieve a desired fire-rating for a partition or floor/ceiling assembly, all penetrations through that assembly must be treated with a firestopping material that meets nationally recognized test standards (ASTM E814 or UL 1479). A penetration (also called a through-penetration) is a hole cut or formed through the entire assembly to permit passage of a penetrant, such as a pipe, conduit, duct or

cable bundle. The annular space, or the gap between the opening in the assembly and the size of the penetrant, must be filled with a firestop sealant and, if needed, a forming material. The forming material (usually mineral wool insulation) serves as a backing or dam for the firestop sealant.

In addition to penetrations, firestopping materials are also used on joint systems between adjacent walls and/or floor/ceiling assemblies. UL identifies four types of joint systems: floor-to-floor, wall-to-wall, floor-to-wall and head-of-wall. The test criteria for all these building joints can be found in the Standard UL 2079, *Tests for Fire Resistance of Building Joint Systems*.

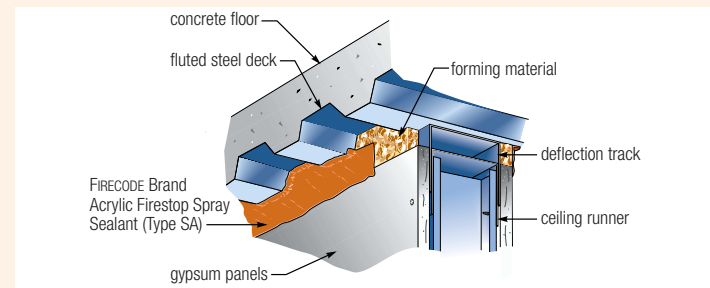
Generally speaking, there are three primary types of firestop sealant materials: mortar, caulk and intumescent.

Mortar-type firestops are applied wet over the forming material (when needed). They are available in either powder or ready-mixed formulations, and are usually the most economical option. They set or harden to form a strong, durable firestop, and are typically used in walls, floors and curtain wall slab edge conditions where strength and economy are required.

Caulk-type firestops are applied from a caulking tube or pail, or are spray-applied. They are easy to install, economical and flexible. They are typically used in dynamic joints in head-of-wall systems, as well as in certain floor and wall penetrations where movement is anticipated and flexibility is required.

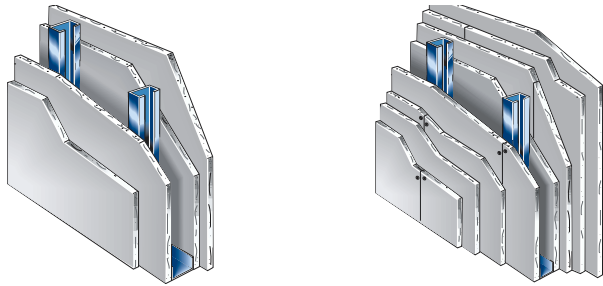
Intumescent-type firestops are specifically designed for use with plastic and insulated pipes, and other penetrants that will be burned or melted when exposed to fire.

Intumescent materials expand when exposed to heat to fill the cavity left by the damaged penetrant and thus prevent the passage of flame and smoke.



Head-of-wall intersections, where drywall partitions meet fluted steel decks, represent one of the more difficult firestopping applications for both specifiers and contractors. UL-classified head-of-wall systems are available that utilize sprayable firestopping products. These products provide a cost-efficient solution for head-of-wall applications with long construction joint runs.

UL DESIGN NUMBER U419: A One-Stop Specification Source for Non-Load-Bearing Walls



UL Design Number U419 provides all the details required for specifying non-load-bearing walls with fire ratings from one to four hours. Shown here are a two-hour wall assembly (left) and a four-hour wall assembly.

Area Separation Walls

For multifamily construction, area separation walls (also known as “fire walls,” “party walls” and “townhouse separation walls”) serve to protect residents of adjacent units in townhouses and apartments in the event of a fire. They must provide both fire protection (usually two hours) and the needed structural stability to withstand the collapse of an adjacent structure without losing their integrity. Both concrete block and gypsum-based systems are commonly used as area separation walls.

A basic masonry area separation wall configuration consists of a non-load-bearing concrete block wall serving as a divider between wood frame construction on either side. Lateral support from the adjacent construction can be provided to stabilize the area separation wall at intermediate floors and roofs, but the lateral attachment must be designed so that the collapse of the adjacent construction in the event of fire will not cause the area separation wall to fall.

Gypsum-based area separation walls consist of 1-inch-thick gypsum liner panels used in conjunction with H-shaped steel studs and C-shaped runners to form thin, space-saving alternatives to concrete block. While meeting the same design requirements for fire and lateral load resistance, the drywall assemblies weight at least 50 percent less than masonry walls, install more quickly and require less floor space. The structural stability of gypsum-based area separation walls is achieved through the use of special aluminum clips that provide lateral support from the structure to the fire wall at intermediate floors and the roof. The clips also function as break-away fuses by melting or yielding from the rise in temperature on the fire side of the wall. The clips, which melt at 1,200 degrees F (a temperature reached relatively quickly in a severe fire), permit the fire-engulfed structure to collapse independently of the area separation wall.

Conclusion

The objectives of this learning activity were to enable you to understand why fire-rated wall and floor/ceiling assemblies must be specified as systems; realize the role that gypsum panels play in fire-rated systems and know how the panels

perform under fire conditions; and understand the basic criteria for specifying firestopping systems, gypsum cavity shaft walls and area separation walls.

The overriding goal of all fire-resistant assembly design is to manage risk and thereby save lives and property in the event of a fire or other catastrophe. For decades, manufacturers, code officials, testing bodies, trade organizations and associations have worked together to help establish the best possible building design and testing protocols. The resulting fire-resistant systems, testing procedures and codes represent the state-of-the-art in life safety design and construction... and they ensure the safest possible living and working environments.

This collective expertise is available to any specifier for any building design. Use it by insisting on a systems approach when specifying materials and by relying on established testing criteria for all fire-resistant design.

Additional Articles and Information: CLICK FOR THIS

As part of this CES learning activity, you are required to read three additional articles relating to fire-resistant assembly design and specifications. Test questions will be included from this information. The articles are:

- **ASTM E119 Fire Endurance of Building Systems:** This article discusses the criteria and testing standards established by ASTM for use in testing assemblies for fire resistance. **To read the article on-line, go to the USG Corporation Web site (www.usg.com), link to “Design Solutions” (located on the top navigation bar), then link to “Fire Construction” (on the side navigation bar) and click on the “ASTM E119 Fire Endurance of Building Systems” link; or go directly to www.usg.com/Design_Solutions/2_2_fire_construct.asp and click on the same story link.** To obtain a fax copy of the article, call USG at 888-874-2450 and ask for the ASTM E119 Fire Endurance of Building Systems Web article.
- **ASTM E84 Surface Burning Characteristics of Building Materials:** This article provides a basic overview of the ASTM criteria used to determine the flame spread and smoke density ratings for an assembly design. **To read the article on-line, go to the USG Corporation Web site (www.usg.com), link to “Design Solutions” (located on the top navigation bar), then link to “Fire Construction” (on the side navigation bar) and click on the “ASTM E84 Surface Burning Characteristics of Building Materials” link; or go directly to www.usg.com/Design_Solutions/2_2_fire_construct.asp and click on the same story link.** To obtain a fax copy of the article, call USG at 888-874-2450 and ask for the ASTM E84 Surface Burning Characteristics of Building Materials Web article.
- **Building and Inspecting Smoke Barriers:** The article provides insights into how gypsum partition walls serve as effective smoke barriers and provides design criteria for creating smoke barriers. **To access the article on-line, go to the Gypsum Association Web site (www.gypsum.org) and click on the “Download Free Gypsum Association Publications” link at the top of the page.** After filling out the required form, download the “Building and Inspecting Smoke Barriers (GA-618-96)” PDF file. To obtain a fax copy of the article, call USG at 888-874-2450 and ask for Gypsum Association publication GA-618-96.

TECHNICAL INFORMATION SOURCES

Following are several leading reference and information sources about fire-rated design issues:

UNITED STATES GYPSUM COMPANY ([WWW.USG.COM](http://www.usg.com))

Because the company originally established most of the fire testing procedures currently used by UL, it can offer unique insights into testing standards and applications. U.S. Gypsum’s technical support department, which includes eight architects, five engineers and 12 technical representatives, is the largest of all gypsum industry manufacturers. For technical assistance, call 800-USG-4YOU or write United States Gypsum Company, P.O. Box 806278, Chicago, IL 60680.

UNDERWRITERS LABORATORIES INC. ([WWW.UL.COM](http://www.ul.com))

To obtain a copy of the *UL Fire Resistance Directory*, call (847) 664-2899, or write to Underwriters Laboratories Inc., Publications Stock, 333 Pfingsten Road, Northbrook, IL 60062.

THE NATIONAL FIRE PROTECTION ASSOCIATION ([WWW.NFPA.ORG](http://www.nfpa.org))

The association provides a wide range of code and standard reports and research data. Contact the association by calling 617-770-3000 or write to the National Fire Protection Agency, P.O. Box 9101, Quincy, MA 02269.

THE GYPSUM ASSOCIATION ([WWW.GYPSUM.ORG](http://www.gypsum.org))

The trade association for the gypsum industry publishes a *Fire Resistance Design Manual (GA-600)* that provides a one-stop reference source for tested fire-resistant wall and floor/ceiling assembly designs. Contact the association by calling 202-289-5400, or write to the Gypsum Association, 810 First St., N.E., Suite 510, Washington DC 20002, or e-mail info@gypsum.org.



Learning Objectives

- Understand why fire-rated wall and floor/ceiling assemblies must be specified as systems;
- Realize the role that gypsum panels play in fire-rated systems and know how the panels perform under fire conditions;
- Understand the basic criteria for specifying firestopping systems, gypsum cavity walls and area separation walls.

Instructions

Refer to the learning objectives above. Complete the questions below. Fill out the self report form on page 231 and submit it or use the Continuing Education self report form on *Record's* website—www.architecturalrecord.com—to receive one AIA/CES Learning Unit including one hour of health safety welfare credit.

Questions

- Q:** 1. Gypsum works as a natural fire-resistant material because:
- A:**
- a: It uses dry construction techniques
 - b: It can be used with light weight steel or wood framing
 - c: Heat energy is dissipated as the water turns to steam
 - d: The gypsum crystals form cracks when the panel's water is converted to steam.
- Q:** 2. A Type X, or fire-resistant gypsum panel, contains additives such as chopped glass fiber that serve to:
- A:**
- a: Reduce the number of fasteners required to attach the panel
 - b: Reduce the size of cracks that form as the panel's water is converted to steam
 - c: Eliminate the need for firestopping
 - d: Increase panel thickness.
- Q:** 3. Type C gypsum panels provide even better fire-resistant performance by:
- A:**
- a: Increasing the amount of gypsum present in the panel
 - b: Reducing the heat generated from fire as it comes into contact with the gypsum panel
 - c: Providing a fire-resistant surface that protects the gypsum core
 - d: Expanding in the presence of heat, compensating somewhat for the panel shrinkage resulting from the dehydration of the gypsum.
- Q:** 4. Which substitutions are generally acceptable?:
- A:**
- a: A Type X panel may be substituted for a Type C panel of the same thickness
 - b: A 5/8 inch Type X panel may always be substituted for a 1/2 inch Type C panel
 - c: A Type C panel may be substituted for a Type X panel of the same thickness
 - d: No substitutions are ever allowed.
- Q:** 5. A benefit of gypsum-based area separation walls over basic masonry construction is:
- A:**
- a: They weigh at least 50 percent less
 - b: They provide lateral load resistance
 - c: The collapse of the adjacent construction due to fire will not cause the area separation wall to fail
 - d: They protect residents of adjacent units in the event of fire.
- Q:** 6. The structural stability of gypsum-based area separation walls is achieved through use of:
- A:**
- a: Large-sized gypsum panels
 - b: Break-away aluminum clips that provide lateral support from the structure to the firewall
 - c: Steel studs and runners
 - d: A non-load-bearing concrete block wall.
- Q:** 7. A benefit of intumescent-type firestop sealant material over other primary types is:
- A:**
- a: It provides flexibility of movement through the penetrations
 - b: It expands when exposed to heat to fill the cavity left by damaged penetrant
 - c: It is the most economical option available
 - d: It fills in the annular space of a penetration through assemblies.
- Q:** 8. What properties help gypsum board walls function as effective smoke barriers?:
- A:**
- a: They can be used on load-bearing and non-load-bearing wall assemblies
 - b: They can be applied in multiple layers
 - c: They install quickly and cost effectively
 - d: They are constructed to achieve a significant degree of fire resistance, sound isolation and reduction of air leakage.
- Q:** 9. Under ASTM E119, a hose stream test:
- A:**
- a: Measures an assembly's ability to withstand lateral impact from falling debris during the fire endurance period and before active fire suppression efforts begin
 - b: Is an indication of how long a room or zone can contain a fully developed blaze before it spreads to adjacent areas of the building
 - c: Determines fire-fighting practices or strategies at the fire site
 - d: Measures how quickly fire develops on an assembly's surface material once that material is exposed to flame.
- Q:** 10. Flame-spread ratings determined through ASTM E84:
- A:**
- a: Measure the transmission of heat through an assembly to the unexposed surface
 - b: Are measured by a hose stream test
 - c: Indicate how likely a fire is to move from its point of origin, and how fast.
 - d: Determine the firestopping material needed in through penetrations in fire-rated systems.

About USG

USG Corporation is a Fortune 500 company with subsidiaries that are market leaders in their key product groups: gypsum wallboard, joint compound and related gypsum products; cement board; gypsum fiber panels; ceiling tile and grid; and building products distribution.

United States Gypsum Company, a subsidiary of USG Corporation, manufactures two types of gypsum panels for use in fire-rated assemblies: SHEETROCK® Brand Gypsum Panels, FIRECODE® Core and SHEETROCK Brand Gypsum Panels, FIRECODE C Core. The company also offers USG Cavity Shaft Wall Systems, USG Area Separation Wall Systems and a range of SHEETROCK Brand firestopping products.

For more information about United States Gypsum Company's products and systems, write USG Corporation, P.O. Box 806278, Chicago, IL 60680-4124, call USG's Customer Service Department at 800-USG-4YOU or visit the company's Web site at www.usg.com.



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